WAMBO COAL PTY LIMITED

WAMBO COAL MINE
LONGWALL 24 TO 26 MODIFICATION

MODIFICATION REPORT

For the Modification of DA 305-7-2003 (MOD 19)
Optimisation and Continued Operation
of the Approved South Bates Extension Underground Mine

APPENDIX A

Subsidence Assessment

Peabody

REPORT: SUBSIDENCE PREDICTIONS AND IMPACT ASSESSMENTS

WAMBO COAL:

South Bates Extension Underground Mine Longwalls 24 to 26 Modification Subsidence Assessment

Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Modification Application for the South Bates Extension Underground Mine Longwalls 24-26 Modification

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft issue	JB	-	23 Dec 21
02	Draft issue	JB	-	19 Jan 22
03	Draft issue	JB	KK	17 Mar 22
04	Draft issue	JB	KK	22 Mar 22
A	Final issue	JB	KK	21 Jun 22

Report produced to: Support the Modification Application for the South Bates Extension Longwalls 24-26 Modification for modified WYLW24 to WYLW26 in the Whybrow Seam.

Previous reports:

Report No. MSEC848 (Rev. A) – South Bates Extension Modification Subsidence Assessment – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Modification Application for the South Bates Extension Modification, dated 11 January 2017.

Report No. MSEC935 (Rev. A) – South Bates Extension Subsidence Assessment – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan Application for the South Bates Extension WYLW17 to WYLW20, dated the 19 April 2018.

Report No. MSEC1012 (Rev. A) – South Bates Extension Subsidence Assessment – The Effects of the Modified Finishing Ends of Whybrow Longwalls 17 to 20 on the Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of an Application to Amend the Extraction Plan, dated 28 February 2019.

Report No. MSEC1069 (Rev. A) – South Bates Extension Subsidence Assessment – The Effects of the Modified Commencing End of Whybrow Longwall 19 on the Subsidence Predictions and Impact Assessments for the Natural and Built Features, dated 24 October 2019.

Report No. MSEC1080 (Rev. B) – South Bates Extension Subsidence Assessment – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan Application for WYLW21 to WYLW24 at the South Bates Extension Underground Mine, dated 27 May 2020.

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

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

EXECUTIVE SUMMARY

Wambo Coal Pty Limited (WCPL) operates the Wambo Coal Mine, which is located in the Hunter Coalfield of New South Wales. The mine was approved under Part 4 of the *Environmental Planning and Assessment Act 1979*, in February 2004, which included the extraction of longwalls in the Whybrow, Wambo, Woodlands Hill and Arrowfield Seams.

The Development Consent (DA 305-7-2003, as modified) allows for the extraction of Longwalls 17 to 25 in the Whybrow Seam (WYLW17 to WYLW25) at the South Bates Extension Underground Mine (SBEUM) mining area of the Wambo Coal Mine. The SBEUM was approved as part of the separate South Bates Extension Modification Application (MOD 17) in 2017. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC848 in support of the South Bates Extension Modification Application (MOD 17).

The layout of the WYLW17 to WYLW25 adopted in the South Bates Extension Modification Application (MOD 17) and Report No. MSEC848 is referred to as the *MOD 17 Layout* in this report.

The existing/approved SBEUM incorporates minor changes to the MOD 17 Layout adopted through Extraction Plan process in accordance with Development Consent (DA 305-7-2003) and is referred to as the *Existing/Approved Layout* in this report.

WCPL proposes to modify Development Consent (DA 305-7-2003) to allow for the re-orientation of WYLW24 and WYLW25 and the addition of WYLW26 on the north-western side of the SBEUM mining area. The Modification would not change the existing/approved WYLW17 to WYLW23. The modified SBEUM therefore consists of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 and is referred to as the *Modified Layout* in this report.

The predicted subsidence effects for the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 (i.e. Modified Layout) have been determined using the Incremental Profile Method. The maximum predicted subsidence effects these modified longwalls are the same or slightly less than those based on the MOD 17 Layout.

The maximum predicted subsidence effects for the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 are 1950 mm vertical subsidence (i.e. 65 % of the maximum extraction height of 3.0 m), 80 mm/m tilt (i.e. 8.0 % or 1 in 12) and greater than 3.0 km^{-1} curvature (i.e. a minimum radius of curvature less than 0.3 km). The maximum predicted subsidence effects occur in the eastern part of the SBEUM mining area where the depths of cover are the shallowest.

The Study Area has been defined as the surface area enclosed by the greater of the 26.5° angle of draw lines from the extents of longwalls, based on both the MOD 17 Layout and Modified Layout, and the predicted total 20 mm subsidence contour due to the mining the longwalls based on both layouts. Other features which could be subjected to far-field or valley-related movements and could be sensitive to such effects have also been assessed in this report.

Several natural and built features have been identified within or near the Study Area including: North Wambo Creek, Waterfall Creek, ephemeral drainage lines, the Wollemi Escarpment and other cliffs, minor cliffs and pagodas, steep slopes, the Wollemi National Park, unsealed tracks and trails, farm dams, the Montrose Open Cut Pit, Aboriginal heritage sites, survey control marks and unused building structures.

The assessments and recommendations provided in this report should be read in conjunction with those provided in the reports by other specialist consultants on the project. The main findings from this report are as follows:

- North Wambo Creek is located above the SBEUM mining area based on both the MOD 17 Layout and Modified Layout. However, the length of creek located above the longwalls based on the Modified Layout is approximately 2.1 km less than that based on the MOD 17 Layout. The predicted subsidence effects and the assessed impacts, based on the Modified Layout, are similar to or less than those based on the MOD 17 Layout.

  The upper reaches (i.e. first and second order sections) of Waterfall Creek are located above the northern end of the modified WYLW26. The third order section of this creek is located outside the Study Area at a minimum distance of 180 m north of the modified longwalls. The predicted subsidence effects and assessed impacts for the first and second order sections of Waterfall Creek, based on the Modified Layout, are greater than those assessed based on the MOD 17 Layout which did not mine directly beneath the creek.

There are also unnamed drainage lines located across the Study Area which form tributaries to North Wambo Creek and Waterfall Creek. The total length of these drainage lines above the SBEUM mining area, based on the Modified Layout, is less than that based on the MOD 17 Layout.

Ponding areas are predicted to develop along North Wambo Creek and the ephemeral drainage lines located directly above the SBEUM mining area having depths up to approximately 1.5 m and overall lengths up to approximately 225 m. If adverse impacts were to develop due to the increased ponding, these could be remediated by locally re-grading the stream beds, so as to re-establish the natural gradients. Overall, less surface area would be affected by topographical depressions and potential ponding for the Modified Layout compared to the MOD 17 Layout.

Fracturing and compression heaving are expected to develop along the sections of the streams located directly above the SBEUM mining area. The impacts are expected to be similar to those observed along the streams above the previously extracted WYLW11 to WYLW13 at the South Bates Underground Mine and WYLW17 to WYLW20 at the SBEUM. It may be necessary to remediate the larger surface deformations by infilling with surface soil or other suitable materials, or by locally regrading and recompacting the surface.

- Cliffs have been identified within and near the Study Area which have been categorised into three groups, being: *Cliffs Associated with the Wollemi Escarpment*; *Intermediate Level Cliffs* (i.e. located beneath the escarpment); and *Low Level Cliffs* (i.e. near the base of the steep slopes directly above the south-western ends of the approved longwalls).

  The Cliffs Associated with the Wollemi Escarpment and the Intermediate Level Cliffs are located outside the 26.5° angle of draw line from the existing/approved WYLW17 to WYLW23. There are no cliffs located near the modified WYLW24 to WYLW26. The nearest cliffs are located 760 m west of the modified longwalls.

  The Cliffs Associated with the Wollemi Escarpment and the Intermediate Level Cliffs are predicted to experience less than 20 mm vertical subsidence. While these could experience very low levels of vertical subsidence, they are unlikely to experience measurable conventional tilts, curvatures or strains. It is unlikely, therefore, that the high-level cliffs would experience adverse impacts due to the mining of the longwalls based on the Modified Layout.

  The Low Level Cliffs are located partially above the existing/approved WYLW20 and WYLW21. These cliffs are discontinuous and are separated with sections of minor cliffs and rock outcrops. The predicted subsidence effects and assessed impacts for the Low Level Cliffs, based on the Modified Layout, are the same as those based on the MOD 17 Layout.

- Steep slopes are located above and near the south-western ends of the existing/approved WYLW17 to WYLW23 and above and near the modified WYLW26 and to a lesser extent the modified WYLW25.

  Surface cracking and compression heaving could develop along the areas of the steep slopes that are located directly above the SBEUM mining area. Impacts are not anticipated along the steep slopes located outside and to the south-west of the SBEUM mining area. Surface remediation might be required, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface.

- The Wollemi National Park is located outside and to the west of the SBEUM mining area. The boundary of the National Park is at minimum distances of 265 m from the existing/approved WYLW17 to WYLW23 and 115 m from the modified WYLW24 to WYLW26.

  The land within the National Park is predicted to experience less than 20 mm vertical subsidence and it is not expected to experience measurable conventional tilts, curvatures or strains. The National Park could experience low-level far-field horizontal movements; however, these bodily movements are not expected to be associated with any measurable strains. It is unlikely, therefore, that the Wollemi National Park would be adversely impacted by the vertical or far-field horizontal movements.

- There are unsealed tracks and trails located across the Study Area which are used for the mining operations and for firefighting activities. It is expected that these roads could be maintained in safe and serviceable conditions using normal road maintenance techniques.

- There are 15 farm dams located on WCPL owned land within the Study Area, of which, eight dams are located directly above the existing/approved WYLW17 to WYLW23 and five dams are located directly above the modified WYLW24 to WYLW26.

  Fracturing and buckling could occur in the uppermost bedrock beneath the farm dams, which could adversely affect the water holding capacities of the farm dams. It may be necessary to remediate some of the farm dams, at the completion of mining, by excavating and re-establishing cohesive material in the beds of the farm dams to reduce permeability.

- The mining related infrastructure within the Study Area includes the Montrose Open Cut Pit, exploration drill holes, an11 kV powerline and ventilation shaft. It is recommended that a geotechnical assessment of the highwall be undertaken based on the effects of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26. It is also recommended that the exploration drill holes are capped (if not already done) prior to being directly mined beneath.

- There are 59 Aboriginal heritage sites that have been identified within the Study Area, of which, 38 of these sites are located above or near the approved WYLW24 and WYLW25 and the modified WYLW24 to WYLW26, referred to as the Aboriginal Heritage Study Area.

  There are 38 open sites located within the Aboriginal Heritage Study Area. It is unlikely that the artefacts and PADs would be adversely impacted by the mining-induced surface cracking.

  The rock shelters are located outside the Aboriginal Heritage Study Area and are directly above the existing WYLW18 to WYLW21. These sites do not show visual impacts from the mining of these longwalls. It is unlikely that adverse impacts would occur to the rock shelters due to the mining of the approved and proposed longwalls due to their distances from these future longwalls.

  The scarred tree is also located outside the Aboriginal Heritage Study Area above the approved WYLW21. The predicted subsidence effects for this site do not change due to the proposed modifications.

- The Whynot Homestead and associated sheds are located above the existing/approved WYLW21. No adverse impacts were observed due to the existing mining beneath these structures and no future impacts are anticipated due to the mining of the existing/approved WYLW22 and WYLW23 and the modified WYLW24 to WYLW26.

  There are two unused sheds located above the southern end of the modified WYLW26. Adverse impacts are not anticipated. It is recommended that these sheds are visually monitored during active subsidence.

The assessments provided in this report indicate that the levels of impact on the natural and built features can be managed by the preparation and implementation of the appropriate management strategies. It should be noted, however, that more detailed assessments of some natural and built features have been undertaken by other specialist consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

CONTENTS

Tables

Table numbers are prefixed by the number of the chapter in which they are presented.

Figures

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

Drawings

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

Drawing No.	*Description*	*Revision*
MSEC1224-01	Overall layout and monitoring lines	A
MSEC1224-02	General layout	A
MSEC1224-03	Surface level contours	A
MSEC1224-04	Whybrow Seam floor contours	A
MSEC1224-05	Whybrow Seam thickness contours	A
MSEC1224-06	Whybrow Seam depth of cover contours	A
MSEC1224-07	Geological structures at seam level	A
MSEC1224-08	Natural features	A
MSEC1224-09	Built features and Aboriginal heritage sites	A
MSEC1224-10	Predicted total subsidence contours after WYLW23	A
MSEC1224-11	Predicted total subsidence contours after WYLW24	A
MSEC1224-12	Predicted total subsidence contours after WYLW25	A
MSEC1224-13	Predicted total subsidence contours after WYLW26	A

1.1. Background

Wambo Coal Pty Limited (WCPL) operates the Wambo Coal Mine, which is located in the Hunter Coalfield of New South Wales (NSW). The mine was approved under Part 4 of the *Environmental Planning and Assessment Act 1979*, in February 2004, and through subsequent modifications. WCPL has approval to extract longwalls in the Whybrow, Wambo, Woodlands Hill and Arrowfield Seams.

The Development Consent (DA 305-7-2003, as modified) allows for the extraction of Longwalls 17 to 25 in the Whybrow Seam (WYLW17 to WYLW25) at the South Bates Extension Underground Mine (SBEUM) mining area of the Wambo Coal Mine. The SBEUM was approved as part of the separate South Bates Extension Modification Application (MOD 17) in 2017. Mine Subsidence Engineering Consultants (MSEC) prepared Report No. MSEC848 in support of the South Bates Extension Modification Application (MOD 17).

The layout of the WYLW17 to WYLW25 adopted in the South Bates Extension Modification Application (MOD 17) and Report No. MSEC848 is referred to as the *MOD 17 Layout* in this report.

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WCPL proposes to modify Development Consent (DA 305-7-2003) to allow for the re-orientation of WYLW24 and WYLW25 and the addition of WYLW26 on the north-western side of the SBEUM mining area. The Modification would not change the existing/approved WYLW17 to WYLW23. The modified SBEUM therefore consists of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 and is referred to as the *Modified Layout* in this report.

The comparison between the MOD 17 underground mining area, the existing/approved WYLW17 to WYLW25 and the modified WYLW24 to WYLW26 is provided in Fig. 1.1.

MSEC has been engaged by WCPL to:

- provide subsidence predictions for the Modified Layout including the cumulative subsidence due to the adjacent existing/approved longwalls;
- compare the predictions with the values presented in the South Bates Extension Modification Application (MOD 17) and Report No. MSEC848;
- update the subsidence predictions for the natural and built features located above and near the SBEUM mining area;
- review and update the impact assessments, in conjunction with other specialist consultants, for each of these natural and built features; and
- recommend management strategies and monitoring.

This report has been prepared to support the Modification Application (MOD 19) for WYLW24 to WYLW26 at the SBEUM which will be submitted to the Department of Planning, Industry and Environment (DPIE).

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

Chapter 3 provides an overview of the methods that have been used to predict the subsidence effects due to the mining of the Modified Layout.

Chapter 4 provides the maximum predicted subsidence effects due to the mining of the Modified Layout.

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

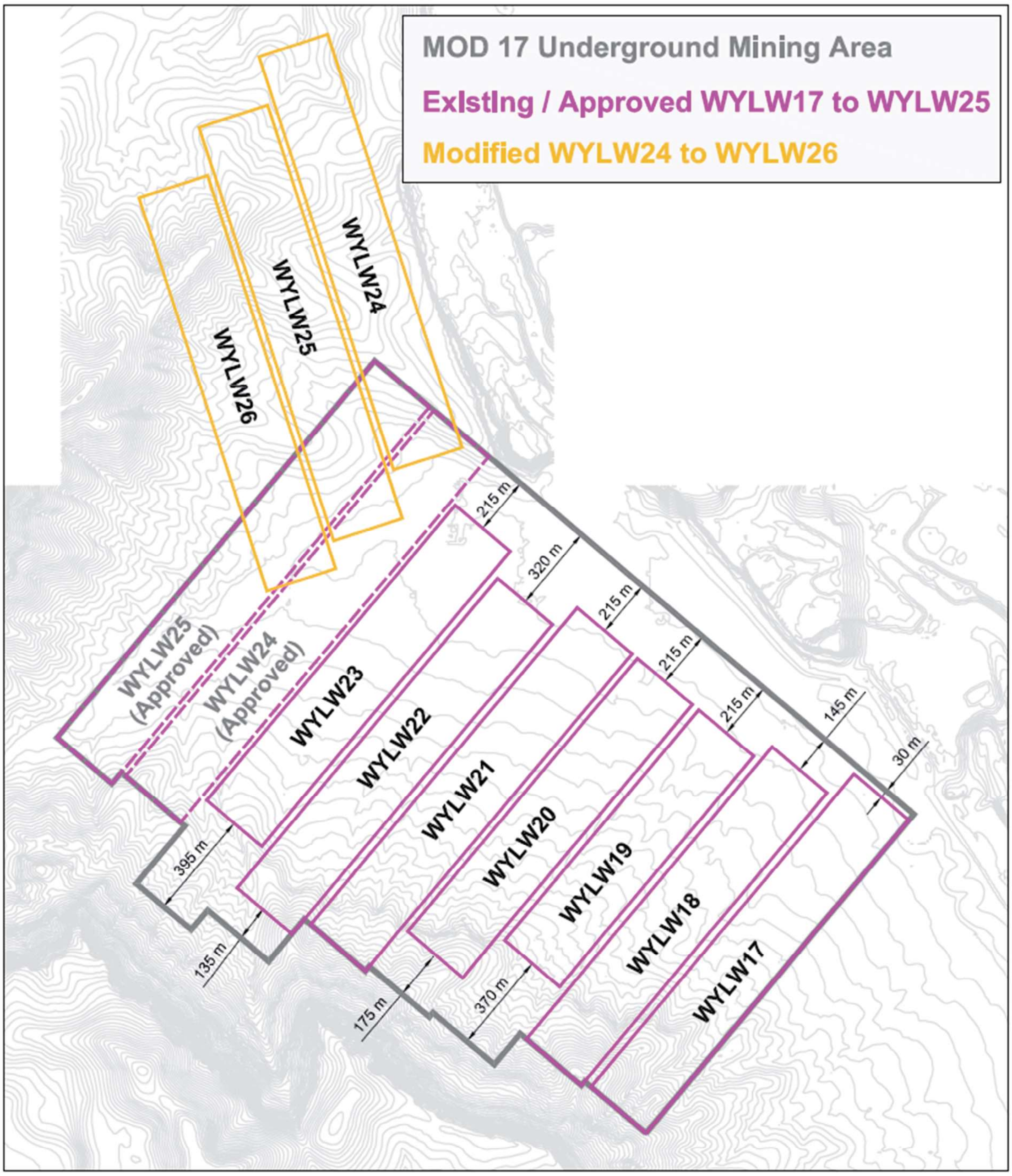


Fig. 1.1 Comparison of the longwall mining areas

1.2. Mining geometry

The MOD 17 Underground Mining Area and Modified Layout are overlaid in Drawings Nos. MSEC1224-01 and MSEC1224-02, in Appendix E.

The existing/approved WYLW17 to WYLW23 based on the MOD 17 Layout originally had overall void lengths varying between 1510 m and 2015 m, overall void widths of 261 m and solid chain pillar widths varying between 26 m and 31 m. The commencing (i.e. south-western) and finishing (i.e. north-eastern) ends of these longwalls have since been shortened, as illustrated in Fig. 1.1.

A summary of the dimensions for WYLW24 to WYLW26 based on the MOD 17 Layout and Modified Layout is provided in Table 1.1.

Table 1.1 Geometry of WYLW24 to WYLW26 based on MOD 17 Layout and Modified Layout

Layout	Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
MOD 17 Layout (MSEC848)	WYLW24	1740	261	21
	WYLW25	1795	261	21
Modified Layout (MSEC1224)	WYLW24	1580	262	-
	WYLW25	1585	262	25
	WYLW26	1505	262	25

The lengths of WYLW24 to WYLW25 would reduce relative to the extents based on the MOD 17 Layout as a result of the Modification. However, the Modification would also include the addition of WYLW26. The lengths of extraction (i.e. excluding the installation heading) are approximately 8.5 m less than the overall void lengths provided in the above table.

The overall void widths of WYLW24 and WYLW25 would slightly increase by 1 m. The overall void width of WYLW26 would be the same as those for WYLW24 and WYLW25. The widths of the longwall extraction faces (i.e. excluding the first workings) are 250 m.

WYLW17 to WYLW23 have been or will be extracted from the south-west towards the north-east (i.e. towards the Montrose Open Cut Pit). WYLW24 to WYLW26 would be extracted from the north to south (i.e. towards the main headings).

1.3. Surface and seam levels

The natural surface and the levels of the Whybrow Seam are illustrated along Sections 1 and 2 in Fig. 1.2 to Fig. 1.3 below. The locations of these sections are shown in Drawings Nos. MSEC1224-03 to MSEC1224-06. The existing/approved WYLW17 to WYLW23 are shown as the cyan outlines and the modified WYLW24 to WYLW26 are shown as the blue outlines.

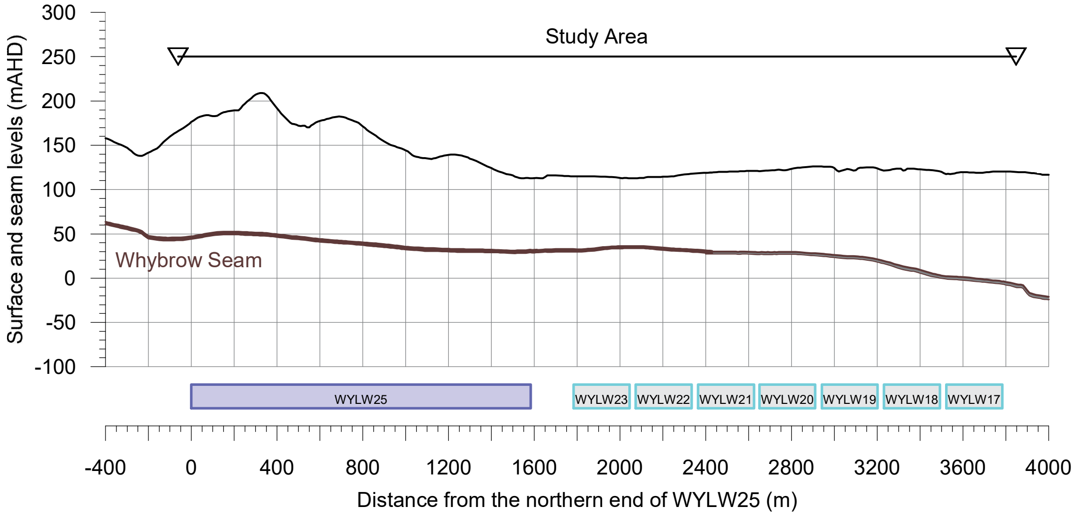


Fig. 1.2 Surface and seam levels along Section 1 through WYLW17 to WYLW23 and the centreline of WYLW25

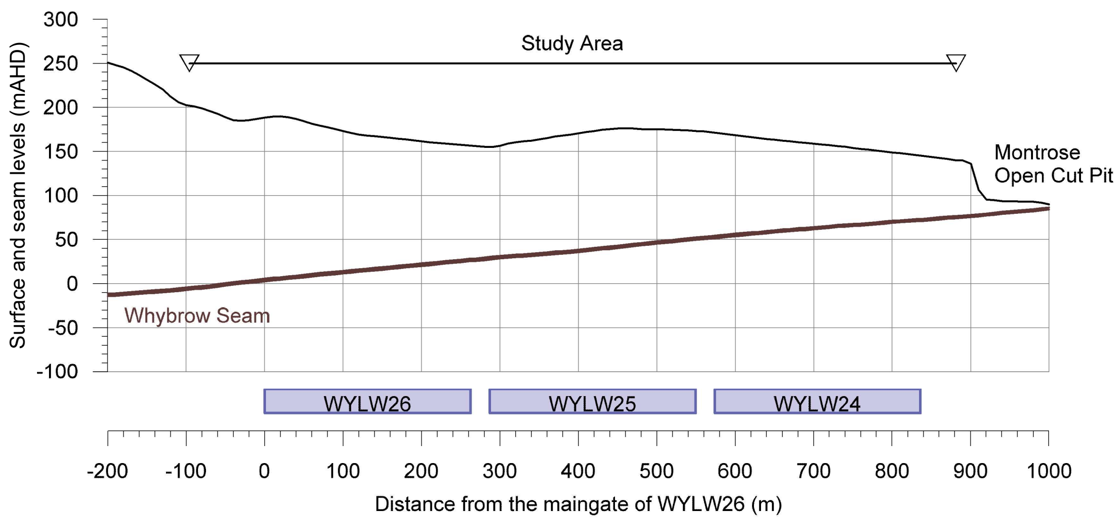


Fig. 1.3 Surface and seam levels along Section 2 through WYLW24 to WYLW26

The surface level contours are shown in Drawing No. MSEC1224-03. The major natural topographical feature in the area is the Wollemi Escarpment which is located to the south-west and west of WYLW17 to WYLW23. Ridgelines cross directly above the existing/approved WYLW17, WYLW18 and WYLW20 and above the modified WYLW26. The Montrose Open Cut Pit is located to the north-east of the SBEUM mining area.

The surface levels directly above the existing/approved WYLW17 to WYLW23 vary from a high point of 285 m above Australian Height Datum (mAHD) above the commencing (i.e. south-western) end of WYLW18 to a low point of 100 mAHD above the finishing (i.e. north-eastern) end of WYLW17.

The surface levels directly above the modified WYLW24 to WYLW26 vary from a high point of 250 m above the northern end of WYLW26 to a low point of 115 mAHD above the finishing (i.e. southern) end of WYLW24. The high point occurs where the ridgeline crosses above WYLW26 and the low point occurs in a tributary to North Wambo Creek.

The seam floor contours, seam thickness contours and depth of cover contours for the Whybrow Seam are shown in Drawings Nos. MSEC1224-04, MSEC1224-05, and MSEC1224-06, respectively. The contours are based on the latest seam information provided by WCPL.

The depths of cover to the Whybrow Seam directly above the existing/approved longwalls vary between a minimum of 60 m above the finishing (i.e. north-eastern) end of WYLW21 and a maximum of 330 m above the commencing (i.e. south-western) ends of WYLW18.

The depths of cover to the Whybrow Seam directly above the modified longwalls vary between a minimum of 60 m above the tailgate of WYLW24 and a maximum of 240 m above the maingate of WYLW26. The shallowest depth of cover occurs along a tributary that crosses WYLW24 and the greatest depth of cover occurs where the ridgeline crosses WYLW26.

The seam floor within the SBEUM mining area generally dips from the north-east towards the south-west. The seam is shallowest and is exposed within the Montrose Open Cut Pit and deepest beneath the Wollemi Escarpment. The average dip of the seam within the extents of the existing/approved WYLW17 to WYLW23 is approximately 6 % or 1 in 17 and the average dip within the extents of the modified WYLW24 to WYLW26 is approximately 8 % or 1 in 12.

The thickness of the Whybrow Seam within the extents of the existing/approved WYLW17 to WYLW23 varies between 2.4 m and 3.6 m and the thickness within the extents of the modified WYLW24 to WYLW26 varies between 2.5 m and 3.5 m. The mining heights for the longwalls are illustrated in Drawing No. MSEC1224-05 and they vary from less than 2.8 up to 3.0 m.

1.4. Geological details

The SBEUM lies in the Hunter Coalfield, within the Northern Sydney Basin. A typical stratigraphic section of the Hunter Coalfield, reproduced from the Department of Mineral Resources (DMR) *Hunter Coalfield Regional 1:100 000 Geology Map*, is shown in Table 1.2 (DMR, 1993).

Table 1.2 Stratigraphy of the Hunter Coalfield (DMR, 1993)

Supergroup	Group	Subgroup	Formation	Seam
Singleton Supergroup	Narrabeen Group		Widden Brook Conglomerate	
	Newcastle Coal Measures	Glen Gallic Subgroup	Greigs Creek Coal	
			Redmanvale Creek Formation	
			Dights Creek Coal	
		Doyles Creek Subgroup	Waterfall Gully Formation	
			Pinegrove Formation	
		Horseshoe Creek Subgroup	Lucernia Coal	
			Strathmore Formation	
			Alcheringa Coal	
			Clifford Formation	
		Appletree Flat Subgroup	Charlton Formation	
			Abbey Green Coal	
			Watts Sandstone	
	Wittingham Coal Measures		Denman Formation	
		Jerrys Plains Subgroup	Mount Leonard Formation	**Whybrow Seam**
			Althorpe Formation	
			Malabar Formation	Redbank Creek Seam
				Wambo Seam
				Whynot Seam
				Blakefield Seam
			Mount Ogilvie Formation	Glen Munro Seam
				Woodlands Hill Seam
			Milbrodale Formation	
			Mount Thorley Formation	Arrowfield Seam
				Bowfield Seam
				Warkworth Seam
			Fairford Formation	
			Burnamwood Formation	Mount Arthur Seam
				Piercefield Seam
				Vaux Seam
				Broonie Seam
				Bayswater Seam
			Archerfield Sandstone	
		Vane Subgroup	Bulga Formation	
			Foybrook Formation	
			Saltwater Creek Formation	

The Whybrow Seam lies within the Jerrys Plains Subgroup of the Wittingham Coal Measures. The rocks of the Wittingham Coal Measures mainly comprise frequently interbedded sandstones and siltstones, but also include isolated thinner beds of conglomerate and tuff. The formations are generally less than 10 m in thickness.

The Denman Formation marks the top of the Wittingham Coal Measures, which is overlain by the Newcastle Coal Measures. The Newcastle Coal Measures comprise the Watts Sandstone and the Appletree Flat, Horseshoe Creek, Doyles Creek and Glen Gallic Subgroups.

WCPL provided the logs for typical drill holes located within the SBEUM mining area, the locations of which are shown in Drawing No. MSEC1224-09. The geological sections for drill hole UG139 (above the existing/approved WYLW21) and drill hole UG242 (above the modified WYLW26) are provided in Table 1.3 and Table 1.4, respectively.

Table 1.3 Geological section of Drill Hole UG139

Depth (m)	Thickness (m)	Lithology
0 ~ 0.5	0.5	Soil
0.5 ~ 9	8.5	Clay
9 ~ 15.5	6.5	Sandstone
15.5 ~ 17	1.5	Siltstone
17 ~ 18	1	Sandstone
18 ~ 20	2	Sandstone (70 %) and Siltstone (30 %)
20 ~ 21	1	Sandstone (70 %) and Claystone (30 %)
21 ~ 22.5	1.5	Claystone
22.5 ~ 24	1.5	Sandstone (70 %) and Siltstone (30 %)
24 ~ 25	1	Sandstone
25 ~ 26	1	Claystone
26 ~ 49	23	Sandstone
49 ~ 54	5	Sandstone (80 %) and Siltstone (20 %)
54 ~ 57	3	Sandstone
57 ~ 62	5	Siltstone (70 %) and Sandstone (30 %)
62 ~ 64	2	Siltstone
64 ~ 81	17	Sandstone
81 ~ 82	1	Siltstone
82 ~ 87	5	Siltstone (80 %) and Sandstone (20 %)
87 ~ 88.5	1.5	Siltstone
88.5 ~ 110.5	22	Claystone
110.5 ~ 113	2.5	Coal (Whybrow Seam)
113 ~ 114	1	Claystone
114 ~ 115	1	Sandstone (70 %) and Claystone (30 %)
115 ~ 116	1	Sandstone (50 %) and Siderite (50 %)
116 ~ 117	1	Sandstone
117 ~ 122	5	Sandstone (70 %) and Siltstone (30 %)
122 ~ 127	5	Sandstone
127 ~ 130	3	Whybrow Seam

Table 1.4 Geological section of Drill Hole UG242

Depth (m)	Thickness (m)	Lithology
0 ~ 5	5	Clay
5 ~ 6	1	Sandstone
6 ~ 13	7	Siltstone
13 ~ 21	8	Sandstone
21 ~ 24	3	Siltstone
24 ~ 25	1	Sandstone
25 ~ 28	3	Tuff and Coal
28 ~ 36	8	Siltstone with Claystone bands
36 ~ 39	3	Sandstone
39 ~ 42	3	Siltstone
42 ~ 43	1	Coal
43 ~ 50	7	Sandstone
50 ~ 53	3	Siltstone
53 ~ 55	2	Sandstone
55 ~ 57	2	Tuff
57 ~ 58	1	Coal
58 ~ 61	3	Siltstone with Claystone bands
61 ~ 62	1	Coal
62 ~ 69	7	Interbedded Sandstone and Siltstone
69 ~ 70	1	Tuff and Coal
70 ~ 71	1	Sandstone
71 ~ 72	1	Coal
72 ~ 77	5	Sandstone
77 ~ 78	1	Siltstone and Coal
78 ~ 92	14	Conglomerate
92 ~ 95	3	Sandstone
95 ~ 97	2	Siltstone
97 ~ 98	1	Tuff
98 ~ 107	9	Siltstone (60 %) and Sandstone (40 %)
107 ~ 124	17	Sandstone
124 ~ 164	40	Siltstone
164 ~ 165	1	Sandstone
165 ~ 167	2	Siltstone
167 ~ 170	3	Whybrow Seam

The overburden of the Whybrow Seam predominately comprises of interbedded sandstone and siltstone layers, with minor claystone, mudstone, shale, tuffaceous and coal layers. The immediate roof of the Whybrow Seam above the existing/approved longwalls (i.e. drill hole UG139) comprises a 22 m thick claystone layer and above the modified WYLW24 to WYLW26 (i.e. drill hole UG242) comprises predominately siltstone with sandstone bands. The immediate floor of the seam comprises interbedded claystone, sandstone, siderite and siltstone.

There are no massive sandstone or conglomerate units within the overburden. The largest unit above the existing/approved longwalls (i.e. drill hole UG139) is the 17 m thick sandstone layer located approximately 30 m above the Whybrow Seam. The largest units above the modified WYLW24 to WYLW26 (i.e. drill hole UG242) are the 17 m sandstone layer and 14 m conglomerate layer located approximately 43 m and 75 m, respectively, above the Whybrow Seam. There is a 40 m thick siltstone layer located approximately 3 m above the Whybrow Seam.

Otherwise, the thicknesses of the formations within the overburden are typically less than 10 m. Other boreholes in the vicinity of the modified SBEUM mining area indicate the presence of other larger sandstone units with thicknesses up to 20 m in the lower part of the overburden.

No adjustment factors have been applied in the subsidence prediction model for any massive strata units or for softer floor conditions, as the existing/approved and modified longwalls are supercritical in width and, therefore, they are predicted to achieve the maximum subsidence for single-seam mining conditions.

The geological features that have been identified at seam level are shown in Drawing No. MSEC1224-07. The largest structure in the area is the *Redmanvale Fault* which is located south-west of the existing/approved WYLW17 to WYLW23. This normal fault has a strike of approximately 325° and dips towards the north-east. The dip angle of normal faults is typically in the range of 70° to 85°. The throw of the Redmanvale Fault is greater than 20 m.

Three sections have been taken through the Redmanvale Fault and the commencing (i.e. south-western) ends of the existing/approved WYLW21, WYLW22 and WYLW23 and these are shown in Fig. 1.4, Fig. 1.5 and Fig. 1.6, respectively. The assumed fault plane is based on a dip angle of 70°.

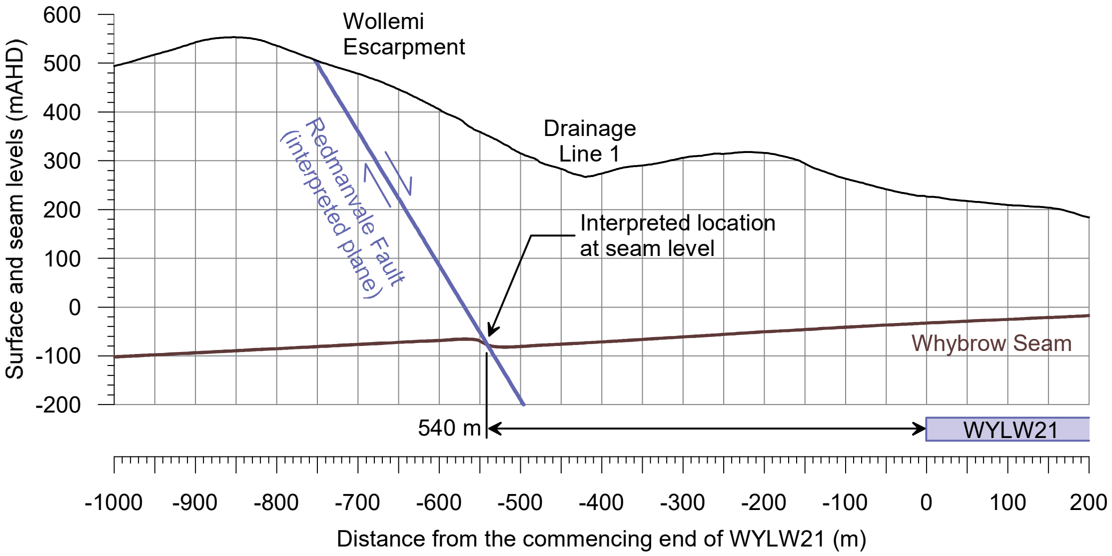


Fig. 1.4 **Section through the Redmanvale Fault and the commencing end of WYLW21**

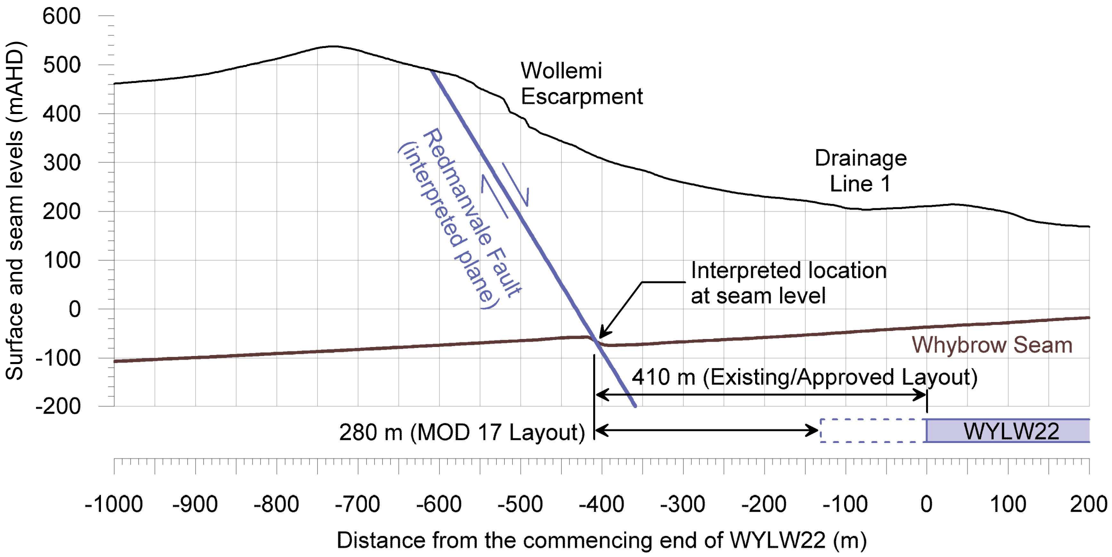


Fig. 1.5 **Section through the Redmanvale Fault and the commencing end of WYLW22**

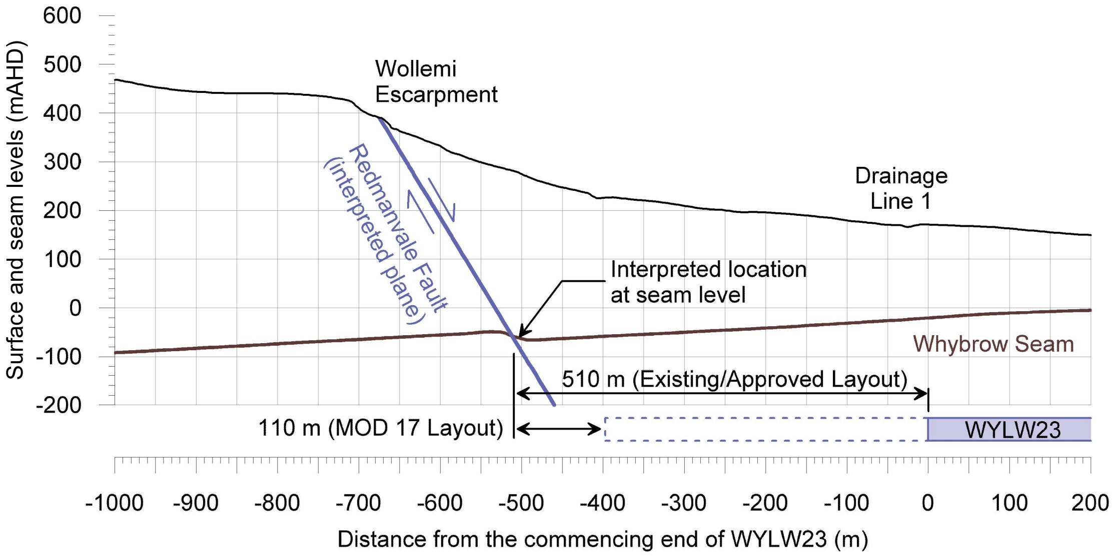


Fig. 1.6 Section through the Redmanvale Fault and the commencing end of WYLW23

The Redmanvale Fault (at seam level) is located at horizontal distances varying between 410 m and 540 m from existing/approved WYLW21 to WYLW23. The surface expression of the fault appears to be associated with the Wollemi Escarpment adjacent to WYLW21 to WYLW23. Further to the south, the surface expression adjacent to the existing/approved WYLW17 to WYLW20 appears to be associated with a tributary to Stony Creek further to the west of the Wollemi Escarpment.

The assumed surface expression of the Redmanvale Fault, based on a 70° dip, is located at horizontal distances varying between 610 m 750 m from the existing/approved WYLW21 to WYLW23. The surface expression of the fault is located at greater distances from the existing/approved WYLW17 to WYLW20.

The component of vertical subsidence at the assumed surface expression of the fault is expected to be negligible (i.e. not measurable) due to the mining of the existing/approved WYLW17 to WYLW23. The potential for differential vertical subsidence to develop at the assumed surface expression of the fault is considered to be very low, due to the footwall block restraining the vertical movement of the hanging block and due to the low levels of predicted vertical subsidence.

The absolute horizontal movements at the assumed surface expression of the fault are predicted to be in the order of 50 mm to 100 mm due to the mining of the existing/approved WYLW17 to WYLW23. These far-field horizontal movements are due to the redistribution of horizontal stress and are directed towards the SBEUM mining area.

The potential for far-field horizontal movements has been reduced as the horizontal in situ stress has already been redistributed due to the mining in the Montrose Open Cut Pit on the north-eastern side of the SBEUM mining area. Also, normal faults are formed through tension in the strata and, therefore, there is likely to be a reduced compressive stress across this fault plane.

The potential for mining-induced shear movements across the fault is expected to be very low due to the fault being located outside of the SBEUM mining area, the dip direction of the fault (i.e. towards the SBEUM mining area), the dip angle of the fault (i.e. greater than 70°) and the direction of the far-field horizontal movements, with the footwall block pushing against the hanging block, with the resultant vertical action opposing gravity. The potential for irregular ground movements at the surface, therefore, is considered to be very low.

The differential movement at the assumed surface expression of the fault due to the far-field horizontal movements is expected to be negligible (i.e. not measurable) due to the extraction of the existing/approved WYLW17 to WYLW23. The potential for impacts on the Wollemi Escarpment, therefore, is considered to be very low as it is parallel to the alignment of the fault and there is low potential for differential movements.

No major faults have been identified within the extents of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26. Minor faults have been identified within the SBEUM mining area with throws typically up to 1 m. A dyke with an ENE-WSE orientation crosses the mid-lengths of the modified WYLW24 to WYLW26. The geological structures within the SBEUM mining area will be better defined through ongoing investigations and the development of first workings.

No adjustment factors have been applied in the subsidence prediction model for the minor faults and dykes within the SBEUM mining area, as the longwalls are generally supercritical in width and, therefore, they are predicted to achieve the maximum subsidence for single-seam mining conditions. Increased subsidence has not been observed in the locations of similar minor faults during the mining of longwalls at the South Bates Underground Mine and the SBEUM.

The surface lithology in the area can be seen in Fig. 1.7, which shows the longwalls and the Study Area overlaid on *Geological Map of Doyles Creek 9032-1-N*, which was published by the DMR (1988).

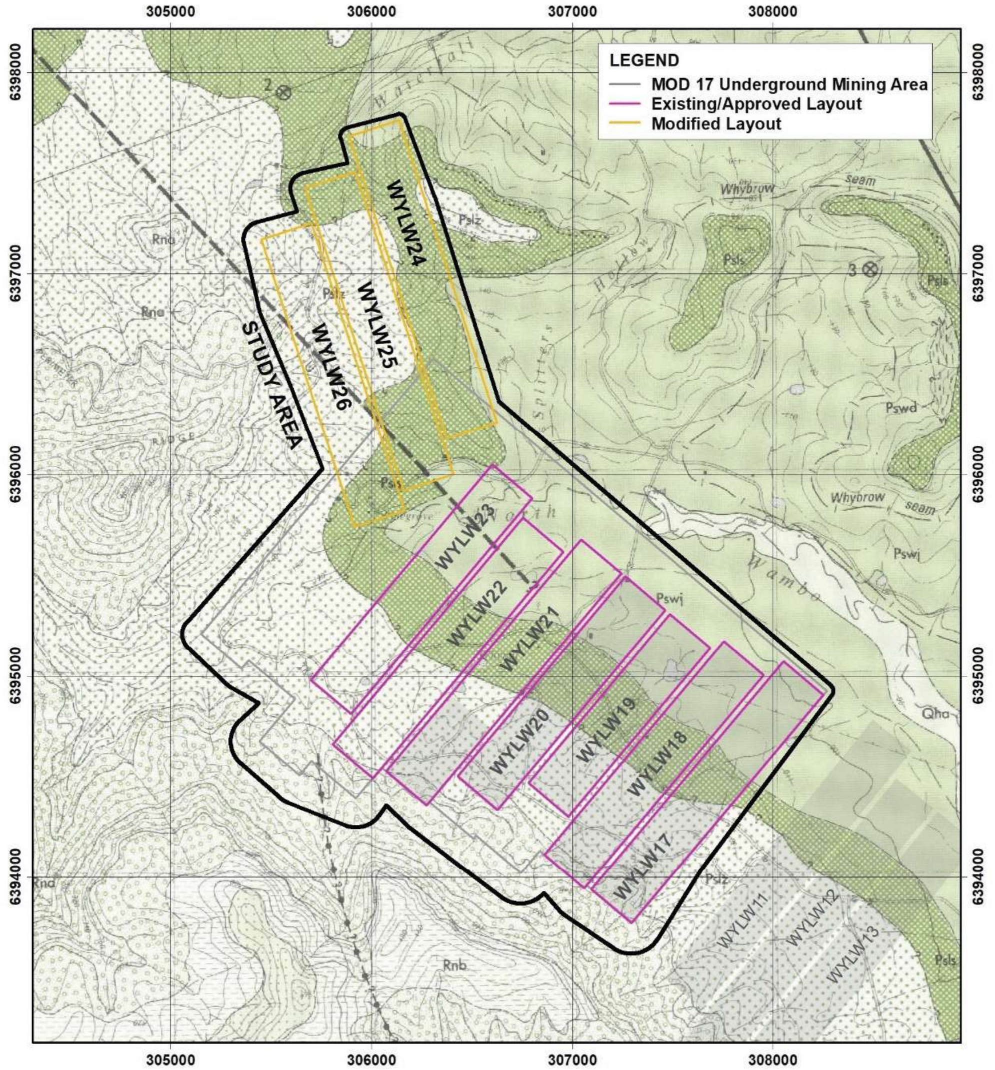


Fig. 1.7 WYLW21 to WYLW24 overlaid on Geological Map Doyles Creek 9032-1-N

The surface lithology generally comprises the Newcastle Coal Measures (Pslz) above the western part of the SBEUM mining area transitioning to the Watts Sandstone (Psls) and Jerrys Plains Subgroup of the Wittingham Coal Measures (Pswj) above the central and eastern parts of the mining area.

The surface lithology adjacent to the north-eastern ends of the existing/approved WYLW17 to WYLW23 has been modified by the construction of the North Wambo Creek Diversion, which included excavation and the placement of backfill. It is not expected that the predicted subsidence movements in this location would be affected by these surface earthworks.

2.1. Definition of the Study Area

The Study Area for this assessment is defined as the surface area that is likely to be affected by the mining of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 in the Whybrow Seam. While only WYLW24 to WYLW26 are proposed to be modified as part of the Modification (MOD 19), the other existing/approved longwalls have also been included.

The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- the 26.5° angle of draw lines from the extents of the existing/approved WYLW17 to WYLW25 based on the MOD 17 Layout and from the modified WYLW24 to WYLW26 based on the Modified Layout; and
- the predicted limit of vertical subsidence, taken as the 20 mm subsidence contour due to the mining of the existing/approved WYLW17 to WYLW25 based on the MOD 17 Layout and due to the mining of the modified WYLW24 to WYLW26 based on the Modified Layout.

The 26.5° angle of draw line is described as the "*surface area defined by the cover depths, angle of draw of 26.5 degrees and the limit of the proposed extraction area in mining leases for all other NSW Coalfields*" (i.e. other than the Southern Coalfield), as stated in Section 6.2 of the Guideline for Applications for Subsidence Management Approvals (DMR, 2003).

The depths of cover contours for the Whybrow Seam are shown in Drawing No. MSEC1224-06. As shown in that drawing, the depths of cover directly above the longwalls vary between 44 m and 330 m. The 26.5° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 22 m and 165 m around the limits of the extraction areas based on both the MOD 17 Layout and Modified Layout.

The predicted limit of vertical subsidence, taken as the predicted 20 mm subsidence contour, has been determined using the Incremental Profile Method (IPM) which is described in Chapter 3. The predicted 20 mm subsidence contour has been determined based on both the MOD 17 Layout and Modified Layout and it is located inside the combined 26.5° angle of draw.

A line has therefore been drawn defining the Study Area, based upon the 26.5° angle of draw based on the MOD 17 Layout and Modified Layout, whichever is furthest from the longwalls, and it is shown in Drawings Nos. MSEC1224-01 to MSEC1224-09.

There are areas that lie outside the Study Area that are expected to experience either far-field movements or valley-related movements. The surface features which could be sensitive to such effects have been identified and have been included in the assessments provided in this report.

2.2. Overview of the natural and built features within the Study Area

A number of the natural and built features within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered *Doyles Creek 9032-1-N*. The Modified Layout and the Study Area have been overlaid on an extract of this CMA map in Fig. 2.1.

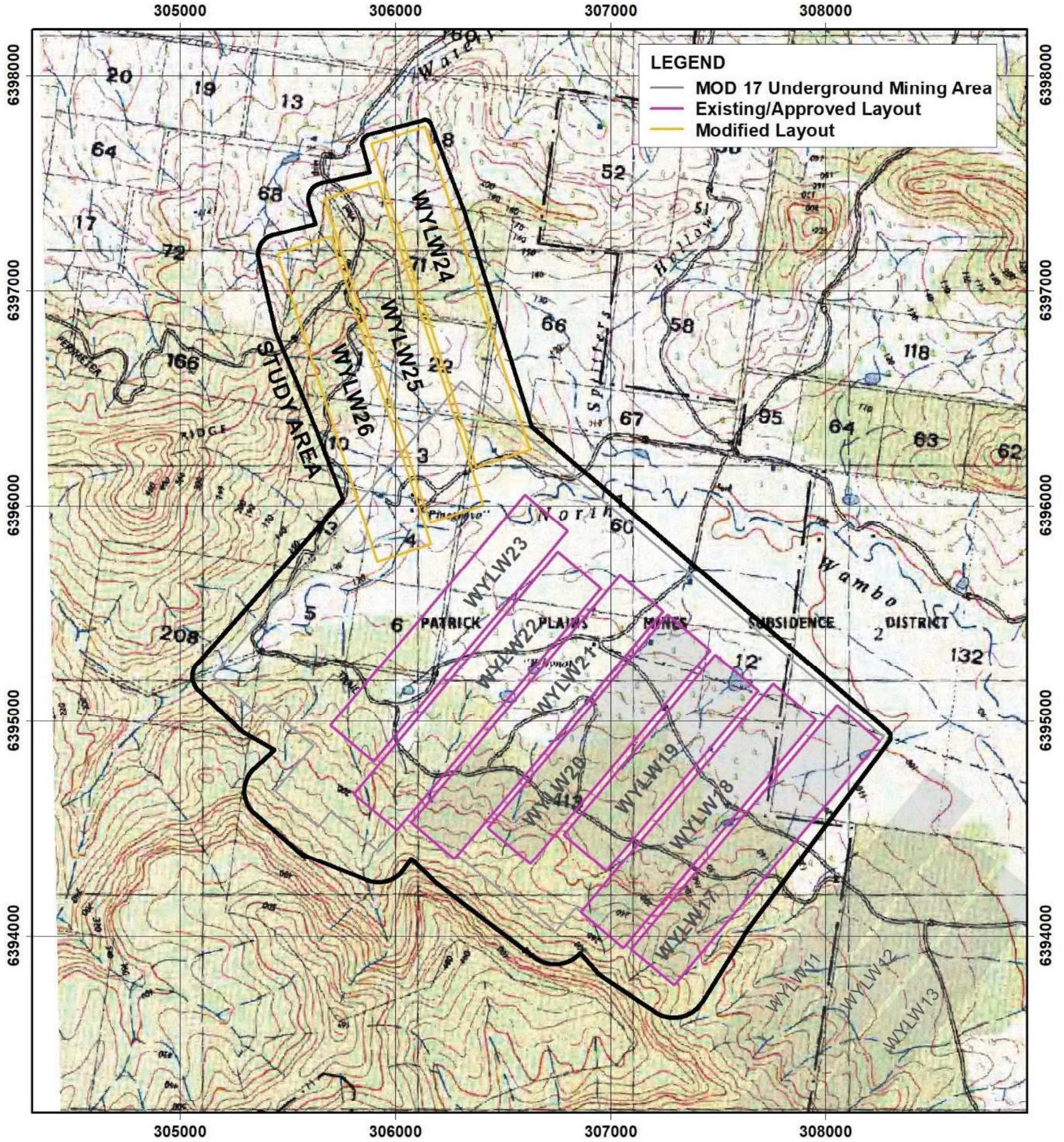


Fig. 2.1 WYLW17 to WYLW26 overlaid on CMA Map No. Doyles Creek 9032-1-N

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. MSEC1224-08 and MSEC1224-09. The descriptions, predictions and impact assessments for each of the natural and built features are provided in Chapters 5 and 6.

Table 2.1 Natural and Built Features within the Study Area

Item	Within Study Area	Section Number
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	×	
Streams	✓	5.2
Aquifers or Known Groundwater Resources	×	
Springs or Groundwater Seeps	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	✓	5.5 & 5.6
Steep Slopes	✓	5.7
Escarpments	✓	5.4
Land Prone to Flooding or Inundation	✓	5.8
Swamps or Wetlands	×	
Water Related Ecosystems	✓	5.9
Threatened or Protected Species	✓	5.10
Lands Defined as Critical Habitat	×	
National Parks	✓	5.11
State Forests	×	
State Recreation or Conservation Areas	×	
Natural Vegetation	✓	5.12
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	×	
Roads (All Types)	✓	6.2.1
Bridges	×	
Tunnels	×	
Culverts	✓	6.2.1
Water, Gas or Sewerage Infrastructure	×	
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	×	
Telecommunication Lines or Associated Plants	×	
Water Tanks, Water or Sewage Treatment Works	×	
Dams, Reservoirs or Associated Works	×	
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	

Item	Within Study Area	Section Number
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	×	6.4.1
Farm Buildings or Sheds	✓	6.8
Tanks	✓	6.8
Gas or Fuel Storages	×	
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.4.2
Farm Dams	✓	6.4.3
Wells or Bores	✓	6.4.4
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	✓	6.5.1
Mine Related Infrastructure Including Exploration Bores and Gas Wells	✓	6.5.2 to 6.5.5
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL SIGNIFICANCE	✓	6.6
AREAS OF HISTORICAL SIGNIFICANCE	✓	6.8.1
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.7
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	6.8.1
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 AND THE METHODS USED TO PREDICT THE SUBSIDENCE EFFECTS FOR THE MODIFIED LAYOUT

3.1. Introduction

The following sections provide overviews of conventional and non-conventional mine subsidence effects and the methods that have been used to predict these movements. Further information is also provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2. Overview of conventional subsidence effects

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

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the longwall goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.

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

- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km^{-1})*, but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.

- **Strain** is the relative differential horizontal 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 distances between two points increase and **Compressive Strains** occur when the distances between two points decrease. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  While 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), and vice versa.

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

3.3. Far-field movements

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

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

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

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.5.

3.4. Overview of non-conventional subsidence movements

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

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

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

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

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

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

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

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

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

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural and built features, which are provided in Chapters 5 and 6, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

3.4.2. Non-conventional subsidence movements due to steep topography

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

Further discussions on the potential for downslope movements for the steep slopes within the Study Area are provided in Section 5.7.

3.4.3. Valley-related movements

The streams within the Study Area will be affected by valley-related movements, which are commonly observed in the Southern Coalfield, but less so in the Hunter and Newcastle Coalfields. 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.

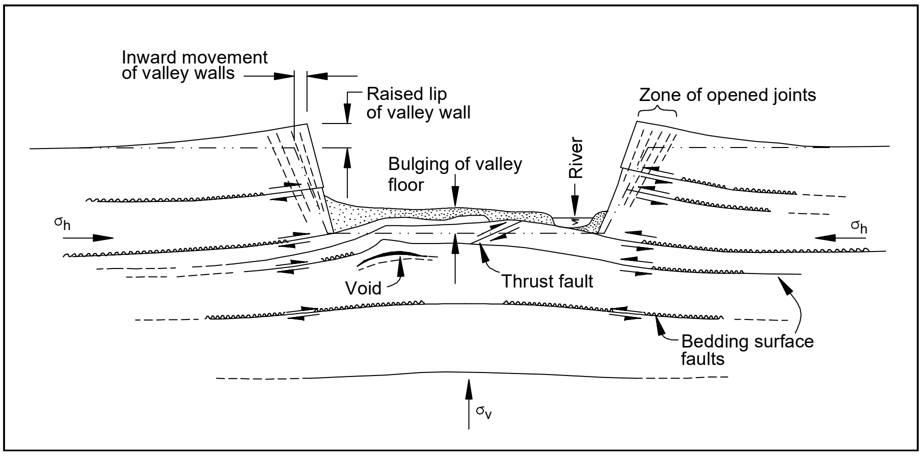


Fig. 3.1 Valley formation in flat-lying sedimentary rocks (after Patton and Hendren 1972)

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 downslope movements. Valley-related movements are normally described by the following parameters:

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

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

The predicted valley-related effects for the streams have been determined using the empirical method outlined in Australian Coal Association Research Program (ACARP) Research Project No. C9067 (Waddington and Kay, 2002), referred to as the 2002 ACARP method. The predicted compressive strains due to these valley-related effects have been determined from the analysis of ground monitoring data from the NSW coalfields.

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 Incremental Profile Method (IPM) was initially developed by Waddington Kay and Associates, now known as MSEC, as part of a study in 1994. The method evolved following detailed analyses of subsidence monitoring data from the Southern Coalfield which was then extended to include detailed subsidence monitoring data from the Newcastle, Hunter and Western Coalfields.

The review of the detailed ground monitoring data from the NSW coalfields showed that while the final subsidence profiles measured over a series of longwalls were irregular, the observed incremental subsidence profiles due to the extraction of individual longwalls were consistent in both magnitude and shape and varied according to local geology, depth of cover, panel width, seam thickness, the extent of adjacent previous mining, the pillar width and stability of the chain pillar and a time-related subsidence component.

MSEC developed a series of subsidence prediction curves for the Newcastle and Hunter Coalfields, between 1996 and 1998, after receiving extensive subsidence monitoring data from Centennial Coal for the Cooranbong Life Extension Project (Waddington and Kay, 1998). The subsidence monitoring data from many collieries in the Newcastle and Hunter Coalfields were reviewed and it was found that the incremental subsidence profiles resulting from the extraction of individual longwalls were consistent in shape and magnitude where the mining geometries and overburden geologies were similar.

Since this time, extensive monitoring data has been gathered from mines in the Southern, Newcastle, Hunter and Western Coalfields of NSW and from the Bowen Basin in Queensland, including: Airly, Angus Place, Appin, Awaba, Baal Bone, Bellambi, Beltana, Blakefield South, Bulga, Bulli, Burwood, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Donaldson, Eastern Main, Ellalong, Elouera, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Moranbah North, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, NRE Wongawilli, Oaky Creek, Ravensworth, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

Based on the extensive empirical data, MSEC has developed standard subsidence prediction curves for the Southern, Western, Newcastle and Hunter Coalfields. The prediction curves can then be further refined, for the local geology and local conditions, based on the available monitoring data from the area. Discussions on the calibration of the IPM for the longwalls at the SBEUM are provided in Section 3.6.

The prediction of subsidence is a three stage process where, first, the magnitude of each increment is calculated, then, the shape of each incremental profile is determined and, finally, the total subsidence profile is derived by adding the incremental profiles from each longwall in the series. In this way, subsidence predictions can be made anywhere above or outside the extracted longwalls, based on the local surface and seam information.

For longwalls in the Newcastle and Hunter Coalfields, the maximum predicted incremental subsidence is initially determined, using the IPM subsidence prediction curves for a single isolated panel, based on the longwall void width (W) and the depth of cover (H). The incremental subsidence is then increased, using the IPM subsidence prediction curves for multiple panels, based on the longwall series, panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H). In this way, the influence of the panel width (W), depth of cover (H), as well as panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H) are each considered.

The shapes of the incremental subsidence profiles are then determined using the large empirical database of observed incremental subsidence profiles from the Hunter Coalfield. The profile shapes are derived from the normalised subsidence profiles for monitoring lines where the mining geometry and overburden geology are similar to that for the longwalls at the SBEUM. The profile shapes can be further refined, based on local monitoring data, which is discussed further in Section 3.6.

Finally, the total subsidence profiles resulting from the series of longwalls are derived by adding the predicted incremental profiles from each of the longwalls. Comparisons of the predicted total subsidence profiles, obtained using the IPM, with observed profiles indicates that the method provides reasonable, if not slightly conservative, predictions where the mining geometry and overburden geology are within the range of the empirical database. The method can also be further tailored to local conditions where monitoring data is available close to the mining area.

3.6. Calibration of the IPM

There are no existing workings located above or below the longwalls at the SBEUM (i.e. single-seam mining conditions). The depths of cover to the Whybrow Seam directly above WYLW17 to WYLW24 vary between 44 m and 330 m. The depths of cover are shallowest above the eastern part of the mining area and are greatest above the western part of the mining area.

The longwall width-to-depth ratios vary between 0.8 in the western part of the mining area and greater than 4.0 in the eastern part of the mining area. The magnitudes of subsidence and the shapes of the subsidence profiles, therefore, will vary considerably over the lengths of these longwalls.

In the eastern part of the mining area, the width-to-depth ratios are greater than 1.4 and, therefore, the longwalls are supercritical in width. The maximum predicted subsidence is expected to be the maximum achievable in the Hunter Coalfield for single-seam mining conditions, which has been found to be 60 % to 65 % of the extracted seam thickness. It has been identified, however, that the measured subsidence varies greatly from point to point, at these very shallow depths of cover, as the result of variations in the overburden geology.

In the western part of the mining area, the width-to-depth ratios are less than 1.4 and, therefore, the longwalls are subcritical in width. As a result, the predicted subsidence is expected to be less than the maximum achievable in the Hunter Coalfield and, hence, less than that predicted in the eastern part of the mining area. Similarly, the predicted tilts, curvatures and strains in the western part of the mining area are less than those predicted in the eastern part of the mining area.

The IPM was previously calibrated to local conditions using ground monitoring data from the Wambo Coal Mine and from other nearby collieries. The available monitoring data included that from WYLW11 to WYLW13 (i.e. single-seam mining conditions) at the South Bates Underground Mine. The monitoring comprised three ground survey lines (7XL-Line, CL11B-Line and CL13B-Line) and LiDAR surveys. Comparisons between the measured and predicted movements for WYLW11 to WYLW13 are provided in the subsidence summary reviews in Reports Nos. MSEC866, MSEC886 and MSEC916.

Ground monitoring data have also been gathered during the extraction of WYLW17 to WYLW20 and part WYLW21 at the SBEUM. The monitoring comprises two ground survey lines (8XL-Line and CL17B-Line) and Light Detecting and Ranging (LiDAR) surveys. Comparisons between the measured and predicted movements for WYLW17 to WYLW21 are provided in the subsidence summary review in Report Nos. MSEC1007, MSEC1135 and MSEC1198.

The measured and predicted vertical subsidence for the combined 7XL-Line and 8XL-Line, due to the extraction of WYLW11 to WYLW13 and WYLW17 to WYLW20, are illustrated in Fig. 3.2. The measured profile of vertical subsidence (i.e. green line) reasonably matches the predicted profile (i.e. red line).

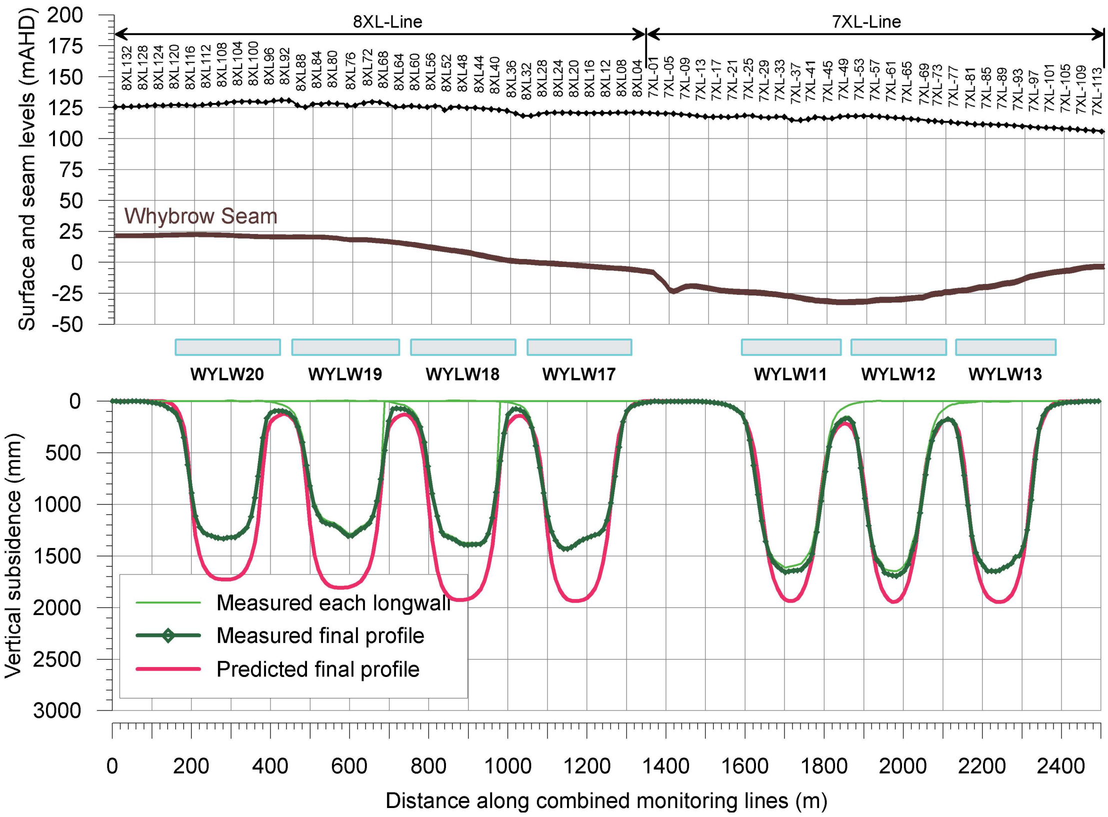


Fig. 3.2 Measured and predicted vertical subsidence along the 7XL-Line and 8XL-Line due to the extraction of WYLW11 to WYLW13 at the South Bates Underground Mine and WYLW17 to WYLW20 at the South Bates Extension Underground Mine

The maximum measured values of vertical subsidence along the 7XL-Line and 8XL-Line are less than the maximum predicted values. The ratio of the maximum measured to maximum predicted vertical subsidence above each of the longwalls vary between 0.85 and 0.87 for WYLW11 to WYLW13 and between 0.72 and 0.77 for WYLW17 to WYLW20. The values of the measured vertical subsidence above the chain pillars are similar to the predicted values.

The measured profile of tilt (not shown) reasonably matches the predicted profile. The measured profile of curvature (also not shown) is irregular (i.e. more erratic) due to survey tolerance, localised irregular ground movements and possibly due to disturbed survey marks. The measured zones of hogging curvature and sagging curvature reasonably matched the predicted zones. The maximum measured tilt and curvatures are similar to the maximum predicted values.

The observations for the other ground monitoring lines above WYLW11 to WYLW13 and WYLW17 to WYLW20 are similar to that described above for the 7XL-Line and 8XL-Line. It is considered, therefore, that the IPM provides predictions that are consistent with the measurements and that it is not necessary to re-calibrate the model based on the monitoring data for the Whybrow Seam.

4.1. Introduction

This chapter provides the maximum predicted conventional subsidence effects due to the mining of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 (i.e. the Modified Layout) in the Whybrow Seam. The predicted subsidence effects and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted values of vertical subsidence, tilt and curvature have been obtained using the standard IPM for the Hunter Coalfield, which is described in Section 3.6. The predicted strains have been determined by analysing the strains measured at the Wambo Coal Mine, and other NSW collieries, where the longwall width-to-depth ratios and extraction heights are similar to those for longwalls based on the Modified Layout.

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

4.2. Maximum predicted conventional subsidence, tilt and curvature

A summary of the maximum predicted values of incremental conventional vertical subsidence, tilt and curvature due to the mining of WYLW17 to WYLW26 is provided in Table 4.1. The incremental values represent the maximum predicted additional movements due to the mining of each of the longwalls based on the Modified Layout.

Table 4.1 Maximum predicted incremental vertical subsidence, tilt and curvature due to the mining of each of WYLW17 to WYLW26 based on the Modified Layout

Component	Due to longwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
Existing/ approved longwalls	WYLW17	1850	75	> 3.0	> 3.0
	WYLW18	1850	60	> 3.0	> 3.0
	WYLW19	1750	65	> 3.0	> 3.0
	WYLW20	1750	70	> 3.0	> 3.0
	WYLW21	1750	70	> 3.0	> 3.0
	WYLW22	1850	75	> 3.0	> 3.0
	WYLW23	1850	75	> 3.0	> 3.0
Modified longwalls	WYLW24	1800	70	> 3.0	> 3.0
	WYLW25	1850	60	> 3.0	> 3.0
	WYLW26	1850	55	> 3.0	> 3.0

The magnitudes of the predicted subsidence effects vary across the SBEUM mining area due to the wide range of depths of cover above the Whybrow Seam. The maximum predicted subsidence effects occur at the finishing (i.e. north-eastern) ends of WYLW17 to WYLW23 and above the eastern part of WYLW24 to WYLW26, where the depths of cover are the shallowest.

The maximum predicted incremental curvatures for each of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 are greater than 3.0 km^{-1} (i.e. minimum radius of curvature of less than 0.3 km). These curvatures are very localised and therefore do not necessarily represent the overall (i.e. macro) ground movements. The magnitudes of the localised curvatures greater than 3.0 km^{-1} become less meaningful and, therefore, the specific values have not been presented.

The predicted total vertical subsidence after the extraction of each of WYLW23 to WYLW26 are shown in Drawings Nos. MSEC1224-10 to MSEC1224-13, respectively. The contours include the accumulated movements due to the mining of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26.

Summaries of the maximum predicted values of total conventional vertical subsidence, tilt and curvature for existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 are provided in Table 4.2 and Table 4.3, respectively. The total values represent the maximum predicted accumulated movements within the Study Area after the completion of each of the longwalls based on the Modified Layout.

Table 4.2 Maximum predicted total vertical subsidence, tilt and curvature due to the mining of the existing/approved WYLW17 to WYLW23

After longwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
WYLW17 to WYLW23	1950	80	> 3.0	> 3.0

Table 4.3 Maximum predicted total vertical subsidence, tilt and curvature due to the mining of the modified WYLW24 to WYLW26

After longwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
WYLW24	1800	70	> 3.0	> 3.0
WYLW25	1900	75	> 3.0	> 3.0
WYLW26	1950	75	> 3.0	> 3.0

The maximum predicted total vertical subsidence is 1950 mm for both the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26 and it represents 65 % of the maximum mining height of 3.0 m. The maximum predicted subsidence movements occur above the finishing (i.e. north-eastern) ends WYLW17 to WYLW23 and above the eastern part of WYLW24 to WYLW26, where the depths of cover are the shallowest.

The maximum predicted total tilt is 80 mm/m (i.e. 8.0 % or 1 in 12) for the existing/approved WYLW17 to WYLW23 and 75 mm/m (i.e. 7.5 % or 1 in 13) for the modified WYLW24 to WYLW26. The maximum predicted tilts occur where the depths of cover are the shallowest.

The maximum predicted total conventional curvature is greater than 3.0 km^{-1} and it represents a minimum radius of curvature of less than 0.3 km. The maximum curvatures are localised and therefore they do not necessarily represent the overall (i.e. macro) ground movements. The magnitudes of the localised curvatures greater than 3.0 km^{-1} become less meaningful and, therefore, the specific values have not been presented.

The predicted conventional subsidence effects vary across the SBEUM mining area as the result of, amongst other factors, variations in the depths of cover and seam thickness. The predicted vertical subsidence varies between the south-western and north-eastern ends of the existing/approved WYLW17 to WYLW23 and between the western and eastern areas above the modified WYLW24 to WYLW26, as shown in Drawings Nos. MSEC1224-10 to MSEC1224-13. It can also be inferred from the spacing of the contours shown in these drawings, that the predicted tilts and curvatures also vary over the lengths of the longwalls.

To illustrate this variation, the predicted profiles of vertical subsidence, tilt and curvature have been determined along two prediction lines. The predicted subsidence effects along Prediction Lines 1 and 2 are shown in Figs. C.01 and C.02, respectively, in Appendix C. The locations of these prediction lines are shown in Drawings Nos. MSEC1224-10 to MSEC1224-13. The predicted profiles based on the Modified Layout are shown as the cyan and blue lines. The predicted profiles based on the MOD 17 Layout are shown as the dashed purple lines for comparison.

4.3. Comparison of the maximum predicted subsidence effects

The predicted subsidence effects for the MOD 17 Layout were originally provided in Report No. MSEC848 which supported the South Bates Extension Modification Application.

A comparison of the maximum predicted total subsidence effects for the MOD 17 Layout and Modified Layout is provided in Table 4.4. The values represent the maximum predicted accumulated movements within the Study Area due to the extraction of all longwalls for the respective layouts.

Table 4.4 Comparison of maximum predicted total subsidence effects

Layout	Longwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
MOD 17 Layout (MSEC848)	WYLW17 to WYLW25	1950	90	> 3.0	> 3.0
Modified Layout (MSEC1224)	WYLW17 to WYLW26	1950	80	> 3.0	> 3.0

The maximum predicted total vertical subsidence of 1950 mm, based on the Modified Layout, is the same as the maximum predicted value based on the MOD 17 Layout. The maximum predicted vertical subsidence does not change as the longwalls are supercritical in width and, therefore, are expected to achieve 65 % of the mining height.

The maximum predicted total tilt of 80 mm/m, based on the Modified Layout, is less than the maximum predicted value based on the MOD 17 Layout of 90 mm/m. The reason for this decrease in tilt is the finishing (i.e. north-eastern) ends of WYLW17 to WYLW23 have been shortened as part of the Extraction Plan process in accordance with Development Consent (DA 305-7-2003), thereby increasing the minimum depths of cover above these longwalls. Also, the minimum depth of cover above WYLW24 to WYLW26 for the Modified Layout of 55 m is greater than the minimum depth of cover above WYLW17 to WYLW25 for the MOD 17 Layout of 44 m.

The maximum predicted total hogging and sagging curvatures are greater than 3.0 km^{-1} (i.e. minimum radius of curvature less than 0.3 km) based on both the MOD 17 Layout and Modified Layout. While specific values have not been presented, the maximum predicted curvatures reduce due to the shortened finishing ends of WYLW17 to WYLW23 and the associated increase in the minimum depths of cover directly above these longwalls and the slightly higher minimum depth of cover for WYLW24 to WYLW26.

4.4. Predicted strains

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

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

In the Hunter Coalfield, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains for single-seam conditions. The maximum predicted strains, therefore, are greater than 30 mm/m above the longwall finishing ends.

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

The range of strains above the longwalls at the SBEUM has been determined using monitoring data from the previously extracted longwalls in the Hunter and Newcastle Coalfields, where the mining geometry is reasonably similar to those for the longwalls based on the Modified Layout. The range of strains measured during the extraction of these longwalls should, therefore, provide a reasonable indication of the range of potential strains for these longwalls.

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

4.4.1. Existing/approved WYLW17 to WYLW23

The predicted strains for WYLW17 to WYLW25 based on the MOD 17 Layout are provided in Report No. MSEC848. The predicted strains for WYLW17 to WYLW23 based on the Modified Layout are similar to or less than those for the MOD 17 Layout, as the shortened finishing (i.e. north-eastern) ends reduce the minimum depths of cover above the longwalls.

The depths of cover above the longwall commencing (i.e. south-western) ends are considerably greater than the depths of cover above the longwall finishing (i.e. north-eastern) ends. The strains have therefore been provided separately for each end.

The depths of cover above the longwall commencing (i.e. south-western) ends are typically greater than 200 m. In these locations, the predicted strains are: 5 mm/m tensile and 4 mm/m compressive based on the 95 % confidence level; and 10 mm/m tensile and 7 mm/m compressive based on the 99 % confidence level.

The depths of cover above the longwall finishing (i.e. north-eastern) ends are typically less than 100 m. In these locations, the predicted strains are: 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence level; and greater than 28 mm/m tensile and greater than 30 mm/m compressive based on the 99 % confidence level.

4.4.2. Modified WYLW24 to WYLW26

The depths of cover above the modified WYLW24 to WYLW26 vary between a minimum of 55 m above the north-eastern area of these longwalls and a maximum of 240 m beneath the ridgeline on the western side of these longwalls. The average depths of cover above each of the longwalls are 90 m for WYLW24, 120 m for WYLW25 and 145 m for WYLW26.

The ranges of the depths of cover and seam thicknesses for the modified WYLW24 to WYLW26 are the same as those for WYLW17 to WYLW25 based on the MOD 17 Layout. Hence, it follows that, the range of predicted strains is also similar, as described in the previous section, where the depths of cover are less than 100 m and where the depths of cover are greater than 200 m.

The depths of cover in the central part of the modified WYLW24 to WYLW26 are typically between 100 m and 200 m and the corresponding longwall width-to-depth ratios vary between 1.3 and 2.6. The predicted strains for this area have been determined by analysing the measured ground strains for monitoring lines from the Hunter and Newcastle Coalfields, where the width-to-depth ratios are within this range. This should provide a reasonable indication of the range of potential strains in the central part of the SBEUM mining area above WYLW24 to WYLW26.

The available monitoring lines have been analysed to extract the maximum tensile and compressive strains that have been measured at any time during mining, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls. A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided a good fit to the raw strain data.

Histograms of the maximum measured tensile and compressive strains for the survey bays located directly above goaf, for previously extracted longwalls in the Hunter and Newcastle Coalfields having width-to-depth ratios between 1.3 and 2.6, are provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

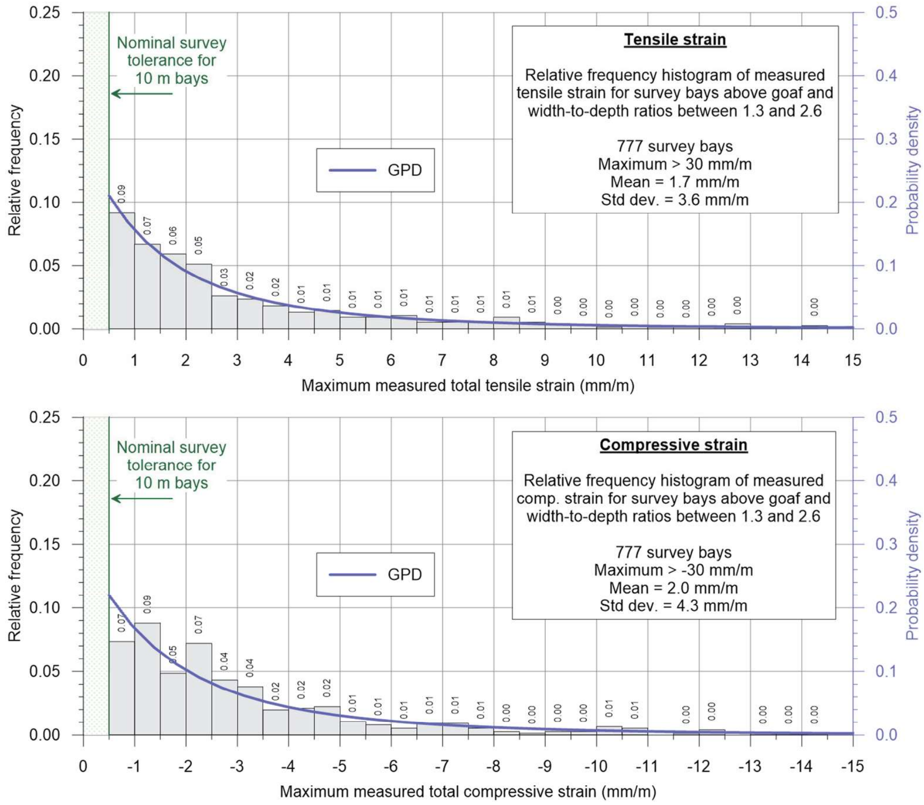


Fig. 4.1 Distributions of the measured maximum tensile and compressive strains for survey bays located above longwalls with width-to-depth ratios between 1.3 and 2.6

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 the longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining are 8 mm/m tensile and 9 mm/m compressive. The 99 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining are 18 mm/m tensile and 19 mm/m compressive.

4.4.3. Maximum predicted strains for the Modified Layout

A summary of the maximum predicted strains for the Modified Layout is provided in Table 4.5.

Table 4.5 Maximum predicted strains for the Modified Layout

Location	Maximum tensile strain (mm/m)		Maximum compressive strain (mm/m)	
	95 % CL	99 % CL	95 % CL	99 % CL
Higher depth of cover (greater than 200 m)	5	10	4	7
Intermediate depth of cover (100 m to 200 m)	8	18	9	19
Lower depth of cover (less than 100 m)	12	> 28	17	> 30

4.5. Predicted far-field horizontal movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the Modified Layout, and the predicted valley-related effects along the streams, it is also likely that far-field horizontal movements will occur outside of the SBEUM mining area.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data from the Southern and Western Coalfields. The far-field horizontal movements resulting from mining were generally orientated towards the extracted panels. At very low levels of far-field horizontal movements; however, there was a high scatter in the orientation of the observed movements.

There is considerably less 3D monitoring data in the Hunter and Newcastle Coalfields that have stable base points and that extend well beyond the mining areas. Based on the available data, the extents of far-field horizontal movements measured in the Hunter Coalfield are less than those measured in the Southern and Western Coalfields. The reason is that the shallower depths of cover in the Hunter Coalfield result in greater movements above the mining areas but lesser movements outside the mining areas. The data from the Southern and Western Coalfields should therefore provide conservative predictions of the far-field horizontal movements for the Modified Layout.

The measured total far-field horizontal movements due to longwall mining in the Southern and Western Coalfields are shown in Fig. 4.2. The measured values (y-axis) are the accumulated movements due to the mining in each mining domain. The distances (x-axis) are those of the survey marks from the nearest longwall (active or completed) in the mining domain.

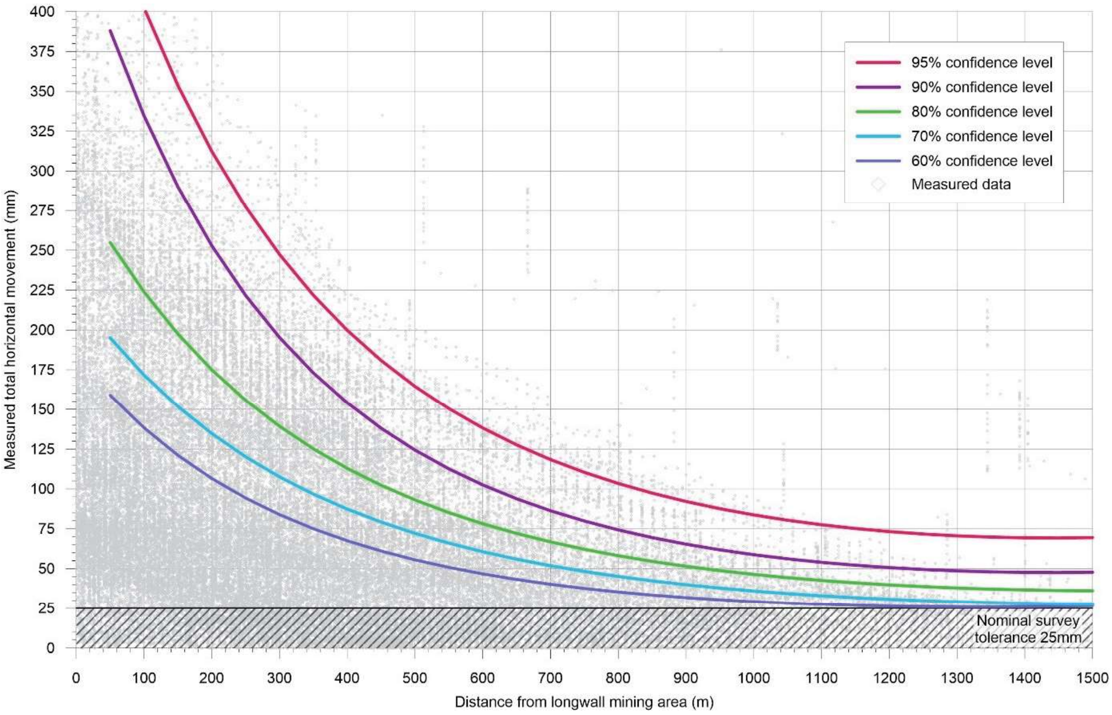


Fig. 4.2 Measured total far-field horizontal movements in the Southern and Western Coalfields

The distributions of far-field horizontal movements in the Southern and Western Coalfields are similar. Confidence levels have therefore been fitted to the data from both these coalfields, as illustrated in Fig. 4.2. The predicted far-field horizontal movement at a distance of 1 km outside the mining area is 80 mm based on the 95 % confidence level.

The Montrose Open Cut Pit is located to the north-east of the modified WYLW24 to WYLW26 as shown in Drawing No. MSEC1224-01. The open cut pit has extracted the overburden material above the Whybrow Seam. The removal of this material would have relieved and redistributed much of the horizontal in situ stress in the overburden strata adjacent to the open cut pit. The potential for far-field horizontal movements in the vicinity of the Montrose Open Cut Pit, therefore, is reduced.

The predicted far-field horizontal movements due to the mining of the modified WYLW24 to WYLW26 are expected to be small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the mining area and are accompanied by very low levels of strain, generally in the order of survey tolerance (i.e. less than 0.3 mm/m). The potential impacts of far-field horizontal movements on the natural and built features within the vicinity of the longwalls based on the Modified Layout are not expected to be significant.

4.6. Non-conventional ground movements

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

Specific predictions of upsidence, closure and compressive strain due to the valley-related effects are provided for the streams in Section 5.2. The impact assessments for the streams are based on both the conventional and valley-related effects. The potential for non-conventional movements associated with steep topography is discussed in Section 5.7.

There are no major geological structures identified within the extents of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26. The Redmanvale Fault is located to the south-west of the SBEUM mining area. Discussions on the potential effects of this fault on the predicted subsidence are provided in Section 1.4.

In most cases, it is not possible to predict the exact locations or magnitudes of the non-conventional anomalous movements due to near-surface geological conditions. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains, including both conventional and non-conventional anomalous strains, which are discussed in Section 4.4.

4.7. Surface deformations

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

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

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

Fracturing of bedrock can also occur in the bases of stream valleys due to the compressive strains associated with valley-related upsidence and closure effects. The impact assessments for valley-related movements are provided in Section 5.2.

The surface deformations due to the mining of WYLW17 to WYLW20 have been recorded by WCPL and these were described in Reports Nos. MSEC1007, MSEC1135 and MSEC1198. The locations of the mapped surface cracking due to the mining of the longwalls in the Whybrow Seam are shown in Fig. 4.3 (Source: WCPL).

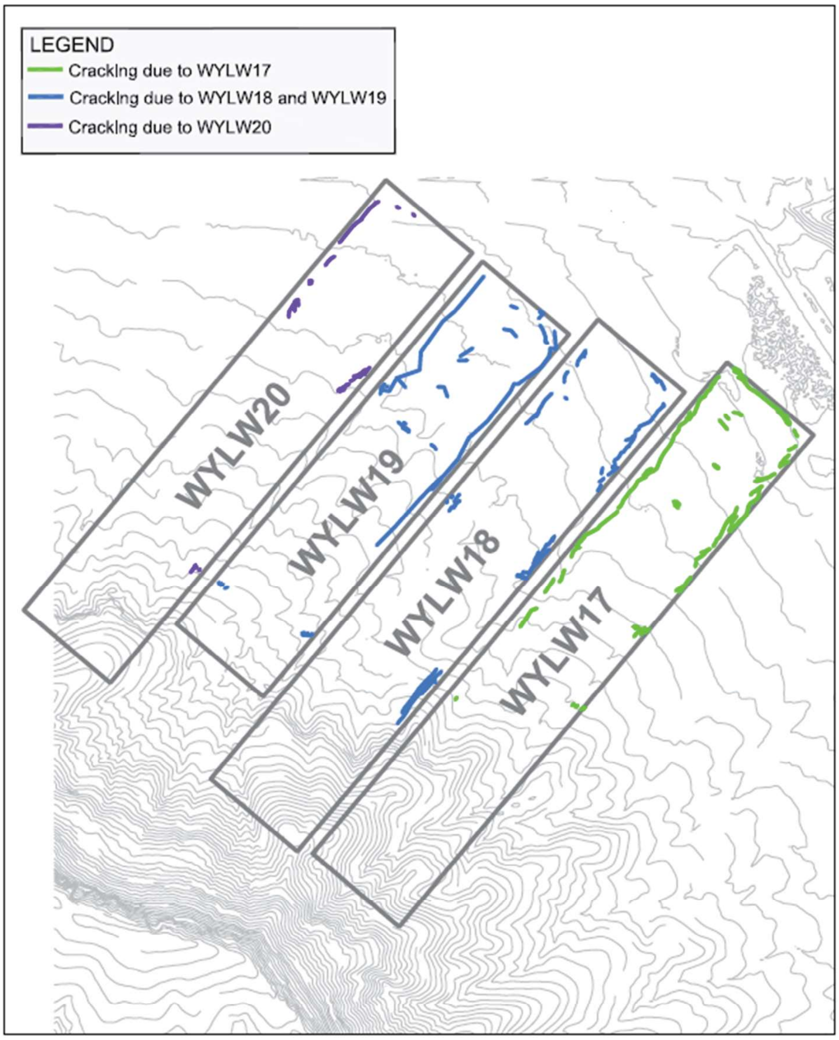


Fig. 4.3 Mapped surface cracking above WYLW17 to WYLW21

The largest surface deformations occurred adjacent to the maingates and tailgates, towards the finishing (i.e. north-eastern) ends of the longwalls, due to the shallower depths of cover. Less extensive cracking was recorded towards the commencing (i.e. south-western) end of the longwalls due to the higher depths of cover and possibly because the less accessible terrain limited inspection and mapping of the surface.

The surface crack widths towards the finishing ends of WYLW17 to WYLW20 were typically between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm. Compression heaving also developed with heights up to approximately 300 mm. Fracturing and spalling of the exposed bedrock developed within the North Wambo Creek Diversion.

More isolated surface cracking developed above the central and south-western ends of WYLW17 to WYLW20. The crack widths were typically between 10 mm and 50 mm, with localised crack widths up to approximately 100 mm. Minor potholes were also observed along the steep slopes near the access tracks.

The total length of the mapped surface cracking directly above WYLW17 to WYLW20 is approximately 3.5 km. The recorded crack widths were generally less than 50 mm (i.e. 90 % of cases). The crack widths were between 50 mm and 100 mm in 7 % of cases and greater than 100 mm in the remaining 3 % of cases. The maximum crack width was approximately 400 mm.

Photographs of the surface deformations that developed above WYLW17 to WYLW20 are provided in Fig. 4.4 to Fig. 4.13.

Fig. 4.4 Surface cracking above north-eastern end of WYLW17

Fig. 4.5 Compression heaving above north-eastern end of WYLW17

Fig. 4.6 Surface cracking along the access tracks above WYLW17

Fig. 4.7 Surface cracking above the middle of WYLW17

Fig. 4.8 Surface cracking on the steep slopes above the south-western end of WYLW17

Fig. 4.9 Surface cracking near the finishing end of WYLW18 (Source: WCPL)

Fig. 4.10 Surface cracking on a steep slope above the south-western end of WYLW18

Fig. 4.11 Surface cracking along an access track above WYLW18 and WYLW19 (Source: WCPL)

Fig. 4.12 Surface cracking adjacent to the tailgate of WYLW20 (Source: WCPL)

Fig. 4.13 Surface cracking near Dam d07 adjacent to the maingate of WYLW20 (Source: WCPL)

Further discussion on surface cracking is provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

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

5.1. Natural features

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

- drinking water catchment areas or declared special areas;
- known springs or groundwater seeps;
- seas or lakes;
- shorelines;
- natural dams;
- swamps or wetlands;
- lands declared as critical habitat under the *Threatened Species Conservation Act 1995*;
- State Recreation Areas or State Conservation Areas;
- State Forests;
- areas of significant geological interest; and
- other significant natural features not described below.

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

5.2. Streams

5.2.1. Description of the streams

The streams are shown in Drawing No. MSEC1224-08.

The natural streams within the Study Area comprise North Wambo Creek, Waterfall Creek and their associated tributaries. The diverted section of North Wambo Creek (i.e. the North Wambo Creek Diversion) is also located within the Study Area.

North Wambo Creek

North Wambo Creek commences along the Wollemi Escarpment to the west of the SBEUM mining area. The upper section of the creek located outside the Study Area is formed within an incised valley at the base of the escarpment. The creek bed comprises a rounded gravel to sandy base. In some locations there is exposed bedrock that has formed into small cascades with isolated pools. There is also significant debris along this section of the creek, including boulders, tree branches and other vegetation.

The lower section of North Wambo Creek is located within the Study Area. This section of creek is a fifth order ephemeral stream with a shallow incision into the natural surface soils. The total length of North Wambo Creek within the Study Area is approximately 2.8 km.

The natural surface level along the section of North Wambo Creek within the Study Area varies from a high point of 132 mAHD at the upstream end to a low point of 107 mAHD at the downstream end. The average natural grade for this section of creek, therefore, is 7 mm/m (i.e. 0.7 % or 1 in 143).

A section of North Wambo Creek is located directly above the SBEUM mining area based on both the MOD 17 Layout and Modified Layout. A summary of the total lengths of the creek above the SBEUM mining area is provided in Table 5.1.

Table 5.1 Total lengths of North Wambo Creek located above the SBEUM mining area

Location	Layout	Creek located above longwalls	Total length above the SBEUM mining area (km)
North Wambo Creek	MOD 17 Layout (MSEC848)	WYLW23, WYLW24 and WYLW25	2.7
	Modified Layout (MSEC1224)	WYLW23, WYLW25 and WYLW26	0.6

The length of North Wambo Creek located directly above the SBEUM mining area based on the Modified Layout is approximately 2.1 km less than that based on the MOD 17 Layout.

Photographs of the upper and lower sections of North Wambo Creek are provided in Fig. 5.1 and Fig. 5.2, respectively. The locations of the photographs are shown in Drawing No. MSEC1224-08.

Fig. 5.1 Upper section of North Wambo Creek located outside the SBEUM mining area (P0649 and P0595)

Fig. 5.2 Lower section of North Wambo Creek located adjacent to the SBEUM mining area (P5458)

The natural section of North Wambo Creek joins the constructed North Wambo Creek Diversion between the SBEUM mining area and the Montrose Open Cut Pit. The start of the creek diversion is located north-east of WYLW22. The downstream section of the creek diversion crosses the Study Area and is located directly above the finishing (i.e. north-eastern) end of WYLW17. Further discussions on the North Wambo Creek Diversion are provided in Section 6.1.

Waterfall Creek

The upper reaches (i.e. first and second order sections) of Waterfall Creek are located within the Study Area. This section of the creek is formed within a shallow valley within the steep slopes. The total length of Waterfall Creek within the Study Area is approximately 0.5 km.

The natural surface level along the section of Waterfall Creek within the Study Area varies from a high point of 246 mAHD at the upstream end to a low point of 169 mAHD at the downstream end. The average natural grade for this section of creek, therefore, is 150 mm/m (i.e. 15 % or 1 in 7).

Waterfall Creek is located outside the SBEUM mining area based on the MOD 17 Layout. However, this creek is located directly above the modified WYLW26. A summary of the total lengths of the creek above the SBEUM mining area is provided in Table 5.2.

Table 5.2 Total lengths of Waterfall Creek located above the SBEUM mining area

Location	Layout	Creek located above longwalls	Total length above the mining area (km)
Waterfall Creek	MOD 17 Layout (MSEC848)	-	0.0
	Modified Layout (MSEC1224)	WYLW26	0.2

The length of Waterfall Creek located directly above the SBEUM mining area therefore increases by approximately 0.2 km due to the Modification.

The base of Waterfall Creek is founded in the natural surface soils. However, there is a step with exposed bedrock located approximately 50 m west of the maingate of the modified WYLW26. There is locally exposed bedrock in other locations along the upper reaches of the creek.

Photographs of the section of Waterfall Creek within the Study Area are provided in Fig. 5.3 to Fig. 5.5.

Fig. 5.3 Valley of Waterfall Creek near the maingate of the modified WYLW26 (P5565)

Fig. 5.4 Upper reaches of Waterfall Creek founded in natural surface soils (P5578)

Fig. 5.5 Step and exposed bedrock along Waterfall Creek west of modified WYLW26 (P5586)

The third order section of Waterfall Creek is located downstream and outside of the Study Area. The start of the third order section of stream is located 180 m north of the modified WYLW26.

Unnamed drainage lines

Ephemeral drainage lines are located across the Study Area. The drainage lines located above the existing/approved WYLW17 to WYLW23 and the southern ends of the modified WYLW24 to WYLW26 are tributaries to North Wambo Creek and the North Wambo Creek Diversion. The drainage lines located above the northern ends of the modified WYLW24 to WYLW26 are tributaries to Waterfall Creek.

The drainage lines have shallow incisions into the natural surface soils, with some isolated bedrock outcropping along the upper reaches. A photograph of a typical drainage line located above the SBEUM mining area is provided in Fig. 5.6.

Fig. 5.6 Typical drainage line located above the SBEUM mining area (P5644)

The natural grades of the drainage lines within the Study Area typically vary between 5 mm/m (i.e. 0.5 % or 1 in 200) and 100 mm/m (i.e. 10 % or 1 in 10), with average natural grades of approximately 30 mm/m to 60 mm/m (i.e. 3 % to 6 % or 1 in 33 to 1 in 17).

5.2.2. Predictions for the streams

North Wambo Creek

The predicted profiles of vertical subsidence, tilt and curvature along North Wambo Creek are shown in Fig. C.03, in Appendix C. The predicted profiles based on the Modified Layout are shown as the cyan and blue lines. The predicted profiles based on the MOD 17 Layout are shown as the dashed purple lines for comparison.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for North Wambo Creek, based on the Modified Layout, is provided in Table 5.3. The values are the maximum predicted subsidence effects for the section of creek located within the Study Area.

Table 5.3 Maximum predicted total vertical subsidence, tilt and curvature for North Wambo Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
North Wambo Creek	After WYLW17 to WYLW23	1950	70	> 3.0	> 3.0
	After WYLW24	1950	70	> 3.0	> 3.0
	After WYLW25	1950	70	> 3.0	> 3.0
	After WYLW26	1950	70	> 3.0	> 3.0

The maximum predicted total tilt for North Wambo Creek is 70 mm/m (i.e. 7.0 % or 1 in 14). The maximum predicted total conventional curvature is greater than 3.0 km^{-1}, which represents a minimum radius of curvature of less than 0.3 km.

The maximum predicted conventional strains for North Wambo Creek, based on applying a factor of 10 to the maximum predicted curvatures, are greater than 30 mm/m tensile and compressive. The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The maximum predicted strains for the section of creek near the finishing (i.e. north-eastern) end of the existing/approved WYLW23 are 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence levels. Lesser strains are predicted further upstream as the depth of cover increases.

Non-conventional movements can also occur and have occurred in the NSW coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The section of North Wambo Creek located directly above the longwalls has a shallow incision into the natural surface soils. The predicted valley-related effects for the creek, therefore, are not significant when compared with the predicted conventional movements.

Waterfall Creek

The predicted profiles of vertical subsidence, tilt and curvature along Waterfall Creek are shown in Fig.C.04, in Appendix C. The predicted profiles based on the Modified Layout are shown as the blue lines.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for Waterfall Creek, based on the Modified Layout, is provided in Table 5.4. The values are the maximum predicted subsidence effects for the section of creek within the Study Area.

Table 5.4 Maximum predicted total vertical subsidence, tilt and curvature for Waterfall Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Waterfall Creek	After WYLW17 to WYLW23	< 20	< 0.5	< 0.01	< 0.01
	After WYLW24	< 20	< 0.5	< 0.01	< 0.01
	After WYLW25	< 20	< 0.5	< 0.01	< 0.01
	After WYLW26	450	13	0.45	0.40

The maximum predicted total tilt for Waterfall Creek is 13 mm/m (i.e. 1.3 % or 1 in 77). The maximum predicted total conventional curvatures are 0.45 km^{-1} hogging and 0.40 km^{-1} sagging, which represent minimum radii of curvatures of 2.2 km and 2.5 km, respectively.

The maximum predicted conventional strains for Waterfall Creek, based on applying a factor of 10 to the maximum predicted curvatures, are 4.5 mm/m tensile and 4.0 mm/m compressive. The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The depths of cover for this creek are typically between 100 m and 200 m and, therefore, the maximum predicted strains are 8 mm/m tensile and 9 mm/m compressive based on the 95 % confidence levels.

Non-conventional movements can also occur and have occurred in the NSW coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The predicted valley-related effects for Waterfall Creek are not significant when compared with the predicted conventional movements.

Unnamed drainage lines

The drainage lines are located across the SBEUM mining area and, therefore, they could experience the full range of predicted subsidence effects. A summary of the maximum predicted conventional subsidence effects within the Study Area is provided in Chapter 4.

5.2.3. Comparison of the predicted subsidence effects for the streams

Comparisons of the maximum predicted total subsidence effects for North Wambo Creek, Waterfall Creek and the drainage lines, based on the MOD 17 Layout and Modified Layout, are provided in Table 5.5, Table 5.6 and Table 5.7, respectively. The values represent the maximum predicted accumulated movements for the sections of the streams within the Study Area due to the extraction of all longwalls for the respective layouts.

Table 5.5 Comparison of maximum predicted total subsidence effects for North Wambo Creek

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
North Wambo Creek	MOD 17 Layout (MSEC848)	1950	80	> 3.0	> 3.0
	Modified Layout (MSEC1224)	1950	70	> 3.0	> 3.0

Table 5.6 Comparison of maximum predicted total subsidence effects for Waterfall Creek

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Waterfall Creek	MOD 17 Layout (MSEC848)	< 20	< 0.5	< 0.01	< 0.01
	Modified Layout (MSEC1224)	450	13	0.45	0.40

Table 5.7 Comparison of maximum predicted total subsidence effects for the drainage lines

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Drainage lines	MOD 17 Layout (MSEC848)	1950	90	> 3.0	> 3.0
	Modified Layout (MSEC1224)	1950	80	> 3.0	> 3.0

The maximum predicted total vertical subsidence for North Wambo Creek is 1950 mm based on both the MOD 17 Layout and Modified Layout. The maximum predicted vertical subsidence does not change as the longwalls are supercritical in width. However, the length of North Wambo Creek located directly above the SBEUM mining area based on the Modified Layout reduces by approximately 2.1 km compared to that based on the MOD 17 Layout. The extent of creek affected by subsidence and, therefore, the potential for adverse impacts also reduce.

Waterfall Creek is located well outside the SBEUM mining area based on the MOD 17 Layout and it is located directly above WYLW26 based on the Modified Layout. The predicted subsidence effects for this creek based on the Modified Layout are therefore greater than those based on the MOD 17 Layout. The following sections provide the impact assessments for Waterfall Creek based on the Modified Layout.

The maximum predicted total vertical subsidence for the drainage lines of 1950 mm, based on the Modified Layout, is the same as the maximum predicted value based on the MOD 17 Layout. The maximum predicted vertical subsidence does not change as the longwalls are supercritical in width.

The maximum predicted total tilt for the drainage lines based on the Modified Layout are slightly less than the maximum predicted values based on the MOD 17 Layout. The predicted curvatures do not change. However, the surface area within the predicted limit of vertical subsidence decreases by 43 ha and this represents a change of approximately 9 %. The total extent of drainage lines affected by subsidence and, therefore, the potential for adverse impacts also reduce.

5.2.4. Impact assessments for the streams

Impact assessments for the streams are provided in the following sections. The assessments provided in this report should be read in conjunction with the assessments provided in the reports by the other specialist consultants on the project.

Potential for increased levels of ponding, flooding and scouring due to the mining-induced tilts

Mining can result in increased levels of ponding in locations where the mining-induced tilts oppose and are greater than the natural gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the banks in the locations where the mining-induced tilts considerably increase the natural gradients that exist before mining.

The maximum predicted tilt for North Wambo Creek is 70 mm/m (i.e. 7.0 % or 1 in 14). The predicted mining-induced tilts are greater than the average natural gradient of the creek above the SBEUM mining area of 6 mm/m (i.e. less than 1 %). Similarly, the maximum predicted tilt for the drainage lines of 80 mm/m (i.e. 8.0 % or 1 in 13) is greater than the average natural gradients of these streams which vary between 30 mm/m to 60 mm/m (i.e. 3 % to 6 %).

The natural and the predicted post-mining surface levels and grades along North Wambo Creek, Waterfall Creek and three typical drainage lines (referred to as Drainage Lines 1 to 3) are illustrated in Fig. 5.7 to Fig. 5.11. The locations of the drainage lines are shown in Drawing No. MSEC1224-08. The profiles shown in these figures are after the completion of all longwalls based on the Modified Layout.

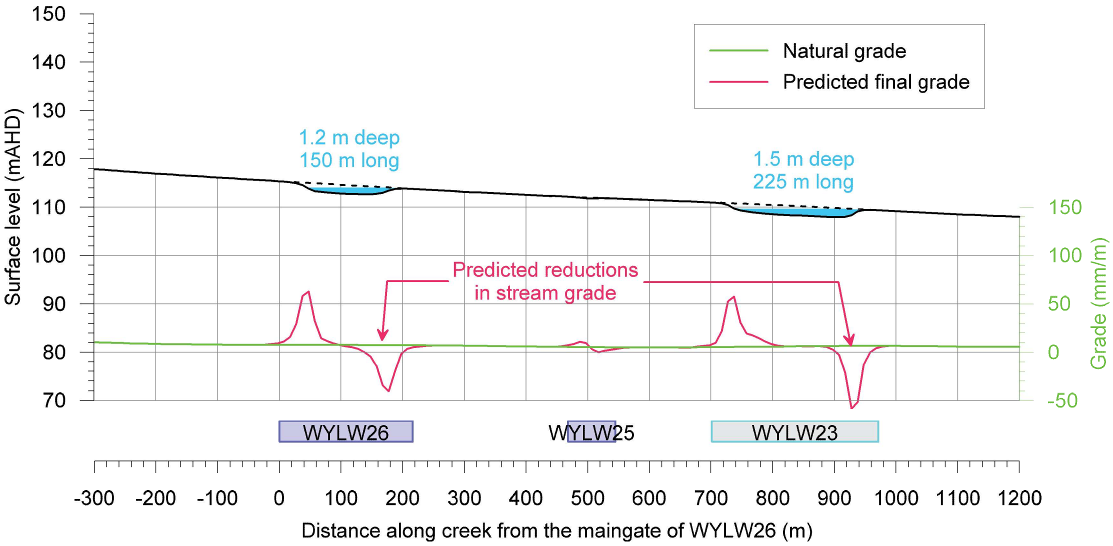


Fig. 5.7 Natural and predicted post-mining surface levels and grades along North Wambo Creek

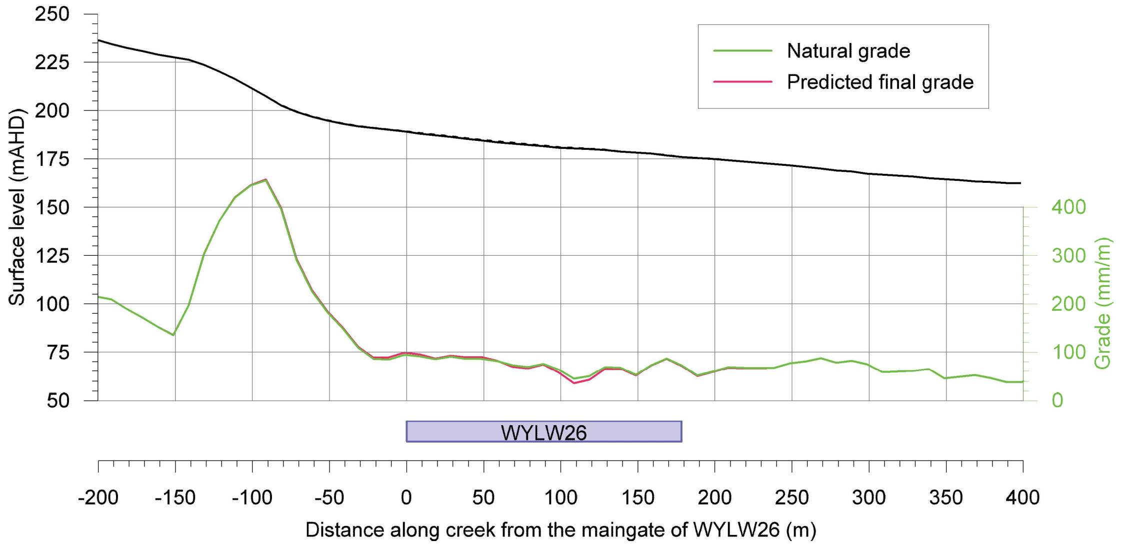


Fig. 5.8 Natural and predicted post-mining surface levels and grades along Waterfall Creek

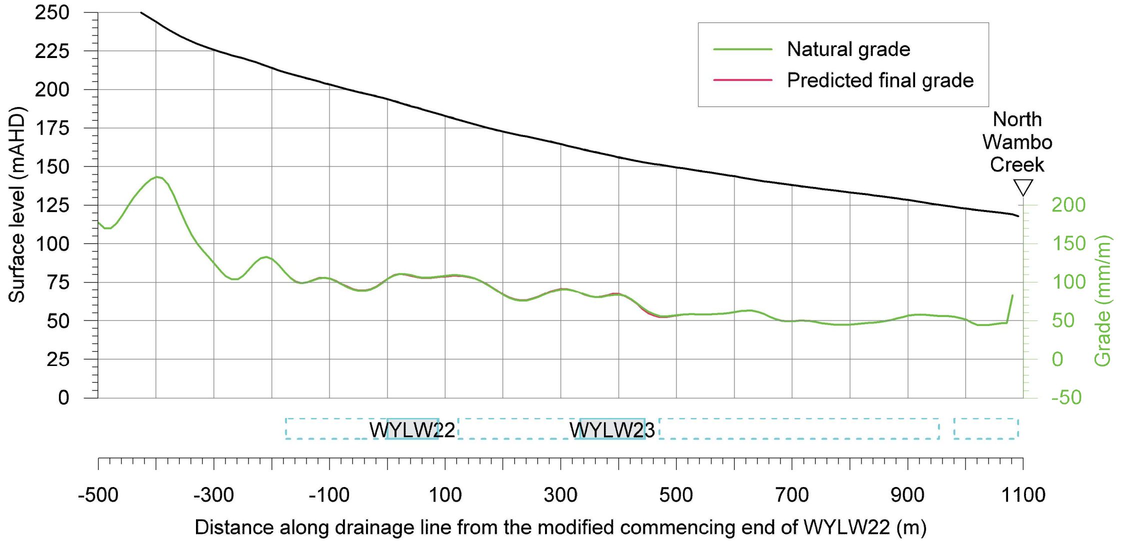


Fig. 5.9 Natural and predicted post-mining surface levels and grades along Drainage Line 1

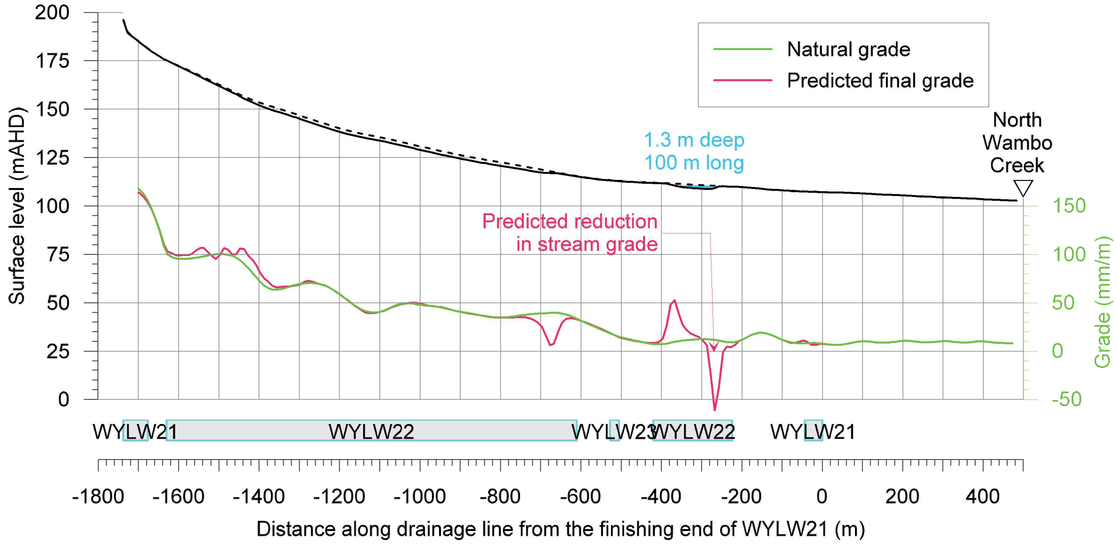


Fig. 5.10 Natural and predicted post-mining surface levels and grades along Drainage Line 2

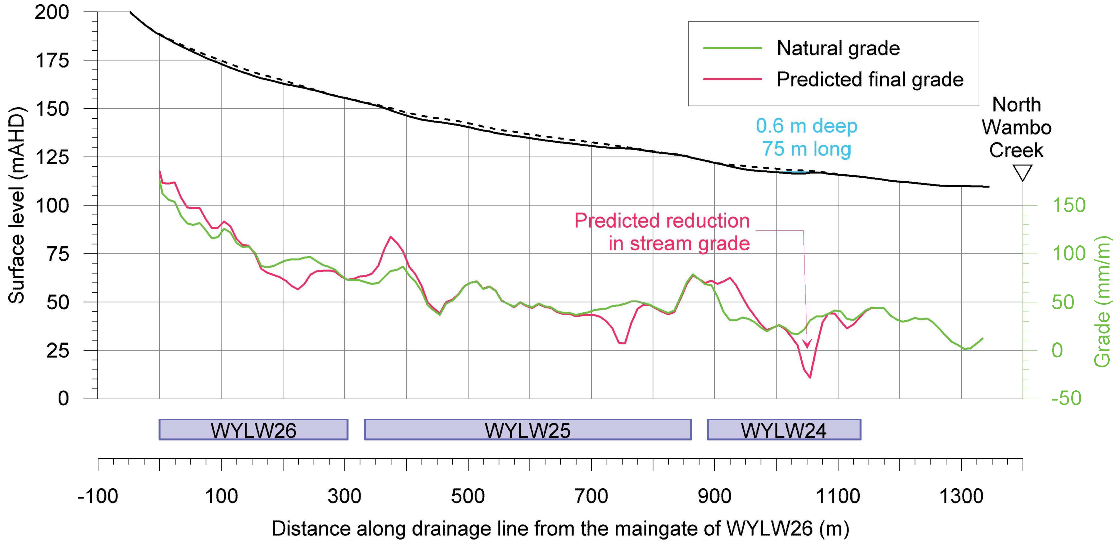


Fig. 5.11 Natural and predicted post-mining surface levels and grades along Drainage Line 3

There are predicted reversals of grade along North Wambo Creek, Drainage Line 2 and Drainage Line 3. Ponding areas are predicted to develop upstream of the chain pillars and the perimeter of the SBEUM mining area along each of these streams. There are no predicted reversals of grade along Waterfall Creek or Drainage Line 1 due to their higher natural gradients.

It is noted that the predicted ponding areas along North Wambo Creek, Drainage Line 2 and Drainage Line 3 differ from the topographical depressions discussed in Section 5.8 and indicated in Fig. 5.29, as they have been based on the predicted changes in surface levels along the original alignments of the streams, i.e. they do not consider the natural grades across the alignments of the streams.

The extraction of the longwalls based on the Modified layout would result in some changes in the stream alignments, due to the natural and mining-induced cross-grades and, in consequence, the actual ponding areas are expected to be less than those illustrated in Fig. 5.7, Fig. 5.10 and Fig. 5.11. The actual extents and depths of the ponding areas are also dependent on several other factors, including rainfall, catchment sizes, surface water runoff, infiltration and evaporation and, therefore, are expected to be smaller than the topographical depressions.

There are two ponding areas predicted to develop along North Wambo Creek, based on the Modified Layout, having maximum depths up to 1.5 m and overall lengths up to 225 m. Five ponding areas were predicted along this creek, based on the MOD 17 Layout, having maximum depths up to 1.4 m and overall lengths up to 300 m. The extent of ponding predicted along North Wambo Creek therefore reduces, due to the Modification, due to the lesser extents that the modified WYLW24 and WYLW25 mine directly beneath the creek.

There is one ponding area predicted to develop along Drainage Line 2, based on the Modified Layout, having maximum depth of 1.3 m and an overall length 100 m. Two ponding areas were predicted along this drainage line, based on the MOD 17 Layout, having maximum depths up to 1.3 m and overall lengths up to 175 m. The extent of ponding predicted along Drainage Line 2 based on the Modified Layout is therefore less than that based on the MOD 17 due to the lesser extents that WYLW21 and WYLW22 mine directly beneath the drainage line.

There is one ponding area predicted to develop along Drainage Line 3, based on the Modified Layout, having maximum depth of 0.6 m and an overall length 75 m. While not provided in Report No. MSEC848, two ponding areas were predicted along this drainage line, based on the MOD 17 Layout, having maximum depths up to 0.5 m and overall lengths up to 75 m. The overall level of ponding for Drainage Line 3 therefore does not substantially change between the MOD 17 Layout and the Modified Layout.

If adverse impacts were to develop due to increased ponding along the streams, these could be remediated by locally re-grading the beds so as to re-establish the natural gradients. The streams have shallow incisions in the natural surface soils and, therefore, it is expected that the mining-induced ponding areas could be reduced by locally excavating the channels downstream of these areas. The larger ponding areas may require excavation into the topmost bedrock, depending on the thickness of the overlaying surface soils.

Potential for cracking in the stream beds and fracturing of bedrock

It is expected that fracturing of the topmost bedrock would develop along the sections of the streams located directly above the longwalls based on the Modified Layout. North Wambo Creek, the upper reaches of Waterfall Creek and the drainage lines have shallow incisions into the natural surface soils. Cracking in the beds of the streams would be visible at the surface where the depths of the surface soils are shallow, or where the bedrock is exposed.

The mining-induced compression can also result in dilation and the development of bed separation in the topmost bedrock. The dilation is expected to develop predominately within the top 10 m to 20 m of the bedrock. Compression can also result in buckling of the topmost bedrock resulting in heaving in the overlying surface soils.

North Wambo Creek has been previously mined beneath by Longwalls 1 to 8A in the Wambo Seam (WMLW1 to WMLW8A) at the North Wambo Underground Mine. Surface cracking observed along the creek had widths typically ranging between 10 mm to 50 mm, with localised crack widths up to approximately 100 mm (WCPL, 2014). The North Wambo Creek Diversion has also been previously mined beneath by WYLW11 to WYLW13 (but outside the underlying WMLW14 to WMLW16) and WYLW17. Surface cracking along the creek diversion had widths ranging between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm.

The surface impacts along North Wambo Creek, Waterfall Creek and the drainage lines, based on the Modified Layout, are expected to be similar to those previously observed at the Wambo Coal Mine. Photographs of the surface deformations above the previously extracted WYLW11 to WYLW13 and WYLW17 to WYLW20 are provided in Section 4.7.

The surface area within the predicted limit of vertical subsidence based on the Modified Layout is 43 ha less than that based on the MOD 17 Layout and this represents a change of approximately 9 %. The total extent of drainage lines affected by subsidence and, therefore, the potential for adverse impacts also reduce.

The streams are ephemeral and, therefore, surface water flows only occur during and for short periods after rainfall events. In times of heavy rainfall, the majority of the runoff would flow over the natural surface soil beds and would not be diverted into the dilated strata below. In times of low flow and prior to remediation, however, surface water flows could be diverted into the dilated strata below the beds.

It is expected that fracturing in the underlying bedrock would gradually be filled with surface soils during subsequent flow events, especially during times of heavy rainfall. If the surface cracks were found not to fill naturally, some remedial measures may be required at the completion of mining.

Where necessary, any significant surface cracks in the stream beds could be remediated by infilling with surface soil or other suitable materials or by locally regrading and recompacting the surface.

It is not expected that there would be a direct hydraulic connection between the surface and the longwalls based on the Modified Layout, as this has not been previously observed at the Wambo Coal Mine. This includes the extraction of the Homestead/Wollemi workings in the Whybrow Seam directly beneath Stony Creek, WMLW1 to WMLW8A directly beneath North Wambo and Stony Creeks and WYLW11 to WYLW13 and WYLW17 beneath the North Wambo Creek Diversion.

Similar experiences have been found elsewhere in the Hunter and Newcastle Coalfields indicating that mining-induced fracturing and dilation do not have long term adverse impacts on ephemeral streams comprising natural soil beds. For example, the ephemeral drainage lines at South Bulga and the Beltana No. 1 Underground Mine were previously mined beneath by longwalls in the Whybrow Seam, where the depths of cover varied between 40 m and 200 m. Although surface cracking was observed across the mining area, there were no observable surface water flow diversions in the drainage lines, after the remediation of the larger surface cracks had been completed.

It would be necessary to remediate some sections of the streams after the longwalls mine directly beneath them. This would include re-grading the beds and infilling the larger surface cracking. It is expected that there would be no long-term adverse impacts on these streams after the completion of the necessary surface remediation.

Management strategies have previously been developed for the sections of the streams that have already been directly mined beneath at the Wambo Coal Mine. It is recommended that the existing management strategies for the streams be reviewed and, where required, are revised to include the effects of the longwalls based on the Modified Layout.

5.3. Aquifers and known ground water resources

Descriptions, predictions and the assessment of potential impacts on the aquifers and groundwater resources within the Study Area are provided in the Groundwater Assessment report prepared by SRL (2022).

There are no Ground Water Management Areas, as defined by the DPIE, within the Study Area. WCPL owns two monitoring bores (Refs. GW200831 and GW200832) which are located outside but near the north-eastern end of the approved WYLW23 and the southern end of the modified WYLW24. These monitoring bores could be affected due to the mining of the longwalls based on the Modified Layout. There were no other registered groundwater bores identified within the Study Area.

5.4. Escarpments

The *Wollemi Escarpment* is located to the south-west of the existing/approved WYLW17 to WYLW23. There is no escarpment near the modified WYLW24 to WYLW26.

The Macquarie Dictionary defines an *escarpment* as *"a long, cliff-like ridge of rock, or the like, commonly formed by faulting or fracturing of the earth's crust*". The Collins Dictionary of Geology defines an *escarpment* as *"a high, more or less continuous, cliff or long steep slope situated between a lower more gently inclined surface and a higher surface*". It appears, from these examples, that some definitions of an escarpment include only the cliffs and rock formations, while other definitions also include the steep slopes.

In this report, the escarpment has been defined as the continuous sections of the higher level cliffline along the boundary of the Wollemi National Park. The lower levels of cliffs and minor cliffs, the isolated rock outcrops and the steep slopes have not been included as part of the escarpment. This approach is consistent with that adopted for MOD 17.

The extent of the escarpment was determined from detailed site investigations by MSEC and WCPL on the 21 July 2016, as well as from an orthophotograph and surface level contours which were generated from a LiDAR survey of the area. The extents of the cliffs associated with the Wollemi Escarpment are shown in Fig. 5.12. All the cliffs within the Study Area, including those not associated with the escarpment, are shown in Drawing No. MSEC1224-08.

The impact assessments for the cliffs associated with the Wollemi Escarpment are included in Section 5.5. The impact assessments for the Wollemi National Park are provided in Section 5.11.

5.5. Cliffs

5.5.1. Descriptions of the cliffs

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

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

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

The cliffs and minor cliffs were identified using 1 m surface level contours generated from LiDAR surveys and from detailed site investigations.

The cliffs associated with the Wollemi Escarpment are located south-west of the existing/approved WYLW17 to WYLW23. There are also minor cliffs located directly above and south-west of these existing/approved longwalls.

There are no cliffs identified above or adjacent to the modified WYLW24 to WYLW26. However, there are cliffs located further west of these modified longwalls and within the Wollemi National Park.

The locations of the cliffs in the vicinity of the existing/approved WYLW17 to WYLW23 and modified WYLW24 to WYLW26 are shown in Drawing No. MSEC1224-08. The cliffs have also been shown in more detail in Fig. 5.12 and Fig. 5.13.

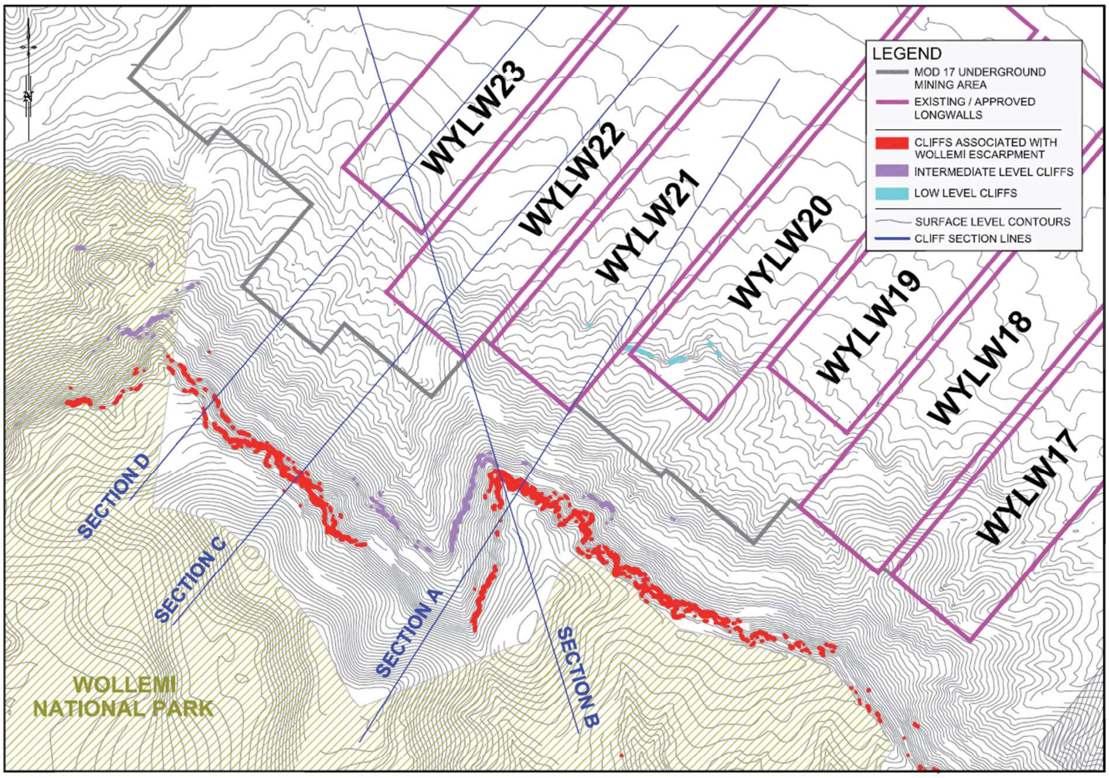


Fig. 5.12 Cliffs located south-west of the commencing ends of the existing/approved WYLW17 to WYLW23

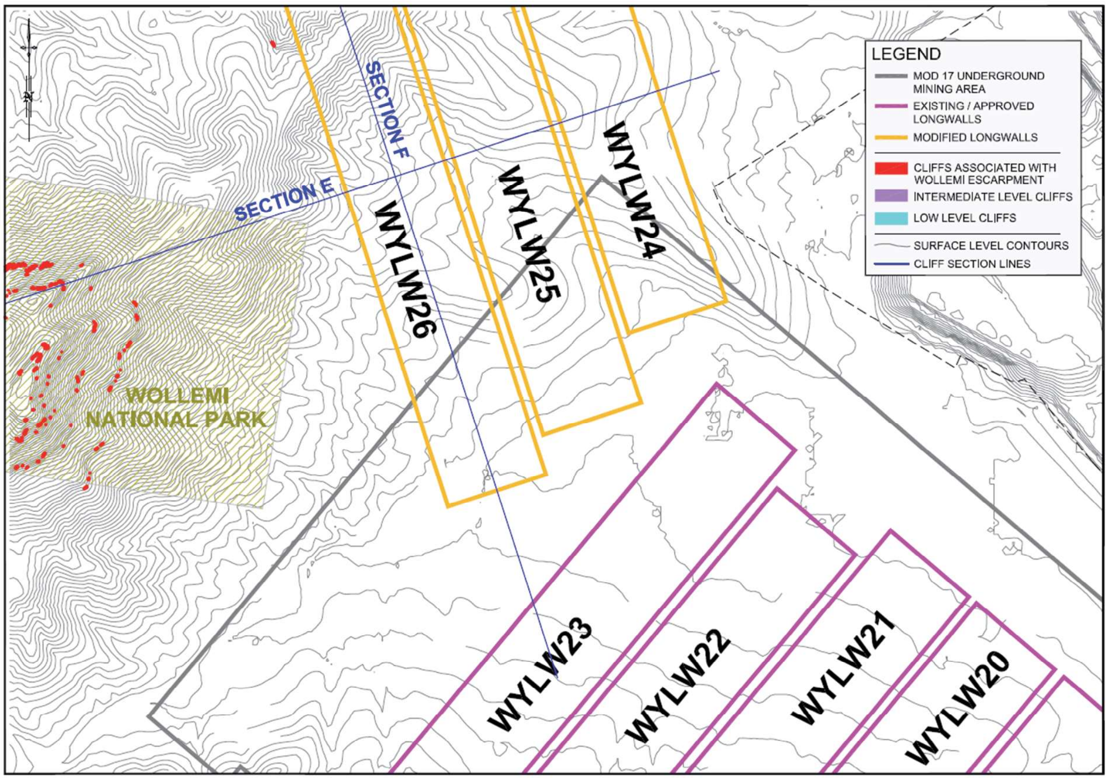


Fig. 5.13 Cliffs located west of the modified WYLW26

The cliffs have been categorised into three groups:

- *Cliffs Associated with the Wollemi Escarpment* (red hatch in Fig. 5.12 and Fig. 5.13) – are the higher level cliffs located along the boundary of the Wollemi National Park to the south-west of the existing/approved WYLW17 to WYLW23 and located within the Wollemi National Park further west of the modified WYLW26. These higher level cliffs outcrop at one or two horizons each having overall heights ranging between 10 m and 40 m. The cliff lines are discontinuous and are separated with sections of minor cliffs and rock outcrops;
- *Intermediate Level Cliffs* (purple hatch in Fig. 5.12) – are located part way down the steep slopes beneath the Wollemi Escarpment to the south-west of the existing/approved WYLW17 to WYLW23. These cliffs have not been considered part of the Wollemi Escarpment. The intermediate level cliffs have heights varying between 10 m and 20 m and continuous lengths up to approximately 50 m; and
- *Low Level Cliffs* (cyan hatch in Fig. 5.12) – are located near the bottom of the steep slopes above the south-western ends of the existing/approved longwalls. The larger low level cliffs are located partially above the existing/approved WYLW20 and WYLW21 having heights varying between 10 m and 15 m and continuous lengths up to approximately 50 m. These cliffs are discontinuous and are separated with sections of minor cliffs and rock outcrops.

Sections A to D have been taken through the commencing (i.e. south-western) ends of the existing/approved WYLW21 to WYLW23, showing the relative locations of the cliffs, in Fig. 5.14 to Fig. 5.17, respectively. Section E has been taken through the Wollemi National Park transverse to the modified WYLW26 and it is shown in Fig. 5.18. The locations of Sections A to E are shown in Fig. 5.12 and Fig. 5.13.

Fig. 5.14 Section A through the Wollemi Escarpment and the commencing end of the existing/approved WYLW21

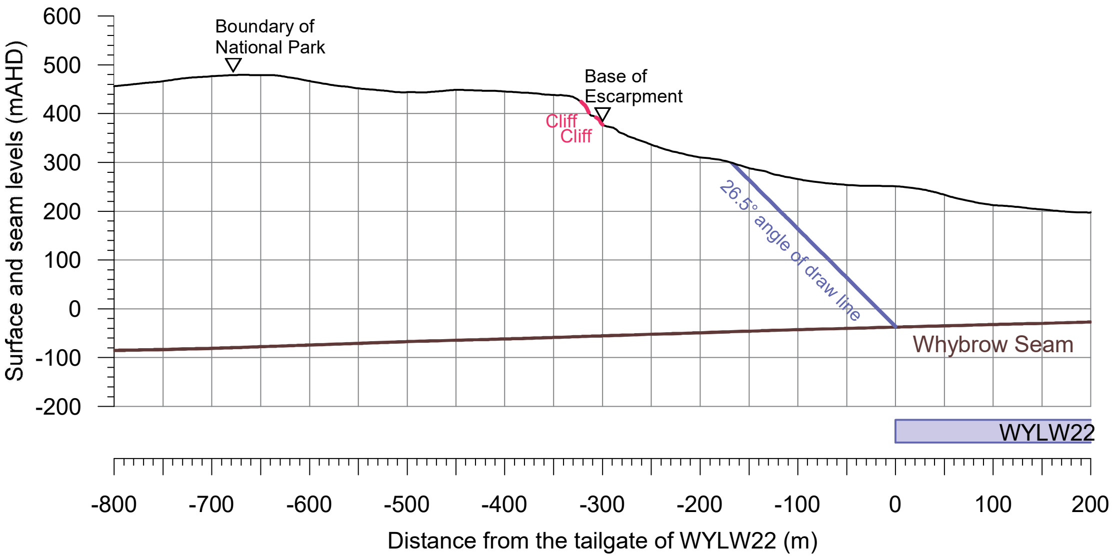


Fig. 5.15 Section B through the Wollemi Escarpment and the tailgate of the existing/approved WYLW22

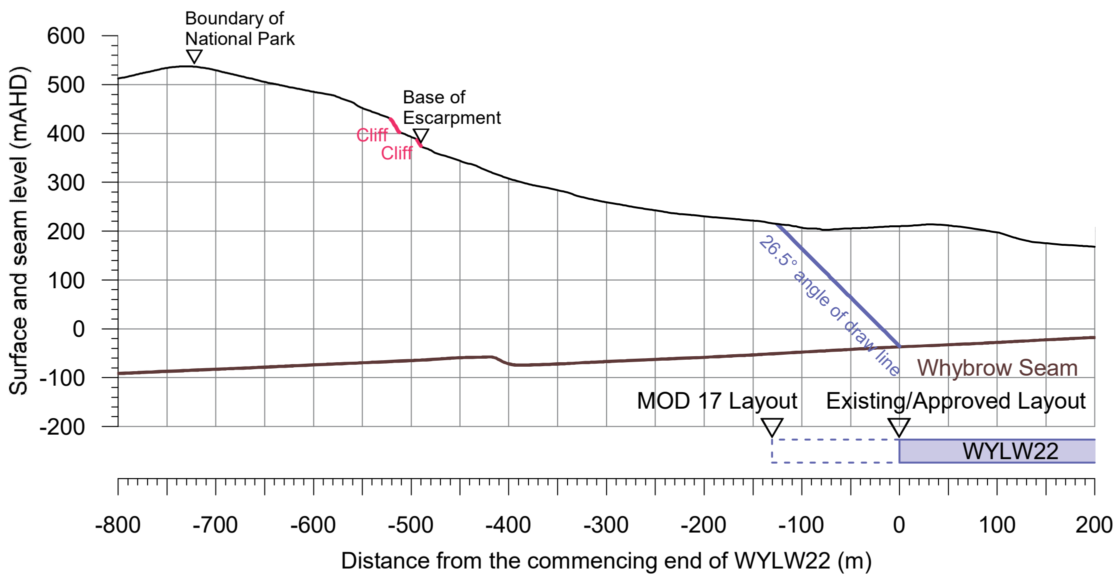


Fig. 5.16 Section C through the Wollemi Escarpment and the commencing end of the existing/approved WYLW22

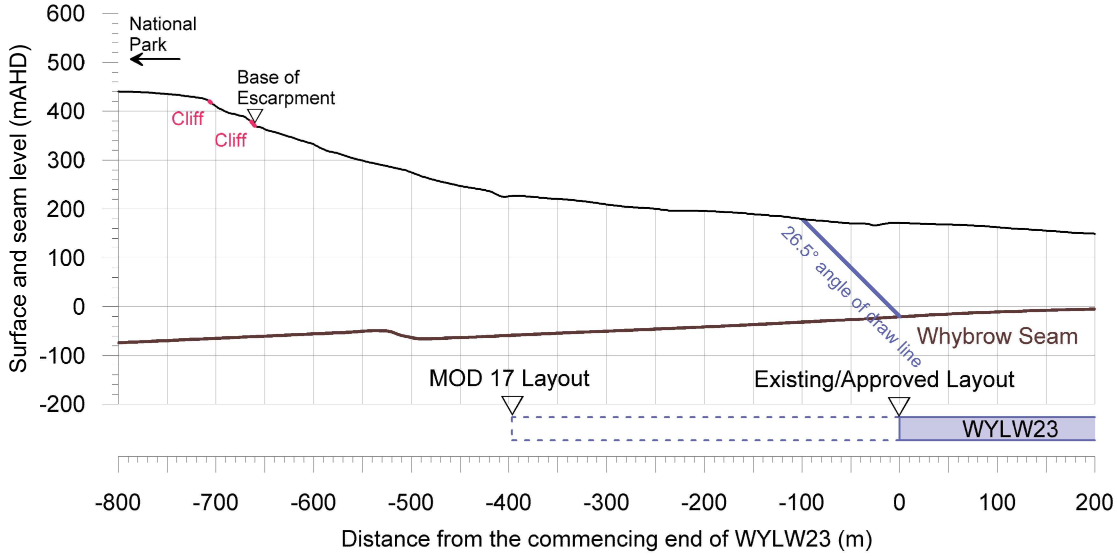


Fig. 5.17 Section D through the Wollemi Escarpment and the commencing end of the existing/approved WYLW23

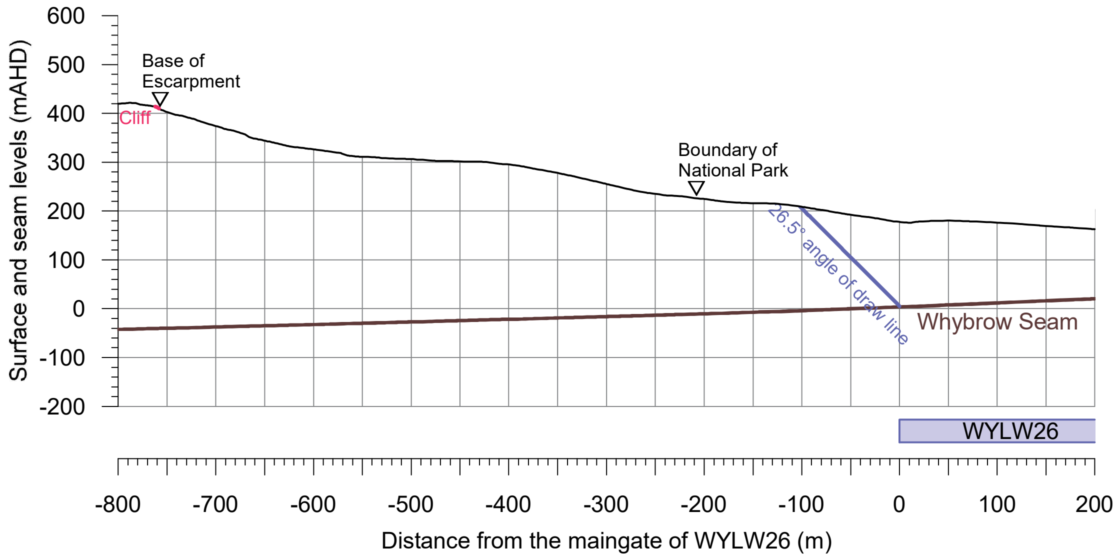


Fig. 5.18 Section E through the Wollemi National Park and the modified WYLW26

The Cliffs Associated with the Wollemi Escarpment are located outside of the 26.5° angle of draw line from the existing/approved WYLW17 to WYLW23 and well outside the angle of draw for the modified WYLW24 to WYLW26. It is noted that the Study Area differs from the 26.5° angle of draw line, as the Study Area is based on an angle of draw using the depth of cover above the longwall commencing ends and, therefore, does not consider the increasing surface elevation to the south-west of the longwalls. For this reason, all the Cliffs Associated with the Wollemi Escarpment, immediately to the south-west of the longwalls, have been included as part of the Study Area and, hence, have been included in the impact assessments provided in this report.

A summary of the minimum distances of the Cliffs Associated with the Wollemi Escarpment from each of the longwalls based on the Modified Layout is provided in Table 5.8.

Table 5.8 Distances of the Cliffs Associated with the Wollemi Escarpment from each of the longwalls based on the Modified Layout

Feature		Longwall	Minimum distance (m)
Cliffs Associated with the Wollemi Escarpment	Existing/approved longwalls	WYLW17	230
		WYLW18	220
		WYLW19	550
		WYLW20	380
		WYLW21	210
		WYLW22	240
		WYLW23	250
	Modified longwalls	WYLW24	> 1000
		WYLW25	> 1000
		WYLW26	760

The Cliffs Associated with the Wollemi Escarpment are located more than 1000 m from WYLW24 and WYLW25 and are located 760 m west of WYLW26 based on the Modified Layout. There are also other minor cliffs located at similar distances from the modified longwalls.

The Intermediate Level Cliffs are located at distances of 210 m and 190 m from the existing/approved WYLW21 and WYLW22, respectively, at their closest point to the longwalls. The Low Level Cliffs are also partially located directly above the existing/approved WYLW20 and WYLW21.

The cliffs, minor cliffs and rock outcrops have formed from the Widden Brook Conglomerate of the Narrabeen Group, as can be seen in Fig. 1.7. Photographs of the Cliffs Associated with the Wollemi Escarpment are provided in Fig. 5.19 to Fig. 5.22. The locations and directions of the photographs are indicated in Drawing No. MSEC1224-08.

Fig. 5.19 Cliffs located south-west of the existing/approved WYLW17 to WYLW21 (P5467)

Fig. 5.20 Cliffs located south-west of the existing/approved WYLW22 and WYLW23 (P5466)

Fig. 5.21 Cliffs located north-west of existing/approved WYLW23 (P5483)

Fig. 5.22 Cliffs located south-west of modified WYLW26 (P5557)

5.5.2. Predictions for the cliffs

A summary of the maximum predicted total vertical subsidence, tilts and curvatures for the cliffs is provided in Table 5.9. The values represent the maximum predicted accumulated movements within 20 m of the mapped extents of the cliffs due to the mining of the longwalls based on the Modified Layout.

Table 5.9 Maximum predicted total vertical subsidence, tilts and curvatures for the cliffs

Location	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Cliffs Associated with the Wollemi Escarpment	< 20	< 0.5	< 0.01	< 0.01
Intermediate Level Cliffs	< 20	< 0.5	< 0.01	< 0.01
Low Level Cliffs	1750	25	0.7	0.7

The Cliffs Associated with the Wollemi Escarpment and the Intermediate Level Cliffs are predicted to experience less than 20 mm vertical subsidence. While these cliffs could experience very low level vertical subsidence, they are not expected to experience measurable tilts, curvatures or strains.

The higher level cliffs could experience far-field horizontal movements. There is no 3D ground monitoring data available at the North Wambo Underground Mine along the steep slopes beneath the Wollemi Escarpment. The predicted far-field horizontal movements, therefore, have been based on the observations at Dendrobium Mine, which has similar or shallower depths of cover and similar natural surface gradients.

Seventeen longwalls have been extracted in Areas 1, 2, 3A and 3B at Dendrobium Mine. The depths of cover vary between 170 m and 320 m in Area 1, 150 m and 310 m in Area 2, 275 m and 385 m in Area 3A and 290 m and 410 m in Area 3B. The longwalls have been extracted in the Wongawilli Seam and had width-to-depth ratios typically ranging between 0.7 and 1.4. Escarpments were located directly above the longwalls in Areas 1 and 2 and the surface was highly undulating in Areas 3A and 3B, with the natural gradients varying between 1 in 3 and 1 in 2 directly above the longwalls.

The measured total 3D horizontal movements at Dendrobium Mine for survey marks located outside the extents of the longwalls (i.e. above solid coal only) are illustrated in Fig. 5.23. The 95 % confidence level for the measured total horizontal movements has been shown as the blue line in this figure.

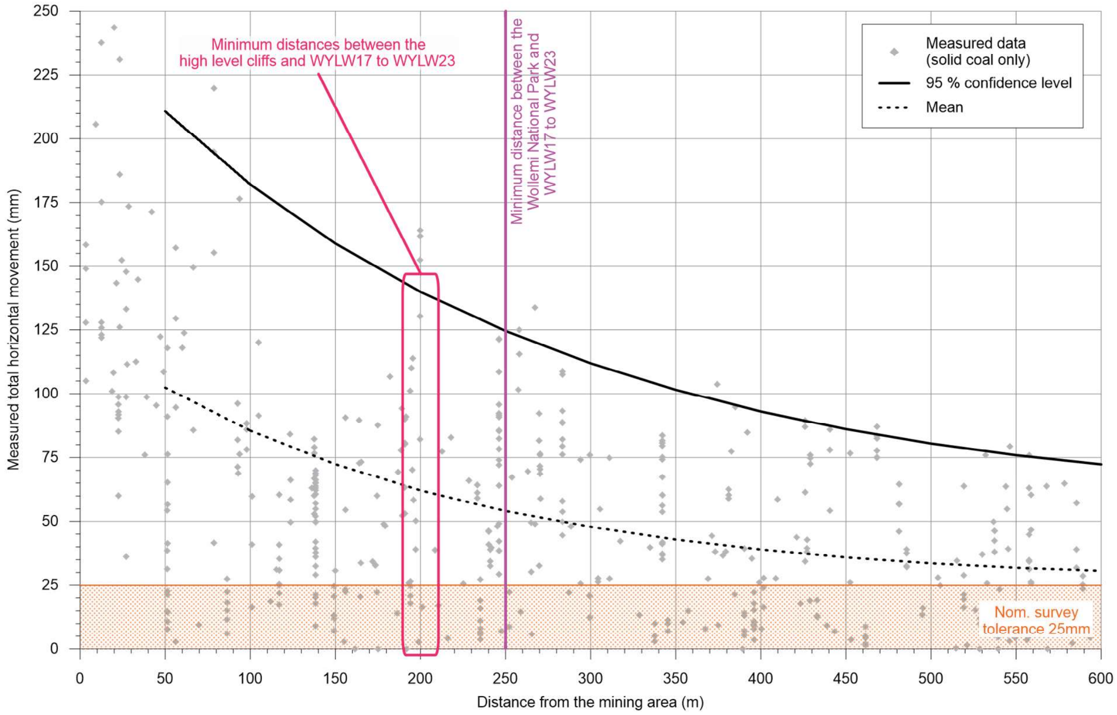


Fig. 5.23 Measured total 3D horizontal movements above solid coal at Dendrobium Mine

The relative locations of the higher level cliffs (i.e. Cliffs Associated with the Wollemi Escarpment and the Intermediate Level Cliffs) are shown in Fig. 5.23. The maximum predicted total far-field horizontal movement for these higher level cliffs is in the order of 140 mm based on the 95 % confidence level. These movements tend to be bodily movements, towards the extracted longwalls, which are accompanied by very low levels of strain, typically less than the order of survey tolerance.

The Low Level Cliffs are partially located above the existing/approved WYLW20 and WYLW21 and they are predicted to have experienced tilts up to 25 mm/m (i.e. 2.5 % or 1 in 40). The maximum predicted curvature for these cliffs is 0.7 km^{-1}, which represents a minimum radius of curvature of 1.4 km.

The maximum predicted conventional strains for the Low Level Cliffs, based on applying a factor of 10 to the maximum predicted curvatures, are 7 mm/m tensile and compressive. The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The maximum predicted strains above the south-western ends of WYLW20 and WYLW21 are 5 mm/m tensile and 4 mm/m compressive based on the 95 % confidence levels.

Non-conventional movements can also occur and have occurred in the NSW coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.5.3. Comparison of the predicted subsidence effects for the cliffs

Comparisons of the maximum predicted total subsidence effects for Cliffs Associated with the Wollemi Escarpment, Intermediate Level Cliffs and Low Level Cliffs, based on the MOD 17 Layout and Modified Layout, are provided in Table 5.10, Table 5.11 and Table 5.12, respectively. The values represent the maximum predicted accumulated movements within 20 m of the mapped extents of the cliffs due to the extraction of all longwalls for the respective layouts.

Table 5.10 Comparison of maximum predicted total subsidence effects for the Cliffs Associated with the Wollemi Escarpment

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Cliffs Associated with the Wollemi Escarpment	MOD 17 Layout (MSEC848)	< 20	< 0.5	< 0.01	< 0.01
	Modified Layout (MSEC1224)	< 20	< 0.5	< 0.01	< 0.01

Table 5.11 Comparison of maximum predicted total subsidence effects for the Intermediate Level Cliffs

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Intermediate Level Cliffs	MOD 17 Layout (MSEC848)	30	0.5	< 0.01	< 0.01
	Modified Layout (MSEC1224)	< 20	< 0.5	< 0.01	< 0.01

Table 5.12 Comparison of maximum predicted total subsidence effects for the Low Level Cliffs

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Low Level Cliffs	MOD 17 Layout (MSEC848)	1750	25	0.7	0.7
	Modified Layout (MSEC1224)	1750	25	0.7	0.7

The Cliffs Associated with the Wollemi Escarpment are predicted to experience less than 20 mm vertical subsidence based on both the Previous and Modified Layouts. The far-field horizontal movements at these cliffs based on the Modified Layout are slightly less than those predicted based on the MOD 17 Layout due to the shortened commencing (i.e. south-western) ends of the existing/approved WYLW19, WYLW20, WYLW22 and WYLW23. While the Cliffs Associated with the Wollemi Escarpment could experience very low level vertical and horizontal effects, they are not predicted to experience measurable tilts, curvatures or strains.

The maximum predicted subsidence and tilt for the Intermediate Level Cliffs, based on the Modified Layout, are slightly less than the maximum predicted values based on the MOD 17 Layout. The predicted subsidence effects for these cliffs based on the Modified Layout are less than those based on the MOD 17 Layout due to the shortened commencing (i.e. south-western) ends of the existing/approved WYLW19, WYLW20, WYLW22 and WYLW23. Only very low level curvatures are predicted for the Intermediate Level Cliffs based on both layouts.

The maximum predicted subsidence effects for the Low Level Cliffs, based on the Modified Layout, are the same as the maximum predicted values based on the MOD 17 Layout. The predictions do not change as these cliffs are located directly above the SBEUM mining area based on both layouts.

5.5.4. Impact assessments for the Cliffs Associated with the Wollemi Escarpment and the Intermediate Level Cliffs

The Cliffs Associated with the Wollemi Escarpment and the Intermediate Level Cliffs are predicted to experience vertical subsidence of less than 20 mm. While these cliffs could experience very low levels of vertical subsidence, they are not expected to experience measurable conventional tilts, curvatures or strains, even if the predicted vertical subsidence was exceeded by a factor of two times.

These higher level cliffs could also experience far-field horizontal movements in the order of 130 mm based on the 95 % confidence level. These movements are expected to be bodily movements towards the extracted longwalls and are not expected to be associated with any measurable strains. It is unlikely, therefore, that the Cliffs Associated with the Wollemi Escarpment and the Intermediate Level Cliffs would experience adverse impacts due to far-field horizontal movements, even if these predictions were exceeded by a factor of two times.

WYLW11 to WYLW13 at the South Bates Underground Mine and WYLW17 to WYLW21 at the SBEUM have been extracted adjacent to the Wollemi Escarpment. The Cliffs Associated with the Wollemi Escarpment are located at minimum distances of 290 m from WYLW12 and 220 m from WYLW18, at their closest points to the mining areas. There have been no reported impacts to these cliffs due to the mining at the South Bates Underground Mine and the SBEUM.

It is not expected, therefore, that there would be adverse impacts on the Cliffs Associated with the Wollemi Escarpment or the Intermediate Level Cliffs due to the mining of the existing/approved WYLW22 and WYLW23 and the modified WYLW24 to WYLW26.

It is recommended that monitoring is undertaken to measure the actual angle of draw to the limit of vertical subsidence. The monitoring could include continuous Global Navigation Satellite System (GNSS) survey monitoring points that provide high accuracy 3D survey data (approximately 3 mm at the first standard deviation) based on continuous GPS reception. It is also recommended that the cliffs are periodically visually inspected during and after the extraction of the longwalls based on the Modified Layout.

5.5.5. Impact assessments for the Low Level Cliffs

The Low Level Cliffs are partially located above the south-western ends of the existing WYLW20 and WYLW21. These cliffs are predicted to have experienced up to 1750 mm vertical subsidence, 25 mm/m tilt (i.e. 2.5 % or 1 in 40) and 0.7 km^{-1} curvature (i.e. a minimum radius of curvature of 1.4 km).

The mining of WYLW20 and WYLW21 beneath the Low Level Cliffs caused minor fracturing and a rockfall affecting less than 10 m^2 of the face of these cliffs. It was assessed in Report No. MSE848 that approximately 7 % to 10 % of the total length, or approximately 3 % to 5 % of the total face area, of the Low Level Cliffs located directly above the longwalls could be impacted.

The approved WYLW22 and WYLW23 and the modified WYLW24 to WYLW26 do not mine directly beneath the Low Level Cliffs. Further impacts are therefore not anticipated due to the mining of the future longwalls.

5.6. Pagodas

There are no pagoda complexes identified within the Study Area. There are isolated pagodas associated with the Wollemi Escarpment that are located outside the SBEUM mining area, south-west of the existing/approved WYLW17 to WYLW23 and south-west of the modified WYLW24 to WYLW26. The pagodas have formed from the Widden Brook Conglomerate and have heights typically up to around 3 m to 5 m.

The pagodas are predicted to typically experience vertical subsidence less than 20 mm. While the pagodas could experience very low levels of vertical subsidence, they are not expected to experience measurable tilts, curvatures or strains. It is unlikely, therefore, that the isolated pagodas would experience adverse impacts as a result of the extraction of the longwalls based on the Modified Layout.

5.7. Steep slopes

5.7.1. Descriptions of the steep slopes

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

Steep slopes have been identified above and adjacent to the commencing (i.e. south-western) ends of the existing/approved WYLW17 to WYLW23. These steep slopes extend up to the Wollemi Escarpment which is located outside the 26.5° angle of draw line from these longwalls.

Steep slopes have also been identified above the modified WYLW26 and to a lesser extent the modified WYLW25 where a ridgeline extends across the northern ends of these longwalls. These steep slopes are located below the boundary of the Wollemi National Park. There are no cliffs identified near the modified WYLW24 to WYLW26.

Photographs of the steep slopes located above the modified WYLW25 and WYLW26 are provided in Fig. 5.24 and Fig. 5.25, respectively.

Fig. 5.24 Steep slopes above the modified WYLW25 (P5594)

Fig. 5.25 Steep slopes above the modified WYLW26 (P5519)

The natural slopes near the commencing (i.e. south-western) end of WYLW22 (Section C), near the commencing (i.e. south-western) end of WYLW23 (Section D) and along the centreline of the modified WYLW26 (Section F) are illustrated in Fig. 5.26, Fig. 5.27 and Fig. 5.28, respectively. The locations of Sections C and D are shown in Fig. 5.12 and Section F is shown in Fig. 5.13.

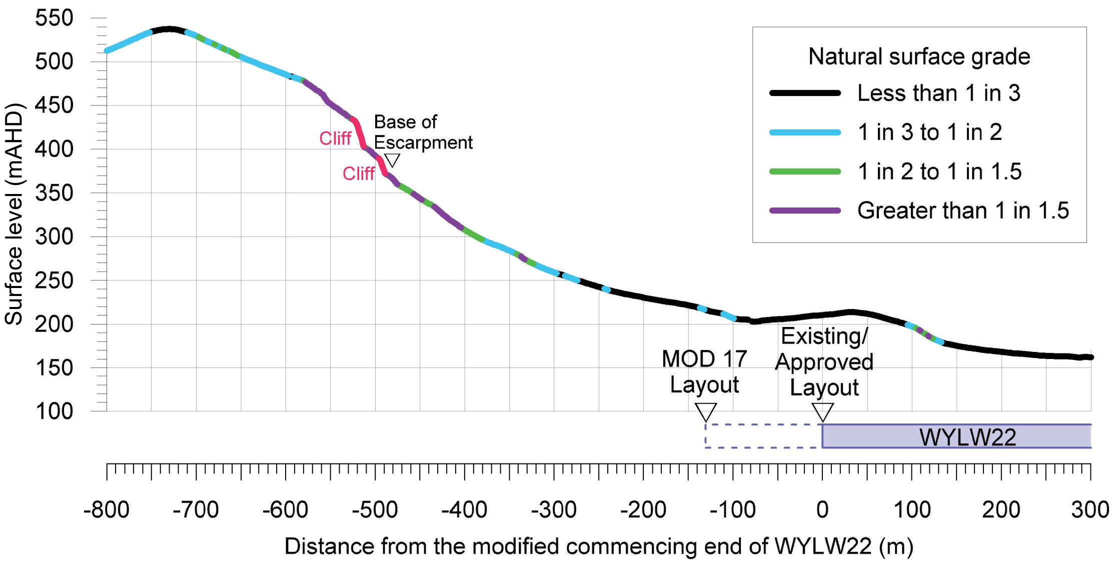


Fig. 5.26 Section C through the steep slopes and the commencing end of the existing/approved WYLW22

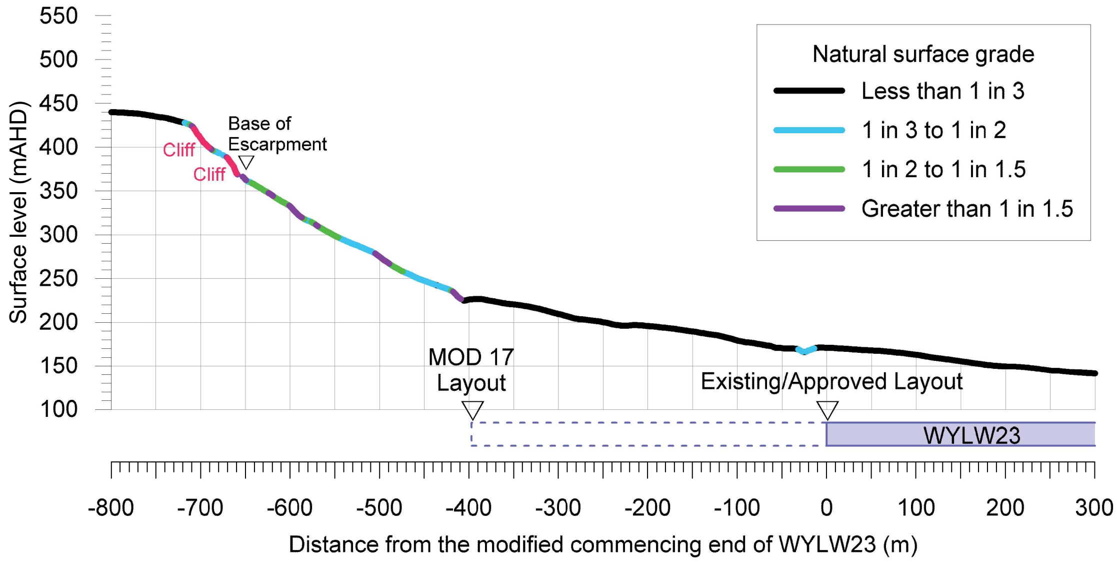


Fig. 5.27 Section D through the steep slopes and the commencing end of the existing/approved WYLW23

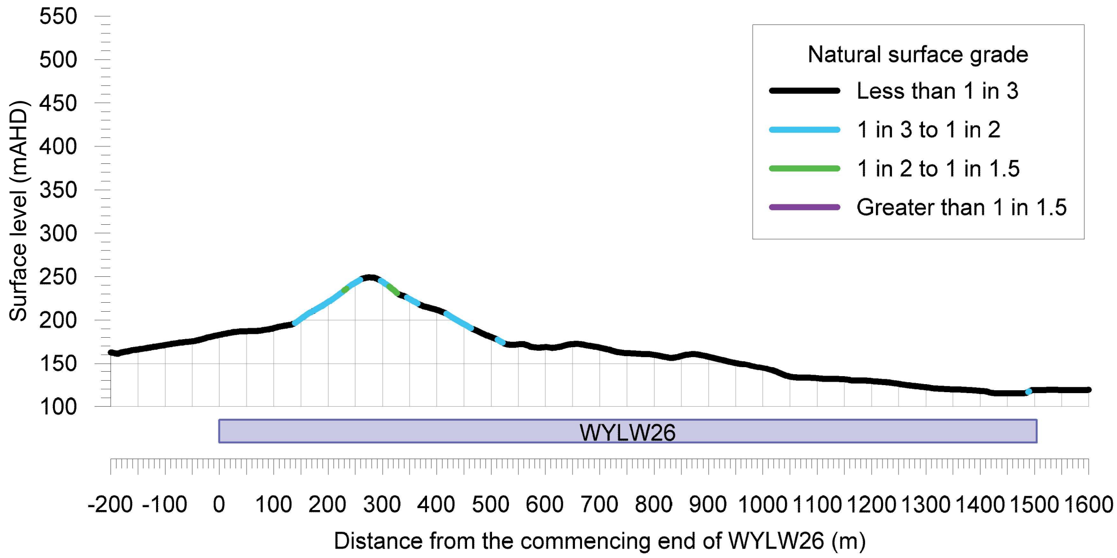


Fig. 5.28 Section F through the steep slopes and the centreline of the modified WYLW26

The natural surface gradients directly above the existing/approved WYLW17 to WYLW23 typically range between 1 in 3 and 1 in 2. The slopes are locally steeper at the base of the Low Level Cliffs, above WYLW20 and WYLW21, with gradients up to approximately 1 in 1.5.

The natural surface gradients directly above the modified WYLW24 to WYLW26 also typically range between 1 in 3 and 1 in 2. The slopes are locally steeper on the western side of the modified WYLW26 (i.e. outside the SBEUM mining area) along the upper reaches of Waterfall Creek.

The surface soils along the steep slopes above the longwalls based on the Modified Layout are generally derived from the Widden Brook Conglomerate (Rna), as can be inferred from Fig. 1.7. The slopes are stabilised by the natural vegetation, which can be seen in Fig. 5.32.

There are also isolated steep slopes elsewhere above the SBEUM mining area which are generally associated with the banks of the streams.

5.7.2. Predictions for the steep slopes

A summary of the maximum predicted total subsidence, tilts and curvatures for the steep slopes is provided in Table 5.13. The values represent the maximum predicted accumulated movements for the steep slopes within the Study Area due to the extraction of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26.

Table 5.13 Maximum predicted total vertical subsidence, tilts and curvatures for the steep slopes

Location	Longwalls	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Steep slopes	Existing/ approved WYLW17 to WYLW23	1950	30	1.0	1.0
	Modified WYLW25 and WYLW26	1950	40	2.0	2.0

The steep slopes above the existing/approved WYLW17 to WYLW23 are predicted to experience tilts up to 30 mm/m (i.e. 3 % or 1 in 33). The maximum predicted curvature for these steep slopes is 1.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 1 km.

The maximum predicted conventional strains for the steep slopes above the existing/approved WYLW17 to WYLW23, based on applying a factor of 10 to the maximum predicted curvatures, are 10 mm/m tensile and compressive. The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The maximum predicted strains near the commencing (i.e. south-western) ends of WYLW17 to WYLW23 (i.e. depths of cover greater than 200 m) are 5 mm/m tensile and 4 mm/m compressive.

The steep slopes above the modified WYLW24 to WYLW26 are predicted to experience tilts up to 40 mm/m (i.e. 4.0 % or 1 in 25). The maximum predicted curvature for these steep slopes is 2.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 0.5 km.

The maximum predicted conventional strains for the steep slopes above the modified WYLW24 to WYLW26, based on applying a factor of 10 to the maximum predicted curvatures, are 20 mm/m tensile and compressive. The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The maximum predicted strains for the steep slopes above the modified WYLW24 to WYLW26 (i.e. depths of cover between 100 m and 200 m) are 8 mm/m tensile and 9 mm/m compressive based on the 95 % confidence levels.

Non-conventional movements can also occur and have occurred in the NSW coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.7.3. Comparison of the predicted subsidence effects for the steep slopes

Comparison of the maximum predicted total subsidence effects for the steep slopes above the SBEUM mining area, based on the MOD 17 Layout and Modified Layout, are provided in Table 5.14 and Table 5.15, respectively. The values represent the maximum predicted accumulated movements for the steep slopes within the Study Area due to the extraction of all longwalls for the respective layouts.

Table 5.14 Comparison of maximum predicted total subsidence effects for the steep slopes above the existing/approved WYLW17 to WYLW23

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Steep slopes above WYLW17 to WYLW23	MOD 17 Layout (MSEC848)	1950	30	1.0	1.0
	Modified Layout (MSEC1224)	1950	30	1.0	1.0

Table 5.15 Comparison of maximum predicted total subsidence effects for the steep slopes above the modified WYLW24 to WYLW26

Location	Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Steep slopes above WYLW24 to WYLW26	MOD 17 Layout (MSEC848)	< 20	< 0.5	< 0.01	< 0.01
	Modified Layout (MSEC1224)	1950	40	2.0	2.0

The maximum predicted subsidence effects for the steep slopes above the existing/approved WYLW17 to WYLW23, based on the Modified Layout, are the same as the maximum predicted values based on the MOD 17 Layout. The predicted subsidence effects for these steep slopes do not change as they occur above the eastern extents of the steep slopes, where the depths of cover are shallowest, which are located above the SBEUM mining area based on both layouts.

The maximum predicted subsidence effects for the steep slopes above the modified WYLW24 to WYLW26, based on the Modified Layout, are greater than the maximum predicted values based on the MOD 17 Layout. The reason is that these steep slopes are located outside the extents of the SBEUM mining area based on the MOD 17 Layout.

5.7.4. Impact assessments for the steep slopes

The maximum predicted tilt for the steep slopes of 40 mm/m (i.e. 4.0 % or 1 in 25) is small when compared to the natural surface grades, which are greater than 1 in 3. It is unlikely, therefore, that the mining-induced tilts themselves would result in any adverse impact on the stability of the steep slopes.

The steep slopes are more likely to be impacted by curvature and ground strain, rather than tilt. The potential impacts would generally result from the movement of the natural surface in the downslope direction, resulting in tension cracks appearing at the tops and on the sides of the steep slopes and compression ridges forming at the bottoms of the steep slopes.

The south-western ends of WYLW11 to WYLW13 at the South Bates Underground Mine and the existing/approved WYLW17 to WYLW21 at the SBEUM have previously mined beneath the steep slopes. Surface cracking recorded due to the mining of these longwalls is described in Section 4.7. It is noted, however, that the visual inspections above the south-western ends of these longwalls were limited due to the steep terrain and heavy vegetation.

Surface cracking recorded on the steep slopes had widths typically ranging between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm. Photographs of cracking on the steep slopes are provided in Fig. 4.8 and Fig. 4.10. Similar surface deformations are expected where the existing/approved WYLW22 and WYLW23 and the modified WYLW26 mine beneath the steep slopes.

The steep slopes are heavily vegetated and natural erosion due to soil instability (i.e. natural downslope movements) was not readily apparent from the site investigations undertaken. If tension cracks were to develop, due to the mining of the longwalls based on the Modified Layout, it is possible that soil erosion could occur if these cracks were left untreated.

It is possible, therefore, that some remediation might be required, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the surface soils in the longer term. Similarly, where cracking restricts the passage of vehicles along the tracks and fire trails that are required to be open for access, it is recommended that these cracks are treated in the same way.

5.8. Land prone to flooding or inundation

The land within the Study Area generally falls in a north-easterly direction from the Wollemi Escarpment and steep slopes towards the North Wambo Creek and the creek diversion. The natural surface level contours (grey lines) and the predicted post-mining surface level contours (green lines) above the longwalls based on the Modified Layout are illustrated in Fig. 5.29. The alignment of North Wambo Creek and the creek diversion is shown as the blue line in this figure.

The predicted extents of the mining-induced topographical depressions are also illustrated in Fig. 5.29, as the cyan hatching, based on the predicted post-mining surface level contours for the Modified Layout. The predicted topographical depressions for the MOD 17 Layout are also shown as the dashed black outlines in this figure for comparison. The actual extents and depths of increased ponding in these locations are dependent on a number of other factors, including rainfall, catchment sizes, surface water runoff, infiltration and evaporation and, therefore, these are expected to be smaller than the topographical depressions.

Mining-induced topographical depressions based on the Modified Layout (i.e. cyan hatching) are predicted to develop above the finishing (i.e. north-eastern) ends of the existing/approved WYLW18 to WYLW23 and above the finishing (i.e. southern ends) of the modified WYLW24 to WYLW26. The topographical depressions are predicted to have depths up to approximately 1.4 m and surface areas up to approximately 0.8 ha.

In comparison, the mining-induced topographical depressions based on the MOD 17 Layout (i.e. dashed black outlines) were predicted to have depths up to approximately 1.4 m and surface areas up to 2.5 ha. These topographical depressions occurred above the north-eastern extent of the MOD 17 underground mining area.

The actual depths and extents of increased ponding in these locations are expected to be less than the predicted topographical depressions due to the various other factors described previously. The potential for increased ponding along the alignments of North Wambo Creek and typical drainage lines are discussed further in Section 5.2.4.

There are no predicted topographical depressions (i.e. areas of increased ponding) away from the finishing ends of the longwalls based on the Modified Layout apart from the isolated locations along the drainage lines. It is not considered, therefore, that the land across the Study Area is naturally susceptible to flooding or inundation.

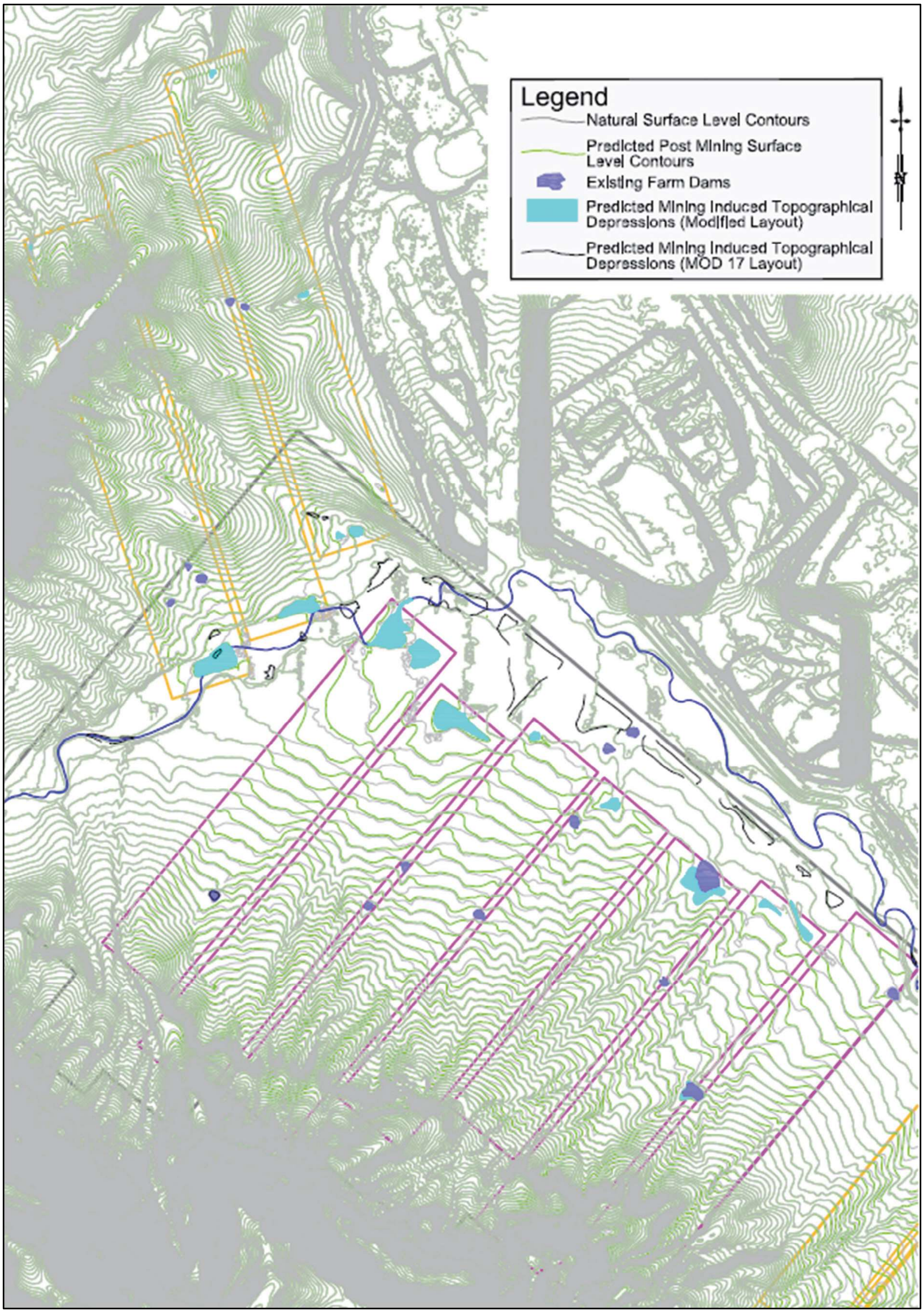


Fig. 5.29 Natural and predicted subsided surface levels and predicted mining-induced topographical depressions based on the Modified Layout

5.9. Water related ecosystems

There are water related ecosystems associated with the drainage within the Study Area, which are described and assessed in the report prepared by Eco Logical Australia (2022).

5.10. Threatened or protected species

An investigation of the flora and fauna within the Study Area has been undertaken, which is described and assessed in the reports prepared by Eco Logical Australia (2022).

5.11. National Parks or wilderness areas

The *Wollemi National Park* is shown in Drawings Nos. MSEC1224-01, MSEC1224-02, MSEC1224-08 and MSEC1224-09.

The National Park is located to the south and west of the SBEUM mining area. A summary of the minimum distances of the longwalls, based on the Modified Layout, from the boundary of the National Park is provided in Table 5.16.

Table 5.16 Minimum distances between the longwalls based on the Modified Layout and the boundary of the Wollemi National Park

Type	Longwall	Minimum distance between the longwalls and the Wollemi National Park (m)
Existing/approved longwalls	WYLW17	280
	WYLW18	265
	WYLW19	650
	WYLW20	460
	WYLW21	370
	WYLW22	515
	WYLW23	380
Modified longwalls	WYLW24	690
	WYLW25	400
	WYLW26	115

In comparison the minimum distances of the longwalls, based on the MOD 17 Layout, varied between 120 m for WYLW25 and 445 m for WYLW22. The range of minimum distances for the modified WYLW24 to WYLW26, therefore, is similar to the range of minimum distances for the existing/approved longwalls based on the MOD 17 Layout.

A section through the Wollemi National Park and the modified WYLW26 is shown in Fig. 5.30. This section has been taken where the National Park is located closest to the modified longwalls.

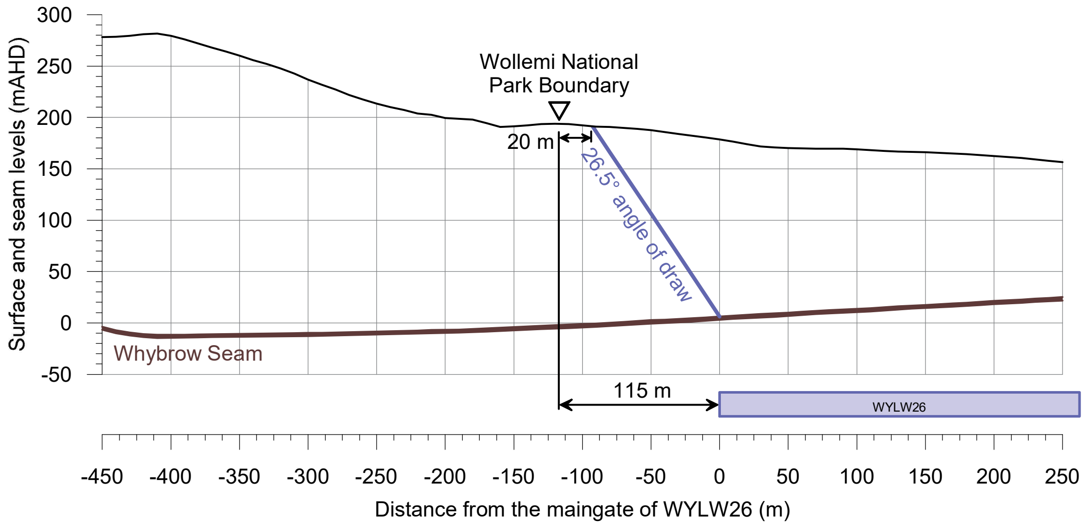


Fig. 5.30 Section through the Wollemi National Park and the modified WYLW26

The boundary of the National Park is located 115 m south-west of the maingate of the modified WYLW26. The boundary is also located outside the 26.5° angle of draw line, as shown in Fig. 5.30, at a minimum distance of approximately 20 m. While the National Park is located outside the 26.5° angle of draw line, it has been included as part of the Study Area as it could experience far-field horizontal movements or valley closure effects.

The land within the National Park is predicted to experience less than 20 mm vertical subsidence due to the mining of the modified WYLW24 to WYLW26, i.e. the boundary is located outside of the limit of vertical subsidence. The magnitude of the predicted vertical subsidence is similar to the natural movements that occur due to the wetting and drying of the surface soils. While the National Park could experience very low levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains.

The Wollemi National Park could experience low level far-field horizontal movements. There is no 3D ground monitoring data available at the North Wambo Underground Mine along the steep slopes beneath the Wollemi National Parks. The predicted far-field horizontal movements, therefore, have been based on the measurements at Dendrobium Mine which has similar or shallower depths of cover and similar natural surface gradients.

The measured total 3D horizontal movements at Dendrobium Mine for survey marks located outside the extents of the longwalls (i.e. above solid coal only) are illustrated in Fig. 5.31. The fitted mean and 95 % confidence level for the measured total horizontal movements have been shown in this figure.

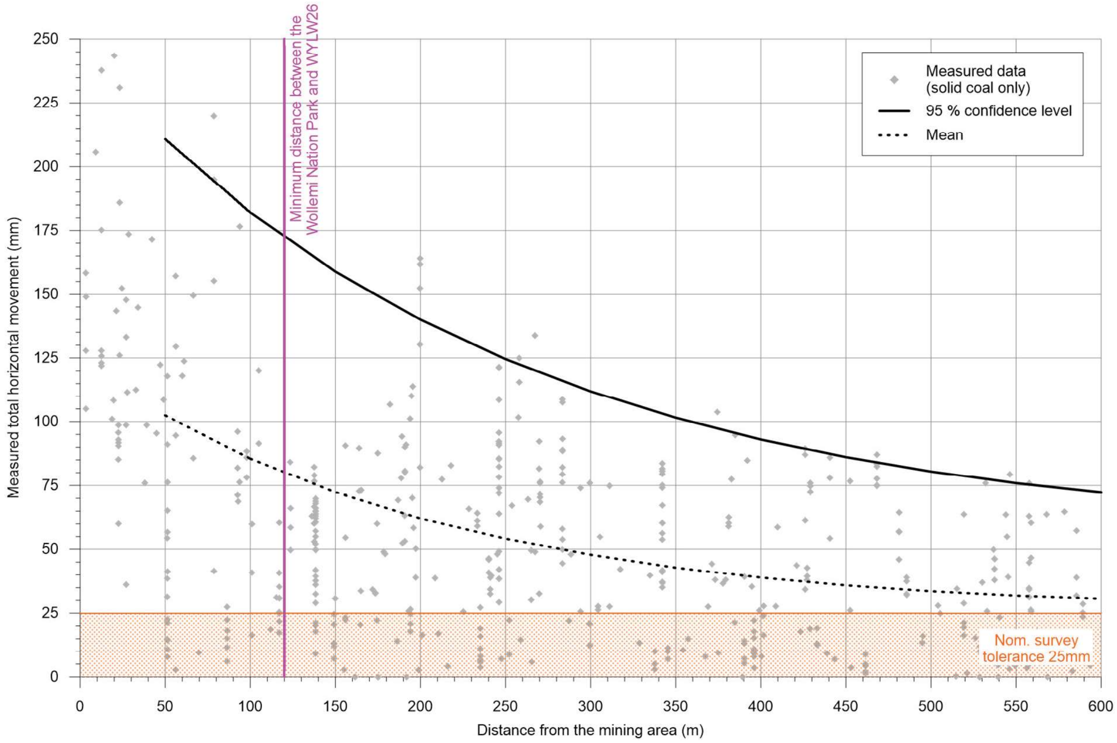


Fig. 5.31 Measured total 3D horizontal movements at Dendrobium Mine

The predicted total far-field horizontal movements at the boundary of the Wollemi Nation Park is approximately 175 mm based on the 95 % confidence level. These movements tend to be bodily movements, towards the extracted longwalls, which are accompanied by very low levels of strain, typically less than the order of survey tolerance.

It is unlikely, therefore, that the Wollemi National Park would experience adverse impacts due to the vertical or far-field horizontal movements, even if these predictions were exceeded by a factor of two times. The predictions and impact assessments for the Wollemi Escarpment (i.e. the cliffs along the boundary of the National Park) are provided in Section 5.5.

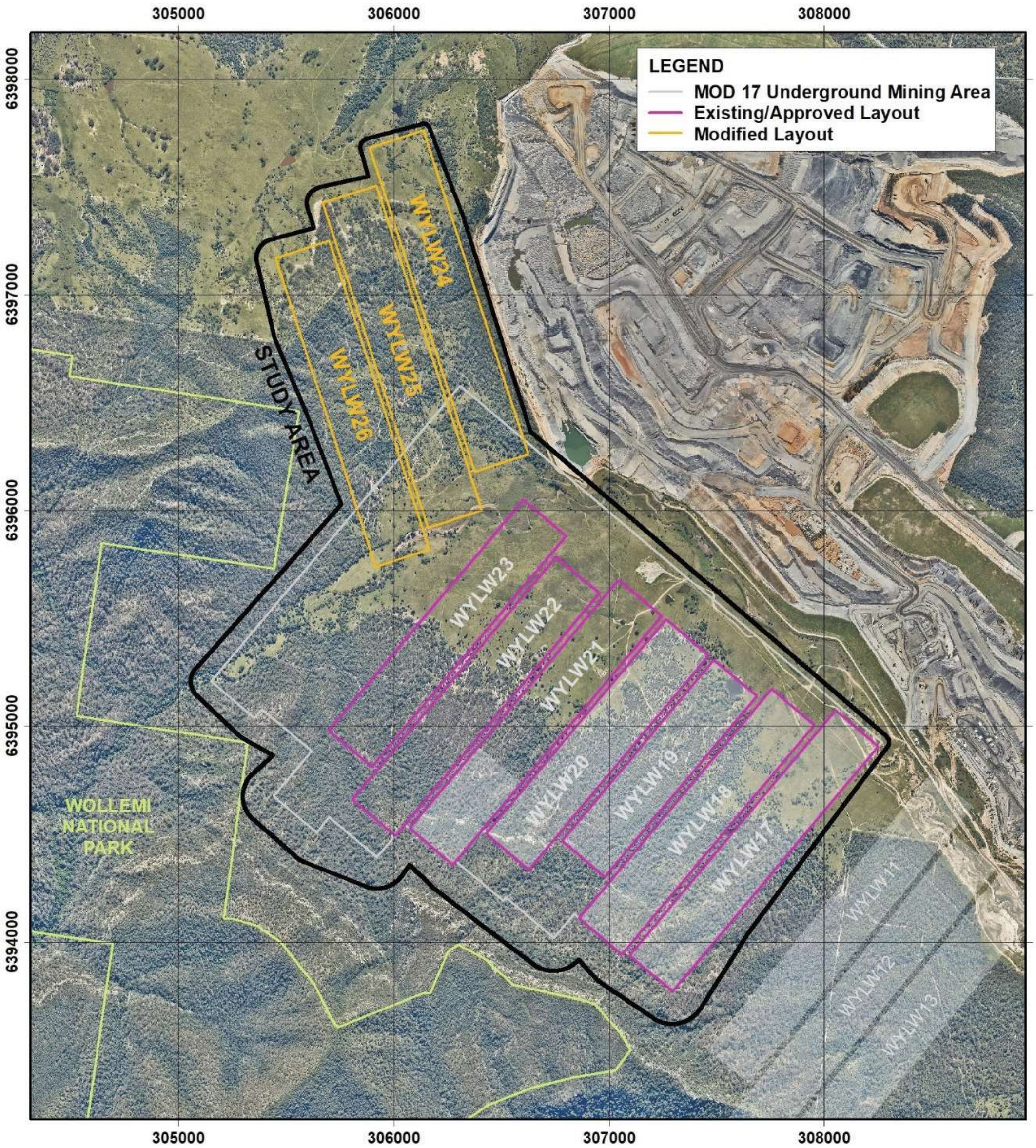
The drainage lines within the National Park are generally located at distances greater than 200 m from the modified longwalls. There are small sections of drainage lines (total length of approximately 0.4 km) that are located at distances between 200 m and 400 m from the maingate of the modified WYLW26.

While minor and isolated fracturing have been observed up to around 400 m from longwall mining in the NSW coalfields, these have occurred within very incised river valleys within the Southern Coalfield and have had no adverse impacts on the streams. The drainage lines within the National Park are on top of the steep slopes (i.e. small valley heights) and, therefore, it is unlikely that mining-induced fracturing would occur at these distances from the longwalls based on the Modified Layout.

It is unlikely that there would be any adverse impacts to the Wollemi National Park, even if the predictions were exceeded by a factor of two times.

5.12. Natural vegetation

There is natural vegetation can be seen in the aerial photograph provided in Fig. 5.32.



Source: Nearmap

Fig. 5.32 WYLW17 to WYLW26 and the Study Area

There is natural vegetation located above the south-western ends of the existing/approved WYLW17 to WYLW23 and above a large part of the modified WYLW24 to WYLW26. However, the land has been largely cleared above the north-eastern ends of the existing/approved WYLW17 to WYLW23 and partially cleared above the northern and southern ends of the modified WYLW24 to WYLW26.

The maximum predicted subsidence effects for the modified WYLW24 to WYLW26 are similar to those predicted for the existing/approved WYLW17 to WYLW23. The potential impacts to the natural vegetation for the modified WYLW24 to WYLW26 are therefore similar to those for the existing/approved WYLW17 to WYLW23.

A detailed survey of the natural vegetation has been undertaken and is described and assessed in the report prepared by Eco Logical Australia (2022). Further discussions are provided by the specialist ecology consultant on the project.

6.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE BUILT FEATURES

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

6.1. The North Wambo Creek Diversion

The North Wambo Creek Diversion is partially located above the finishing (i.e. north-eastern) end of the existing/approved WYLW17. Surface cracking occurred along the diversion where this longwall mined directly beneath it. Descriptions of these impacts are provided in the subsidence summary review in Report No. MSEC1017.

The North Wambo Creek Diversion is located at distances varying between 170 m and 460 m from the other existing/approved WYLW18 to WYLW23 and at distances greater than 600 m from the modified WYLW24 to WYLW26. Further impacts are not anticipated due to the mining of these future longwalls due to their distances from the creek diversion.

6.2. Public utilities

As listed in Table 2.1, there were no public utilities identified within the Study Area, apart from the unsealed roads and the associated drainage culverts, which are described below.

6.2.1. Unsealed roads

There are unsealed tracks and fire trails located within the Study Area. The locations of these roads are shown in Drawing No. MSEC1224-09. The unsealed roads are used for the mining operations and for firefighting activities. Circular concrete culverts have been constructed, in some locations, where the roads cross the drainage lines.

Photographs of typical unsealed tracks located above the modified WYLW24 to WYLW26 are provided in Fig. 6.1.

Fig. 6.1 Typical unsealed tracks (P5490 and P5492)

The unsealed tracks and trails are located across the SBEUM mining area and, therefore, could experience the full range of predicted subsidence effects. A summary of the maximum predicted mine subsidence effects within the Study Area was provided in Chapter 4.

Non-conventional movements can also occur and have occurred in the NSW coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

It is expected that cracking, rippling and stepping of the unsealed road surfaces would occur as each of the longwalls mine beneath them. The largest impacts will occur in the eastern part of the SBEUM mining area where the depths of cover are the shallowest. Examples of impacts observed along the tracks located above WYLW11 to WYLW13 and WYLW17 to WYLW20 are provided in Section 4.7. The crack widths above these longwalls typically varied between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm.

The impacts on the unsealed tracks and fire trails due to the mining of the longwalls based on the Modified Layout are expected to be similar to those observed due to the mining of WYLW11 to WYLW13 and WYLW17 to WYLW20. It is expected that the roads could be maintained in safe and serviceable condition throughout the mining period using normal road maintenance techniques.

The drainage culverts could experience the full range of predicted subsidence effects. The predicted tilts could result in a reduction or, in some cases, a reversal of grade of the drainage culverts. In these cases, the culverts would need to be re-established to provide the minimum required grades. The predicted curvatures and ground strains could result in cracking of the concrete culverts. It may be necessary to repair, or in some cases, replace the affected culverts.

There are existing management strategies for maintaining the unsealed roads that are located above the previously extracted longwalls at the Wambo Coal Mine. It is expected that these same strategies could be used to maintain the unsealed roads which are located directly above the existing/approved WYLW21 to WYLW23 and modified WYLW24 to WYLW26. It is recommended that these roads are periodically visually inspected during active subsidence.

6.3. Public amenities

As listed in Table 2.1, there were no public amenities identified within the Study Area.

6.4. Farm land and facilities

6.4.1. Agricultural utilisation

There is no major farm land or agricultural utilisation identified within the Study Area. The land has been cleared above the north-eastern ends of the existing/approved WYLW17 to WYLW23 and partially cleared above the northern and southern ends of the modified WYLW24 to WYLW26, as shown in Fig. 5.32, and it is used for light grazing. There are also some farm features located within the Study Area which are described in the following sections.

6.4.2. Fences

Fences are located across the Study Area and, therefore, they are expected to experience the full range of predicted subsidence effects. A summary of the maximum predicted conventional subsidence effects within the Study Area is provided in Chapter 4.

Wire 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. These types of fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without significant impacts.

It is likely, therefore, that some of the wire fences within the Study Area would be impacted as the result of the extraction of the longwalls based on the Modified Layout. Impacts on the wire fences could be remediated by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

The management strategies for the fences should be incorporated into the Built Features Management Plan.

6.4.3. Farm dams

The locations of the farm dams are shown in Drawing No. MSEC1224-09. The approved Montrose Water Storage Dam is discussed separately in Section 6.5.5.

There are 15 farm dams located on WCPL owned land within the Study Area. Thirteen of these dams are located directly above the SBEUM mining area, based on the Modified Layout, with eight dams (Refs. d01 to d04 and d07 to d10) above the existing/approved WYLW17 to WYLW23 and five dams (Refs. d11 to d15) above the modified WYLW24 to WYLW26. In comparison, there were 13 dams (Refs. d01 to d13) located above the longwalls based on the MOD 17 Layout.

The surface areas of the farm dams vary between 227 m^2 and 4960 m^2 and the maximum lengths vary between 20 m and 92 m. The largest dam (Ref. d04) is located above the existing WYLW19. The remaining dams within the Study Area have surface areas up to 2130 m^2 and lengths up to 68 m.

The farm dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. The dams within the Study Area are all located on WCPL owned land.

A photograph of a typical farm dam is provided in Fig. 6.2.

Fig. 6.2 Typical farm located above the southern end of the modified WYLW26

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the farm dams is provided in Table 6.1. The values represent the maximum predicted accumulated movements within 20 m of the perimeters of the dams due to the extraction of the longwalls based on the Modified Layout.

Table 6.1 Maximum predicted total vertical subsidence, tilt and curvatures for the farm dams

Location	Longwalls	Ref.	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Farm dams	Above existing/approved WYLW17 to WYLW23	d01	1500	75	> 3.0	> 3.0
		d02	1100	35	1.5	1.0
		d03	500	35	> 3.0	1.0
		d04	1800	80	> 3.0	> 3.0
		d05	< 20	< 0.5	< 0.01	< 0.01
		d06	< 20	< 0.5	< 0.01	< 0.01
		d07	1600	65	> 3.0	> 3.0
		d08	550	35	2.5	1.0
		d09	250	10	0.6	0.5
		d10	250	8	0.7	0.3
	Above modified WYLW24 to WYLW26	d11	1800	15	> 3.0	> 3.0
		d12	1800	50	3.0	> 3.0
		d13	1800	35	2.5	3.0
		d14	350	30	> 3.0	1.5
		d15	1600	55	> 3.0	> 3.0

The farm dams located above and adjacent to the existing/approved WYLW17 to WYL23 are predicted to experience tilts up to 80 mm/m (i.e. 8.0 % or 1 in 13) and curvatures greater than 3.0 km^{-1} (i.e. minimum radius of curvature less than 0.3 km).

The farm dams located above the modified WYLW24 to WYLW26 are predicted to experience tilts up to 55 mm/m (i.e. 5.5 % or 1 in 18) and curvatures greater than 3.0 km^{-1} (i.e. minimum radius of curvature less than 0.3 km).

The maximum predicted conventional strains for the farm dams, based on applying a factor of 10 to the maximum predicted curvatures, are greater than 30 mm/m tensile and compressive. The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The maximum predicted strains for the farm dams (i.e. minimum depths of cover less than 100 m) are 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence levels.

Non-conventional movements can also occur and have occurred in the NSW coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted subsidence effects for the farm dams, based on the Modified Layout, are similar to the maximum predicted values based on the MOD 17 Layout. However, the predicted subsidence effects for dams Refs. d13 to d15 increase as they were located outside the SBEUM mining area based on the MOD 17 Layout.

The predicted final tilts for the farm dams vary between 8 mm/m (i.e. 0.8 % or 1 in 125) and 80 mm/m (i.e. 8.0 % or 1 in 13). Mining-induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side and decreasing on the other. The predicted final changes in freeboard for the farm dams vary from less than 0.1 m to 0.9 m.

The maximum predicted change in freeboard of 0.9 m occurs at dam Ref. d04 as it is located above the finishing (i.e. north-eastern) end of the existing WYLW19. The direction of tilt at this dam is towards the existing WYLW19 and, therefore, it is in the upslope direction and reduces the freeboard on the dam wall. The predicted changes in freeboard for the remaining dams within the Study Area are 0.5 m or less. It is unlikely, therefore, that the predicted tilts would adversely impact on the water storage capacities of the farm dams.

It is expected, at the magnitudes of predicted curvatures and strains, that fracturing and buckling would occur in the uppermost bedrock beneath the natural surface soils. Surface cracking could also occur in the cohesive soils forming the bases and walls of the dams, especially where the depths to bedrock are relatively shallow. It may be necessary to remediate some of the farm dams, at the completion of mining, by excavating and re-establishing cohesive material in the beds of the farm dams to reduce permeability.

It is recommended that the farm dams are visually inspected during active subsidence.

6.4.4. Registered groundwater bores

The registered groundwater bores within the Study Area are shown in Drawing No. MSEC1224-09. The locations and details of these bores were obtained from the Australian Groundwater Explorer, which is publicly available online (BoM, 2021).

WCPL owns two monitoring bores (Refs. GW200831 and GW200832) which are located outside but near the north-eastern end of the existing/approved WYLW23 and the southern end of the modified WYLW24. These two bores could be adversely impacted due to the mining of the longwalls based on the Modified Layout. Impacts could include temporary lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality.

There were no other registered groundwater bores identified within the Study Area.

6.5. Industrial, commercial or business establishments

As listed in Table 2.1, there were no Industrial, Commercial or Business Establishments identified within the Study Area, apart from the mine related infrastructure, which are described below.

6.5.1. Montrose Open Cut Pit

The Montrose Open Cut Pit is located to the north-east of the SBEUM mining area. The current extent of the pit is shown in Drawing No. MSEC1224-01. It is recommended that a geotechnical assessment of the highwall be undertaken based on the effects of the existing/approved WYLW17 to WYLW23 and the modified WYLW24 to WYLW26.

6.5.2. Exploration drill holes

The locations of the exploration drill holes within the Study Area are shown in Drawing No. MSEC1224-09. The drill holes are located directly above and adjacent to the SBEUM mining area and, therefore, could experience the full range of predicted subsidence effects, which were described in Chapter 4. It is likely, therefore, that fracturing and shearing would occur in the drill holes as the result of mining. It is recommended that the exploration drill holes are capped (if not already completed) prior to being directly mined beneath.

6.5.3. 11 kV powerline

An 11 kV powerline is proposed to be constructed by WCPL on the north-eastern side of the existing/approved WYLW17 to WYLW21, as shown in Drawing No. MSEC1224-09. The powerline is located partially above and adjacent to the existing WYLW17 and WYLW18 and it is located at a distances of 100 m or greater from the remaining longwalls.

The 11 kV powerline is predicted to experience less than 20 mm vertical subsidence due to the mining of the longwalls based on the Modified Layout. While the powerline could experience very low level vertical subsidence, it is not predicted to experience measurable tilts, curvatures or strains.

No adverse impacts on the 11 kV powerline are anticipated due to the mining of the remaining existing/approved and modified longwalls.

6.5.4. Ventilation shaft

A ventilation shaft is being constructed by WCPL on the north-eastern side of the approved WYLW21, as shown in Drawing No. MSEC1224-09. The shaft is located 70 m from the finishing end of the approved longwall and it is located outside the 26.5° angle of draw. The predicted vertical subsidence at the surface is less than 20 mm. While the top of the shaft could experience very low level vertical subsidence, it is not predicted to experience measurable tilts, curvatures or strains.

The fans associated with the shaft could be sensitive to the low level tilt. Also, the shaft could experience differential horizontal shear over its height. It is recommended that WCPL develop monitoring and management strategies to maintain the shaft and the associated infrastructure in serviceable conditions during the mining period.

6.5.5. Approved Montrose Water Storage Dam

The approved Montrose Water Storage Dam is proposed to be constructed above the north-eastern ends of the existing WYLW17 to WYLW19, as shown in Drawing No. MSEC1224-09. The design of the dam, therefore, should consider the subsided surface levels and the fractured bedrock resulting from the existing mining.

The overall height of the dam wall will need to be increased by up to 2 m, to account for the subsided surface levels, so as to maintain the design crest of the dam wall. The maximum height of the dam wall, assuming the top of the dam wall at RL121.5 mAHD, is approximately 16.7 m based on the natural surface level contours and approximately 18.3 m based on the predicted subsided surface level contours.

The extraction of the existing longwalls will have resulted in fracturing and buckling of the topmost bedrock. The design of the dam base should comprise a sufficient thickness of cohesive materials to provide the required water holding capacity.

6.6. Aboriginal heritage sites

6.6.1. Descriptions of the Aboriginal heritage sites

The locations of known Aboriginal heritage sites are shown in Drawing No. MSEC1224-09.

There are 59 Aboriginal heritage sites that have been identified within the Study Area, comprising 52 open sites (artefacts or PAD), six rock shelters and one scarred tree. The types of sites are included in Tables D.01 and D.02, in Appendix D.

The area above and adjacent to the approved WYLW24 and WYLW25 and the modified WYLW24 to WYLW26 is referred to as the *Aboriginal Heritage Study Area* hereon. There are 38 Aboriginal heritage sites that are located within the Aboriginal Heritage Study Area, all of which are open sites. Further descriptions of these sites are provided by South East Archaeology (2022).

The remaining 21 Aboriginal heritage sites are located above the existing and approved WYLW17 to WYLW23. These sites comprise open sites, rock shelters and a scarred tree. The majority of these sites have already been directly mined beneath.

The descriptions, predictions and impact assessments for the Aboriginal heritage sites located within the Aboriginal Heritage Study Area and located outside that area are provided separately in the following two sections.

6.6.2. Aboriginal heritage sites located within the Aboriginal Heritage Study Area

There are 38 open sites located within the Aboriginal Heritage Study Area, being Sites 37-5-0358, 37-5-0359, 37-5-0360, 37-5-0605, 37-5-0659, 37-5-0661, 37-5-0662, 37-5-0663, 37-5-0664, 37-5-0668, 37-5-0692, 37-5-0767, 37-5-0782, 37-5-0783 and 37-5-0807, 37-5-0786, 37-5-0787, 37-5-0788, 37-5-0789, 37-5-0790, 37-5-0791, 37-5-0792, 37-5-0793 and Wambo Sites 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527 and 528.

The maximum predicted total subsidence effects for each of the Aboriginal heritage sites located within the Aboriginal Heritage Study Area are provided in Table D.01, in Appendix D. The values are the maximum predicted values within 20 m of the identified locations of each of the sites.

A summary of the maximum predicted total subsidence effects for the Aboriginal heritage sites located within the Aboriginal Heritage Study Area is provided in Table 6.2. The values are the maximum predicted values within 20 m of the identified locations of each of the sites.

Table 6.2 Maximum predicted total subsidence, tilts and curvatures for the Aboriginal heritage sites located within the Aboriginal Heritage Study Area

Site type	Maximum predicted total subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Open sites	1950	80	> 3.0	> 3.0

The maximum predicted total tilt for the Aboriginal heritage sites located within the Aboriginal Heritage Study Area is 80 mm/m (i.e. 8 %, or 1 in 13). The maximum predicted total curvatures are greater than 3.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of less than 0.3 km.

The maximum predicted conventional strains for the Aboriginal heritage sites located within the Aboriginal Heritage Study Area, based on applying a factor of 10 to the maximum predicted curvatures, are greater than 30 mm/m tensile and compressive.

The range of strains will vary considerably across the mining area due to, amongst other factors, variation in the depth of cover. The greatest strains are predicted to occur where the depths of cover are shallowest and lesser strains where the depths of cover are higher.

The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The maximum predicted strains for the Aboriginal heritage sites located above the mining area (i.e. minimum depths of cover less than 100 m) are 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence levels. The predicted strains are less where the depths of cover are greater above the mining area.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted subsidence effects for the Aboriginal heritage sites located within the Aboriginal Heritage Study Area, based on based on the Modified Layout, are the same as or slightly less than the maximum predicted values based on the MOD 17 Layout. The maximum predicted values occur at the sites located above the proposed WYLW24 to WYLW26 for the Modified Layout and occur at the sites above the approved WYLW23 and WYLW24 for the MOD 17 Layout.

While the maximum predicted subsidence effects do not change, the predicted values for the individual sites increase in most cases but reduce in other cases. The number of sites predicted to experience more than 20 mm vertical subsidence is 31 based on the Modified Layout and 17 based on the MOD 17 Layout. That is 14 additional sites are predicted to experience more than 20 mm vertical subsidence due to the proposed modifications.

The mining-induced curvatures and strains could cause surface cracking in the vicinity of the open sites, within the Aboriginal Heritage Study Area, where they are located directly above the mining area. It is unlikely that the artefacts and deposits themselves would be impacted by surface cracking. It is possible, however, that if remediation of the surface were required after mining, that these works could potentially impact the open sites.

It is recommended that WCPL develop appropriate protocols and seek the required approvals from the appropriate authorities in the event that remediation of the surface is required in the locations of the open sites. Further assessments of the potential impacts on these sites are provided by South East Archaeology (2022).

6.6.3. Aboriginal heritage sites located outside the Aboriginal Heritage Study Area

There are 21 Aboriginal heritage sites located outside the Aboriginal Heritage Study Area, comprising 14 open sites (Wambo PAD J, PAD K, PAD L and Wambo Sites 230, 231, 308, 309, 310, 483, 493, 494, 496, 497 and 498), six rock shelters (Wambo Sites 499, 500, 501, 502, 503 and 504) and one scarred tree (Wambo Site 324 St 1).

The maximum predicted total subsidence effects for each of the Aboriginal heritage sites located outside the Aboriginal Heritage Study Area are provided in Table D.02, in Appendix D. The values are the maximum predicted values within 20 m of the identified locations of each of the sites.

A summary of the maximum predicted total subsidence effects for the Aboriginal heritage sites located outside the Aboriginal Heritage Study Area is provided in Table 6.3. The values are the maximum predicted values within 20 m of the identified locations of each of the sites.

Table 6.3 Maximum predicted total subsidence, tilts and curvatures for the Aboriginal heritage sites located outside the Aboriginal Heritage Study Area

Site Type	Maximum predicted total subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Open sites	1950	80	> 3.0	> 3.0
Rock shelters	1750	20	0.60	0.60
Scarred tree	1750	60	> 3.0	> 3.0

The maximum predicted total tilt for the Aboriginal heritage sites located outside the Aboriginal Heritage Study Area is 80 mm/m (i.e. 8 %, or 1 in 13) for the open sites. The maximum predicted total curvatures are greater than 3.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of less than 0.3 km, for both the open sites and scarred tree.

The maximum predicted conventional strains for the Aboriginal heritage sites located outside the Aboriginal Heritage Study Area, based on applying a factor of 10 to the maximum predicted curvatures, are greater than 30 mm/m tensile and compressive for the open sites, 6 mm/m tensile and compressive for the rock shelters and greater than 30 mm/m tensile and compressive for the scarred tree.

The range of strains will vary considerably across the mining area due to, amongst other factors, variation in the depth of cover. The greatest strains are predicted to occur where the depths of cover are shallowest and lesser strains where the depths of cover are higher.

The distribution of the predicted strains due to the extraction of the longwalls is described in Section 4.4. The maximum predicted strains for the Aboriginal heritage sites located above the mining area (i.e. minimum depths of cover less than 100 m) are 12 mm/m tensile and 17 mm/m compressive based on the 95 % confidence levels. The predicted strains are less where the depths of cover are greater above the mining area.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted subsidence effects for the Aboriginal heritage sites located outside the Aboriginal Heritage Study Area, based on the Modified Layout, are the same or slightly less than the maximum predicted values based on the MOD 17 Layout. The predicted subsidence effects do not change as the sites are located above the existing and approved longwalls based on both layouts.

Open sites located outside the Aboriginal Heritage Study Area

The open sites are located above the existing and approved WYLW17 to WYLW23.

Surface cracking has developed above the existing longwalls and further surface cracking is expected to develop above the approved longwalls. It is unlikely that the artefacts and deposits themselves would be impacted by surface cracking. It is possible, however, that if remediation of the surface were required after mining, that these works could potentially impact the open sites.

It is recommended that WCPL develop appropriate protocols and seek the required approvals from the appropriate authorities in the event that remediation of the surface is required in the locations of the open sites.

Rock shelters located outside the Aboriginal Heritage Study Area

The rock shelters are located above the western ends of the existing WYLW18 to WYLW21.

It was assessed in Report No. MSEC848 that the mining of these longwalls could result in fracturing of the minor cliffs and rock outcrops and, where the rock is marginally stable, could then result in rockfalls or instabilities. Fracturing and rock falls could therefore potentially adversely impact the rock shelters that are located directly above the mining area.

Rock fracturing developed in the minor cliffs and rock outcrops due to the mining of WYLW18 to WYLW21; however, the rock shelters do not show visual impacts from mining (MSEC, 2021). It is unlikely that adverse impacts would occur to the rock shelters due to the mining of the approved WYLW22 and WYLW23 and the proposed WYLW24 to WYLW26 due to their distances from these longwalls.

It is recommended that visual inspections of the rock shelters are carried out after the completion of each of the approved WYLW22 and WYLW23.

Scarred tree located outside the Aboriginal Heritage Study Area

The scarred tree (Wambo Site 324 St 1) is located directly above the approved WYLW21, towards the finishing (i.e. north-eastern) end of this longwall.

It has been found, from past longwall mining experience, that the incidence of impacts on trees is extremely rare. Impacts in the Hunter and Newcastle Coalfields have been observed where the depths of cover are shallow and/or where the surface terrain is very steep. The depth of cover to the Whybrow Seam in the location of the Scarred Trees is 75 m. The natural surface in the location of the Scarred Tree is relatively flat, with a natural gradient of approximately 1 in 30 (i.e. 3 % or 2°).

The sizes and extents of surface cracking in the vicinity of the scarred tree are expected to be similar to that observed above the eastern ends of the existing WYLW17 to WYLW20 (refer to Section 4.7). The crack widths above these longwalls typically varied between 25 mm and 50 mm, with localised crack widths up to approximately 400 mm.

The likelihood that surface cracking would be coincident with the tree is considered low. It has therefore been assessed that it is very unlikely (i.e. less than 10 %) that the scarred tree would experience adverse impacts due to the mining of the approved WYLW21 to WYLW23 beneath and adjacent to this site.

6.7. State survey control marks

The state survey control marks are shown in Drawing No. MSEC1224-09. The locations and details of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2022).

There are three state survey control marks within the Study Area (Refs. PM183247, SS119671 and TS12077). There are additional state survey control marks identified further afield including within the Montrose Open Cut Pit.

The survey control marks located in the area could be affected by far-field horizontal movements, up to 3 km outside the extents of the SBEUM mining area. Far-field horizontal movements and the methods used to predict such movements are described further in Sections 3.3 and 4.5.

It will be necessary on the completion of the longwalls, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between WCPL and Spatial Services will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

6.8. Building structures

6.8.1. Whynot Homestead

The Whynot Homestead is located above the existing/approved WYLW21. The homestead is a single storey timber framed structure, supported on timber piers, with timber and fibro wall claddings and a metal sheeted roof. An external brick chimney is located on the southern façade of the homestead. The structure is in poor condition and is currently unoccupied. Photographs of the Whynot Homestead are provided in Fig. 6.3. WCPL completed an archival recording of the Whynot Homestead in 2017.


Fig. 6.3 Whynot Homestead

There are other building structures associated with the Whynot Homestead, including timber framed sheds with metal sheet cladding and water storage tanks.

The Whynot Homestead and associated structures are predicted to have experienced vertical subsidence up to 1800 mm, tilts up to 60 mm/m (i.e. 0.6 % or 1 in 17) and curvatures greater than 3.0 km^{-1} (i.e. minimum radius of curvature greater than 0.3 km). The predicted subsidence effects for the Whynot Homestead and associated structures, based on the Modified Layout, are the same as the maximum predicted values based on the MOD 17 Layout as they are located in the middle of the SBEUM mining area.

No adverse impacts were observed to the Whynot Homestead and associated structures due to the mining of WYLW21 directly beneath them. No future impacts are anticipated to these structures due to the mining of the longwalls based on the Modified Layout.

6.8.2. Other building structures

There are two sheds located above the southern end of the modified WYLW26 based on the Modified Layout. These structures were located directly above WYLW25 based on the MOD 17 Layout. The sheds are timber framed with metal sheet cladding. These structures are unused.

Photographs of the two unused sheds are provided in Fig. 6.4.


Fig. 6.4 Unused sheds located above the southern end of the modified WYLW26

A summary of the maximum predicted total vertical subsidence, tilt and curvatures for the unused sheds is provided in Table 6.4. The values represent the maximum predicted accumulated movements within 20 m of the perimeters of the sheds due to the extraction of the longwalls based on the Modified Layout.

Table 6.4 Maximum predicted total vertical subsidence, tilt and curvatures for the unused sheds

Location	Longwalls	Ref.	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Unused sheds	WYLW24 to WYLW26	r10 and r11	1800	60	> 3.0	> 3.0

The unused sheds could experience tilts up to 60 mm/m (i.e. 6 % or 1 in 17), curvatures greater than 3.0 km^{-1} (i.e. minimum radius of curvature less than 0.3 km) and strains greater than 30 mm/m. The predicted subsidence effects for these sheds, based on the Modified Layout, are similar to the maximum predicted values based on the MOD 17 Layout.

The predicted ground movements could result in the distortion of the timber frames and it is possible that some structures could become unsafe due to their existing poor conditions.

It is recommended that the unused sheds located above the southern end of the modified WYLW26 are visually monitored during active subsidence as the longwall extraction face mines directly beneath them. If any structure is identified as unstable or unsafe during monitoring, then measures should be undertaken to stabilise it, such as the provision of temporary bracing, or prevent access to it with the installation of fencing. Alternatively, the structures could be removed prior to active subsidence.

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

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

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

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

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

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

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

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

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

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

APPENDIX B. REFERENCES

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APPENDIX C. FIGURES

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 1 due to WYLW17 to WYLW26

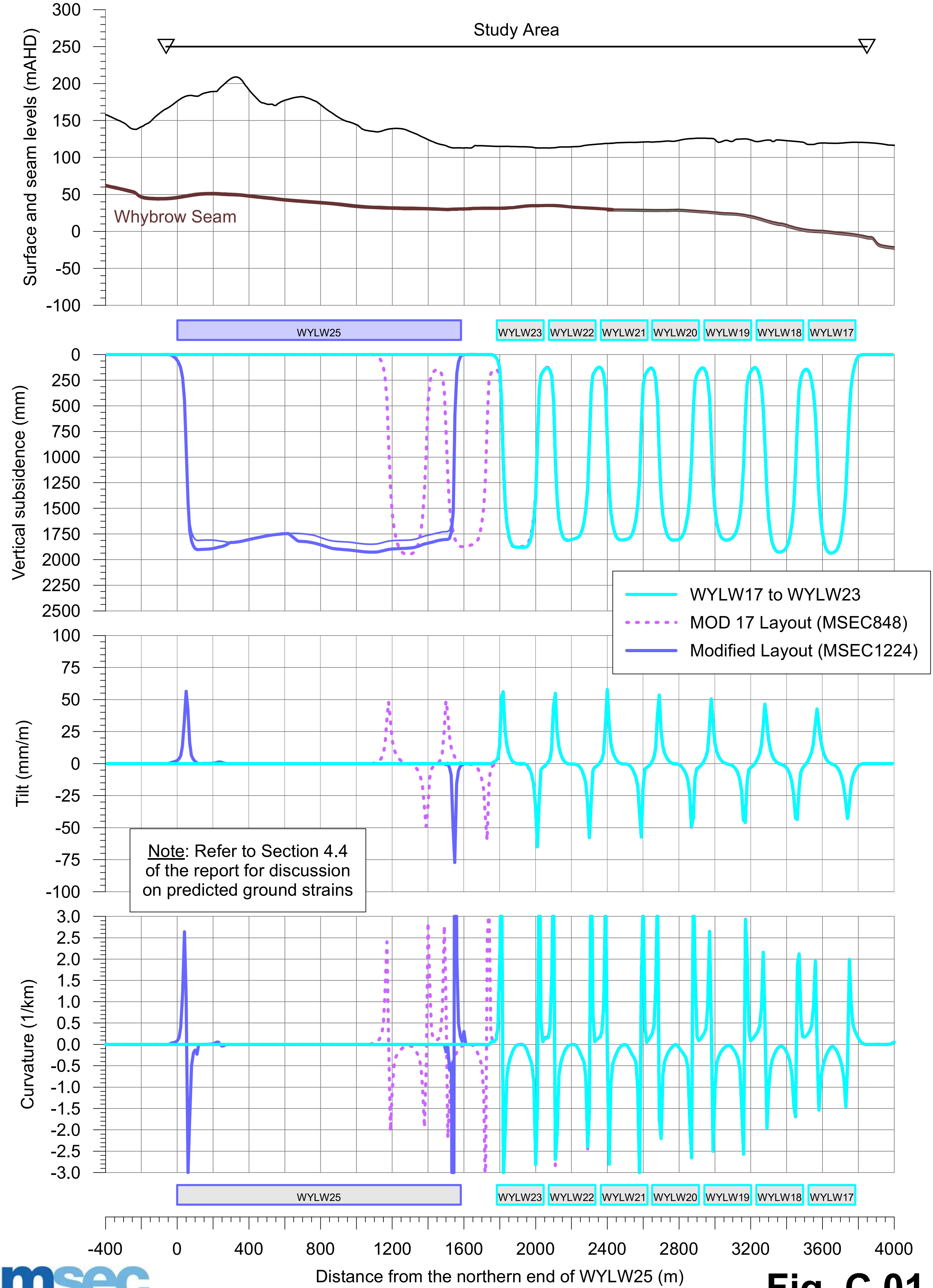

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Fig. C.01

Predicted profiles of vertical subsidence, tilt and curvature along Prediction Line 2 due to WYLW24 to WYLW26

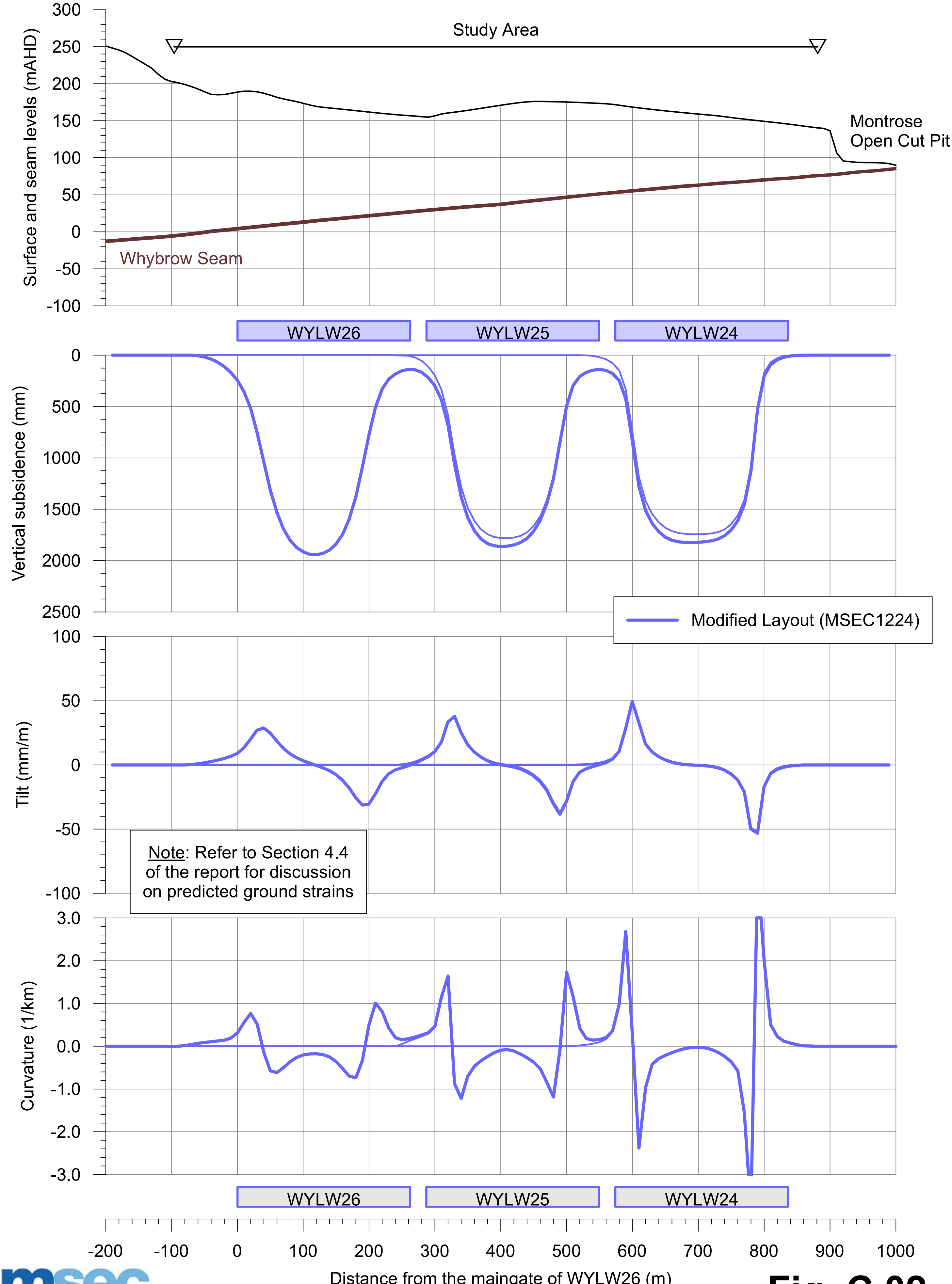

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Fig. C.02

Predicted profiles of vertical subsidence, tilt and curvature along North Wambo Creek and Diversion due to WYLW17 to WYLW26

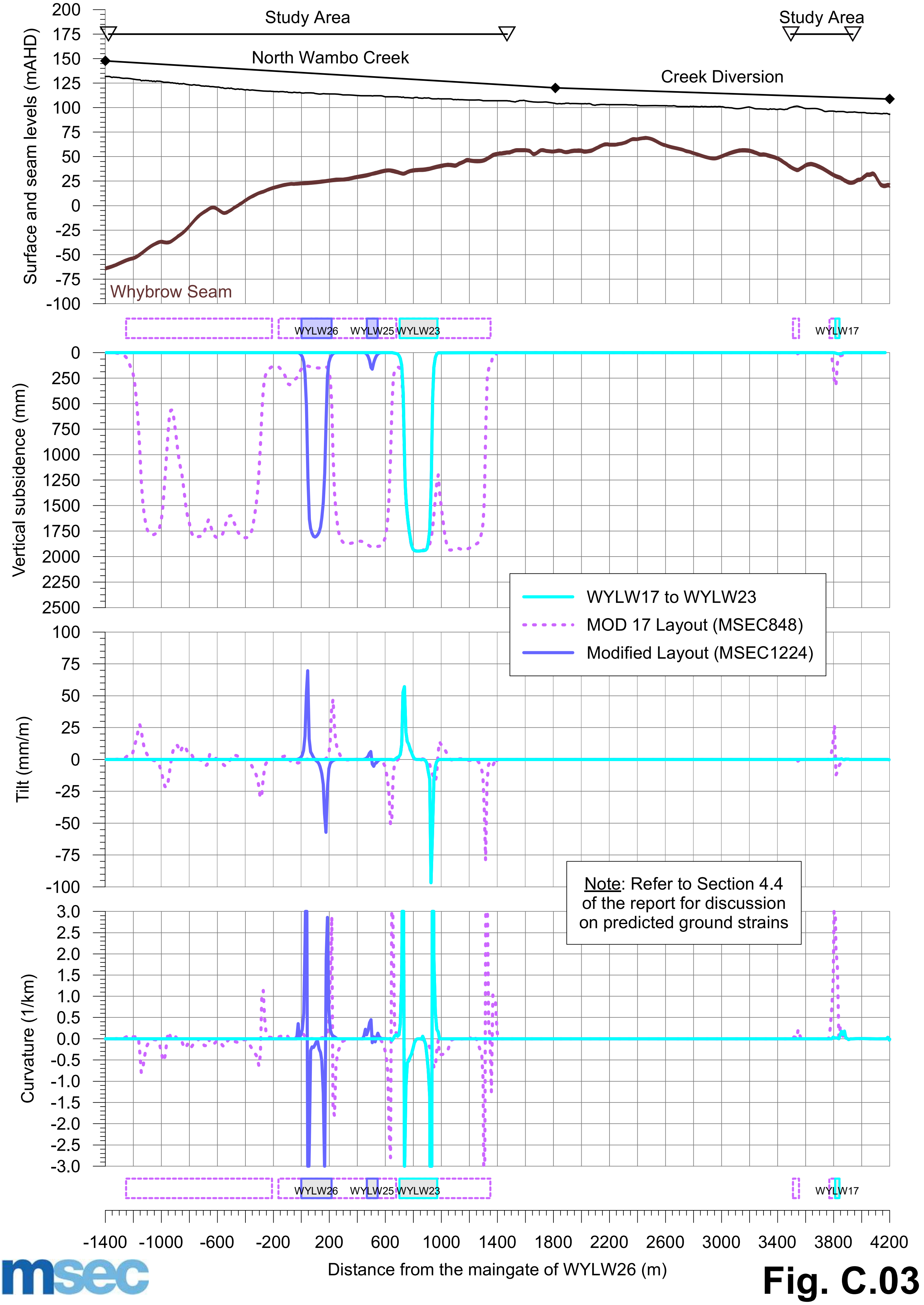

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Fig. C.03

Predicted profiles of vertical subsidence, tilt and curvature along Waterfall Creek due to WYLW17 to WYLW26

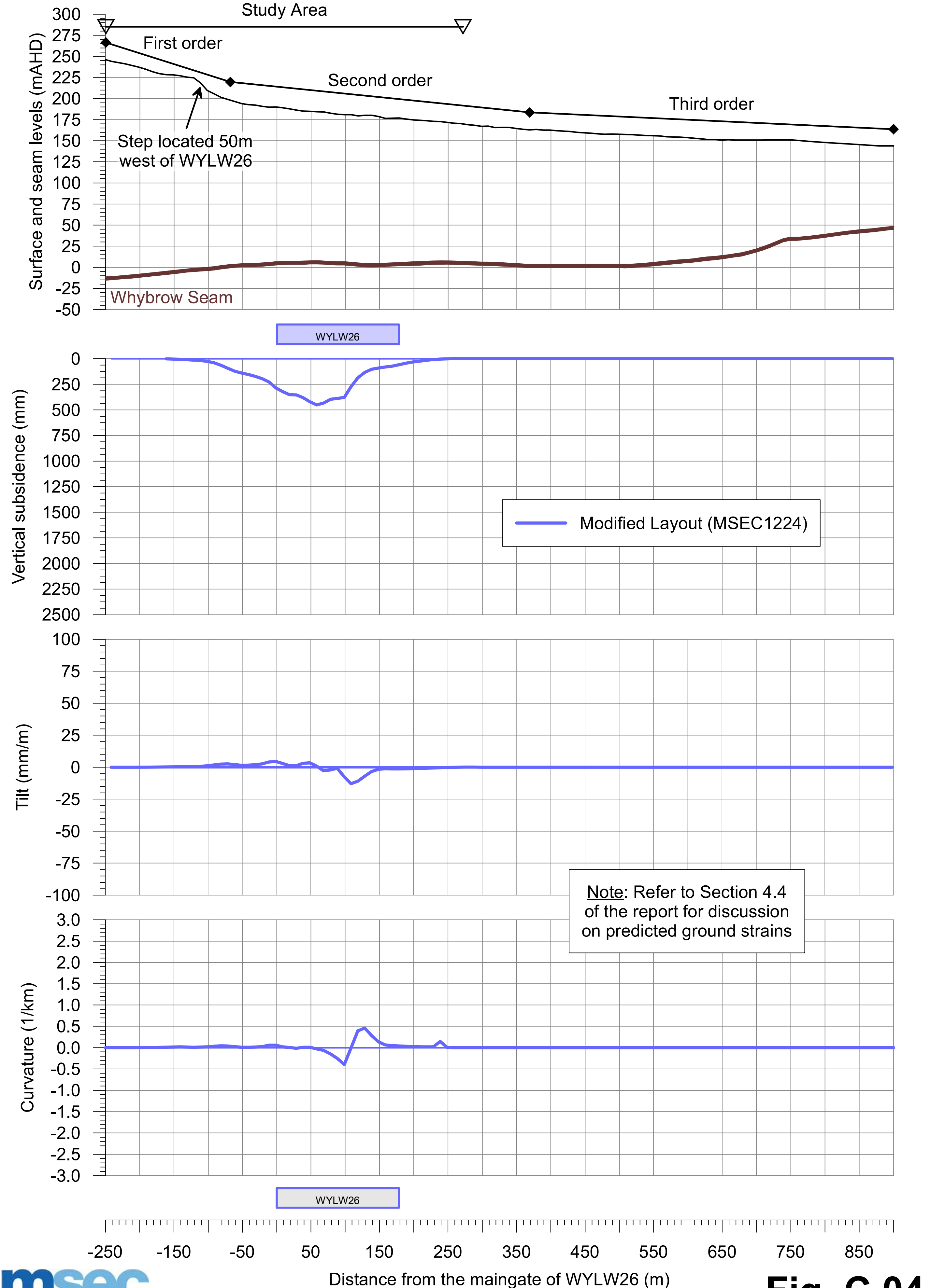

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Fig. C.04

APPENDIX D. TABLES

Table D.01 - Maximum predicted subsidence effects for the Aboriginal heritage sites within the Aboriginal Heritage Study Area

Reference	Type	Located within the Aboriginal Heritage Study Area	Maximum Predicted Total Subsidence based on Previous Layout (mm)	Maximum Predicted Total Tilt based on Previous Layout (mm/m)	Maximum Predicted Total Hogging Curvature based on Previous Layout (1/km)	Maximum Predicted Total Sagging Curvature based on Previous Layout (1/km)	Maximum Predicted Total Subsidence based on Modified Layout (mm)	Maximum Predicted Total Tilt based on Modified Layout (mm/m)	Maximum Predicted Total Hogging Curvature based on Modified Layout (1/km)	Maximum Predicted Total Sagging Curvature based on Modified Layout (1/km)
37-5-0358	Open site	Yes	1950	90	> 3.0	> 3.0	< 20	< 0.5	< 0.01	< 0.01
37-5-0359	Open site	Yes	1950	6	> 3.0	> 3.0	150	20	2.5	0.02
37-5-0360	Open site	Yes	1950	75	> 3.0	> 3.0	1900	80	> 3.0	> 3.0
37-5-0605	Open site	Yes	1800	70	> 3.0	> 3.0	950	80	> 3.0	> 3.0
37-5-0659	Open site	Yes	1400	55	> 3.0	> 3.0	1800	3	3	> 3.0
37-5-0661	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	250	8	0.6	0.2
37-5-0662	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1550	35	1.5	1.5
37-5-0663	Open site	Yes	1950	20	> 3.0	> 3.0	500	35	2.5	0.8
37-5-0664	Open site	Yes	1950	50	> 3.0	> 3.0	1900	55	> 3.0	> 3.0
37-5-0668	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1800	80	> 3.0	> 3.0
37-5-0692	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	25	2	0.1	0.1
37-5-0767	Open site	Yes	1950	60	> 3.0	> 3.0	1850	55	> 3.0	> 3.0
37-5-0782	Open site	Yes	50	4	0.2	0.2	1800	10	2.5	3
37-5-0783 and 37-5-0807	Open site	Yes	1950	7	> 3.0	> 3.0	1900	25	> 3.0	> 3.0
37-5-0786	Open site	Yes	150	9	0.8	0.4	1950	4	> 3.0	> 3.0
37-5-0787	Open site	Yes	< 20	1	0.1	0.02	1900	50	> 3.0	> 3.0
37-5-0788	Open site	Yes	1950	60	> 3.0	> 3.0	1950	50	> 3.0	> 3.0
37-5-0789	Open site	Yes	1950	50	> 3.0	> 3.0	1800	55	> 3.0	> 3.0
37-5-0790	Open site	Yes	1950	70	> 3.0	> 3.0	1600	80	> 3.0	> 3.0
37-5-0791	Open site	Yes	400	40	> 3.0	2.5	1850	60	> 3.0	> 3.0
37-5-0792	Open site	Yes	1800	2	> 3.0	> 3.0	< 20	< 0.5	< 0.01	< 0.01
37-5-0793	Open site	Yes	1700	50	> 3.0	> 3.0	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 513	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1650	35	1	1
Wambo Site 514	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1600	40	1.5	1.5
Wambo Site 515	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 516	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 517	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 518	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1750	50	> 3.0	> 3.0
Wambo Site 519	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1600	70	> 3.0	> 3.0
Wambo Site 520	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	< 20	1	0.1	< 0.01
Wambo Site 521	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	25	3	0.2	0.1
Wambo Site 522	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	50	2	0.1	0.02
Wambo Site 523	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1300	30	0.5	1
Wambo Site 524	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1900	3	> 3.0	> 3.0
Wambo Site 525	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1700	40	2	2
Wambo Site 526	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1550	35	1.5	1
Wambo Site 527	Open site	Yes	< 20	< 0.5	< 0.01	< 0.01	1850	10	1.5	2
Wambo Site 528	Open site	Yes	< 20	1	0.6	0.03	1850	55	> 3.0	> 3.0
		Maximum	**1950**	**90**	**> 3.0**	**> 3.0**	**1950**	**80**	**> 3.0**	**> 3.0**

Table D.02 - Maximum predicted subsidence effects for the Aboriginal heritage sites outside the Aboriginal Heritage Study Area

Reference	Type	Located within the Aboriginal Heritage Study Area	Maximum Predicted Total Subsidence based on Previous Layout (mm)	Maximum Predicted Total Tilt based on Previous Layout (mm/m)	Maximum Predicted Total Hogging Curvature based on Previous Layout (1/km)	Maximum Predicted Total Sagging Curvature based on Previous Layout (1/km)	Maximum Predicted Total Subsidence based on Modified Layout (mm)	Maximum Predicted Total Tilt based on Modified Layout (mm/m)	Maximum Predicted Total Hogging Curvature based on Modified Layout (1/km)	Maximum Predicted Total Sagging Curvature based on Modified Layout (1/km)
Wambo PAD J	Open PAD	No	1950	1	> 3.0	> 3.0	1950	1	> 3.0	> 3.0
Wambo PAD K	Open PAD	No	1750	55	> 3.0	> 3.0	1750	55	> 3.0	> 3.0
Wambo PAD L	Open PAD	No	1800	2	> 3.0	> 3.0	1800	2	> 3.0	> 3.0
Wambo Site 230	Open Artefact Site	No	1800	1	> 3.0	> 3.0	1800	80	> 3.0	> 3.0
Wambo Site 231	Open Artefact Site	No	1600	70	> 3.0	> 3.0	< 20	1	0.2	< 0.01
Wambo Site 308	Open Artefact Site	No	700	25	0.7	0.3	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 309	Open Artefact Site	No	1700	20	0.7	0.9	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 310	Open Artefact Site	No	250	9	0.5	0.03	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 324 St 1	Scarred Tree	No	1700	60	> 3.0	> 3.0	1750	60	> 3.0	> 3.0
Wambo Site 483	Open Artefact Site	No	1750	60	> 3.0	> 3.0	1650	55	> 3.0	> 3.0
Wambo Site 493	Open Artefact Site	No	1600	20	0.4	0.6	1150	20	0.4	0.4
Wambo Site 494	Open Artefact Site	No	200	4	0.2	0.04	200	5	0.1	0.04
Wambo Site 496	Open Artefact Site	No	1700	40	> 3.0	> 3.0	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 497	Open Artefact Site	No	1050	50	3	2	1050	50	3	2
Wambo Site 498	Open Artefact Site	No	1450	35	1.5	1.5	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 499	Rock shelter with PAD	No	400	15	0.4	0.1	400	10	0.3	0.1
Wambo Site 500	Rock shelter with PAD	No	1700	10	0.6	0.6	1750	15	0.6	0.6
Wambo Site 501	Rock shelter with PAD	No	1600	20	0.4	0.6	1700	20	0.4	0.6
Wambo Site 502	Rock shelter with PAD	No	1200	20	0.3	0.3	1250	20	0.3	0.3
Wambo Site 503	Rock shelter with PAD	No	25	< 0.5	< 0.01	< 0.01	< 20	< 0.5	< 0.01	< 0.01
Wambo Site 504	Rock shelter with PAD	No	1500	20	0.5	0.4	1500	20	0.4	0.5
		Maximum	**1950**	**70**	**> 3.0**	**> 3.0**	**1950**	**80**	**> 3.0**	**> 3.0**

APPENDIX E.   DRAWINGS

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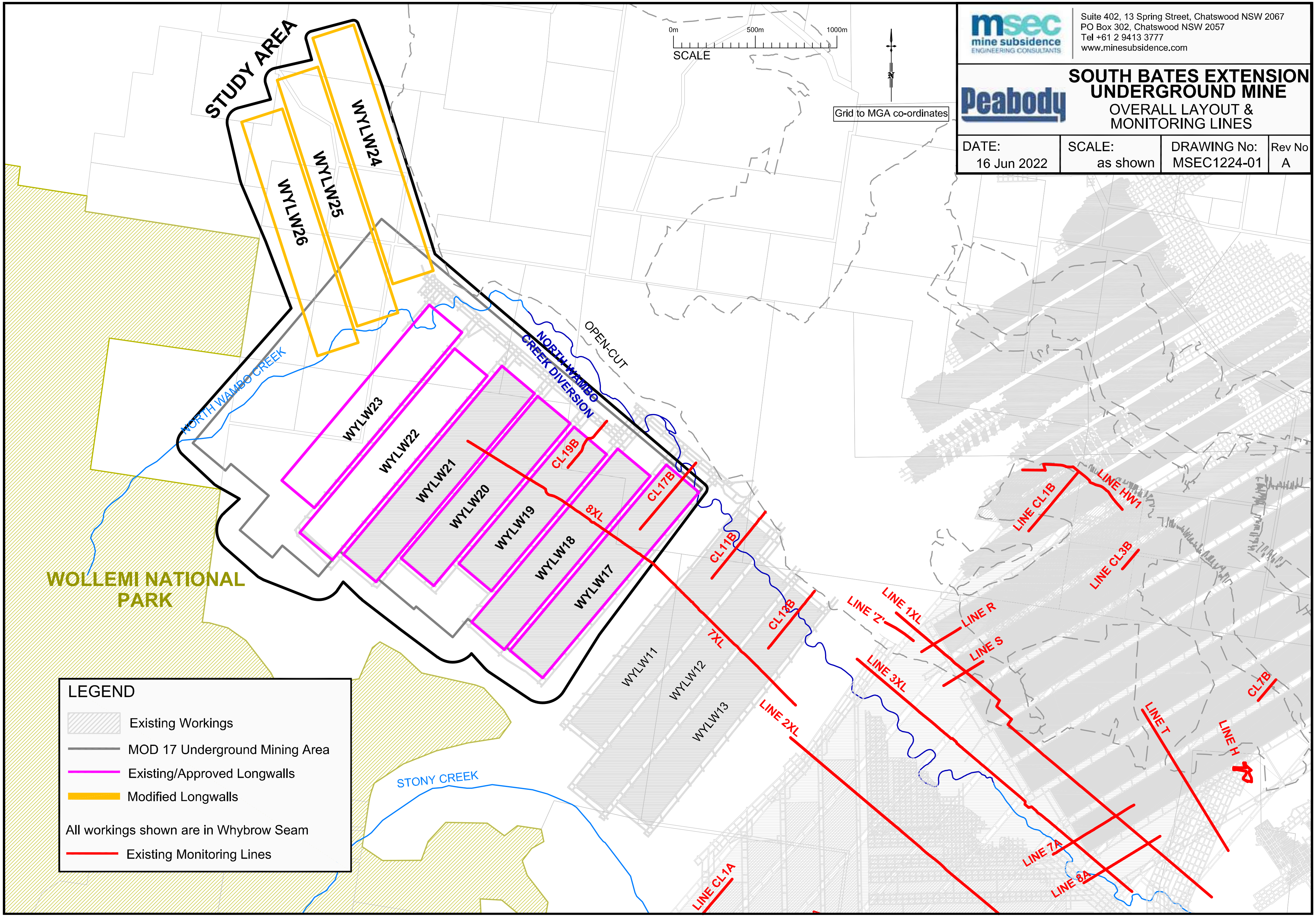

msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

Peabody

SOUTH BATES EXTENSION UNDERGROUND MINE

OVERALL LAYOUT & MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
16 Jun 2022	as shown	MSEC1224-01	A

LEGEND

- Existing Workings
- MOD 17 Underground Mining Area
- Existing/Approved Longwalls
- Modified Longwalls

All workings shown are in Whybrow Seam

- Existing Monitoring Lines

I:\Projects\Wambo\MSEC1224 - Modified of WYLW24 to WYLW26\AcadData\MSEC1224-02 General Layout.dwg

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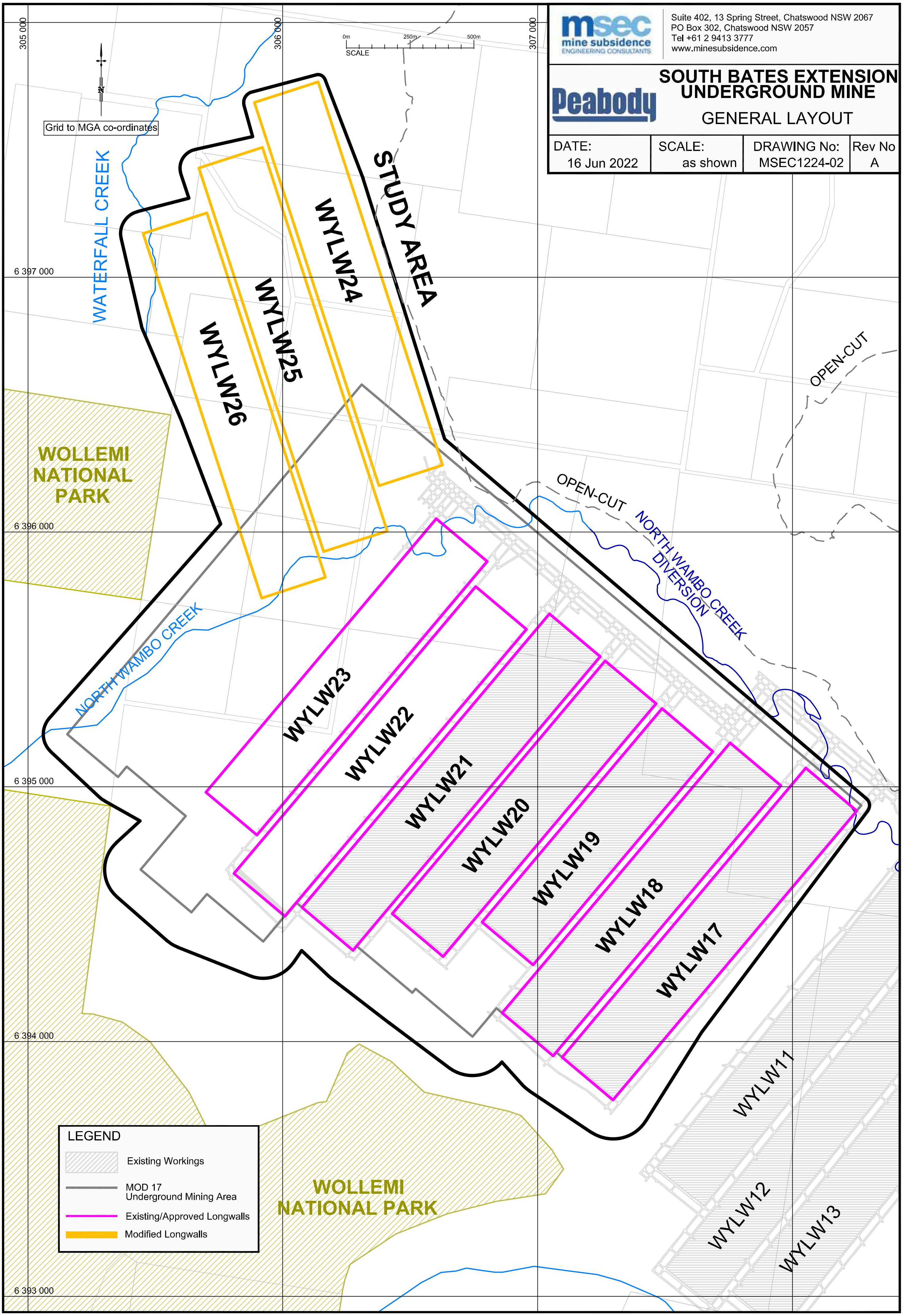
SOUTH BATES EXTENSION UNDERGROUND MINE

GENERAL LAYOUT

DATE:	SCALE:	DRAWING No:	Rev No
16 Jun 2022	as shown	MSEC1224-02	A



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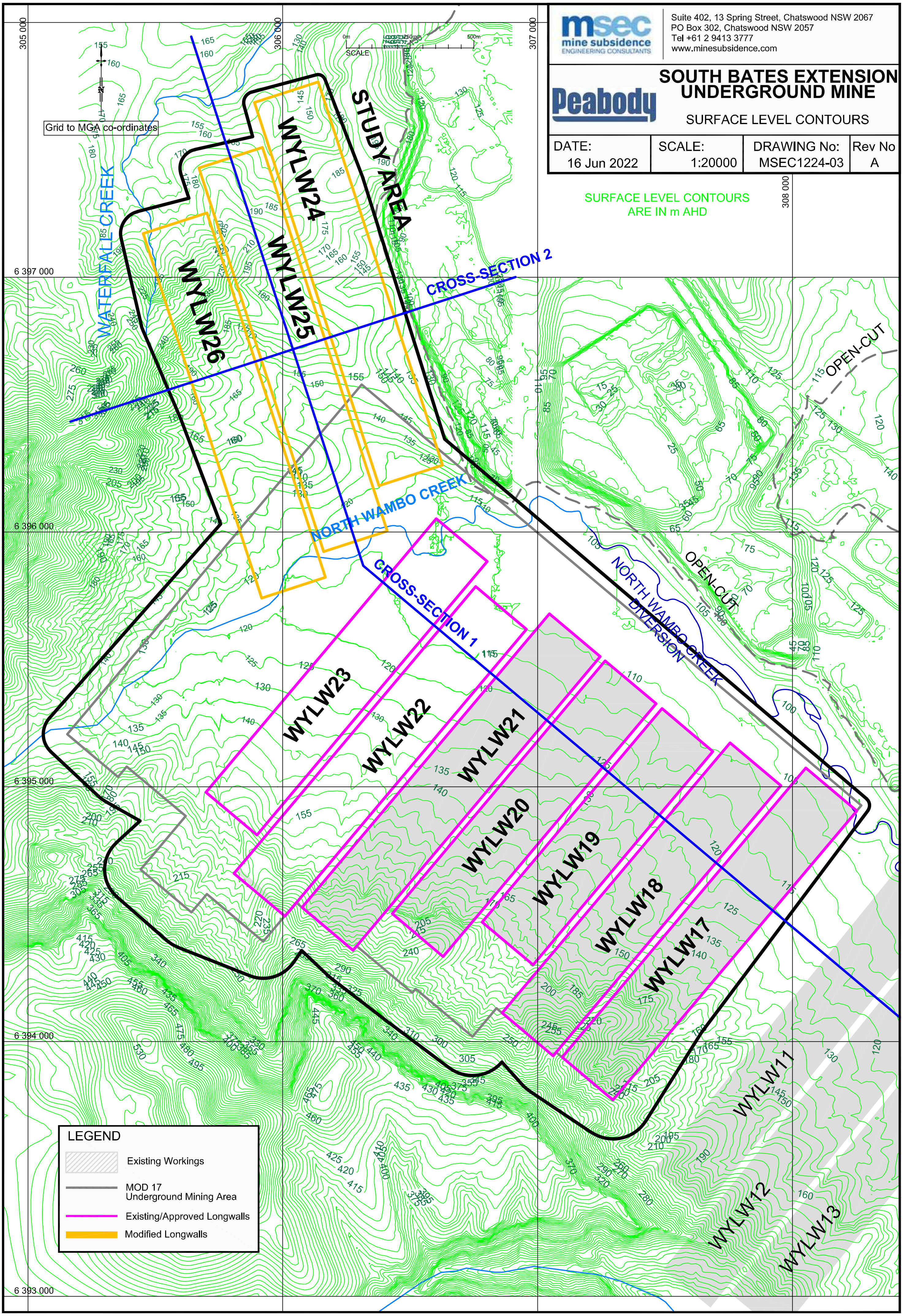

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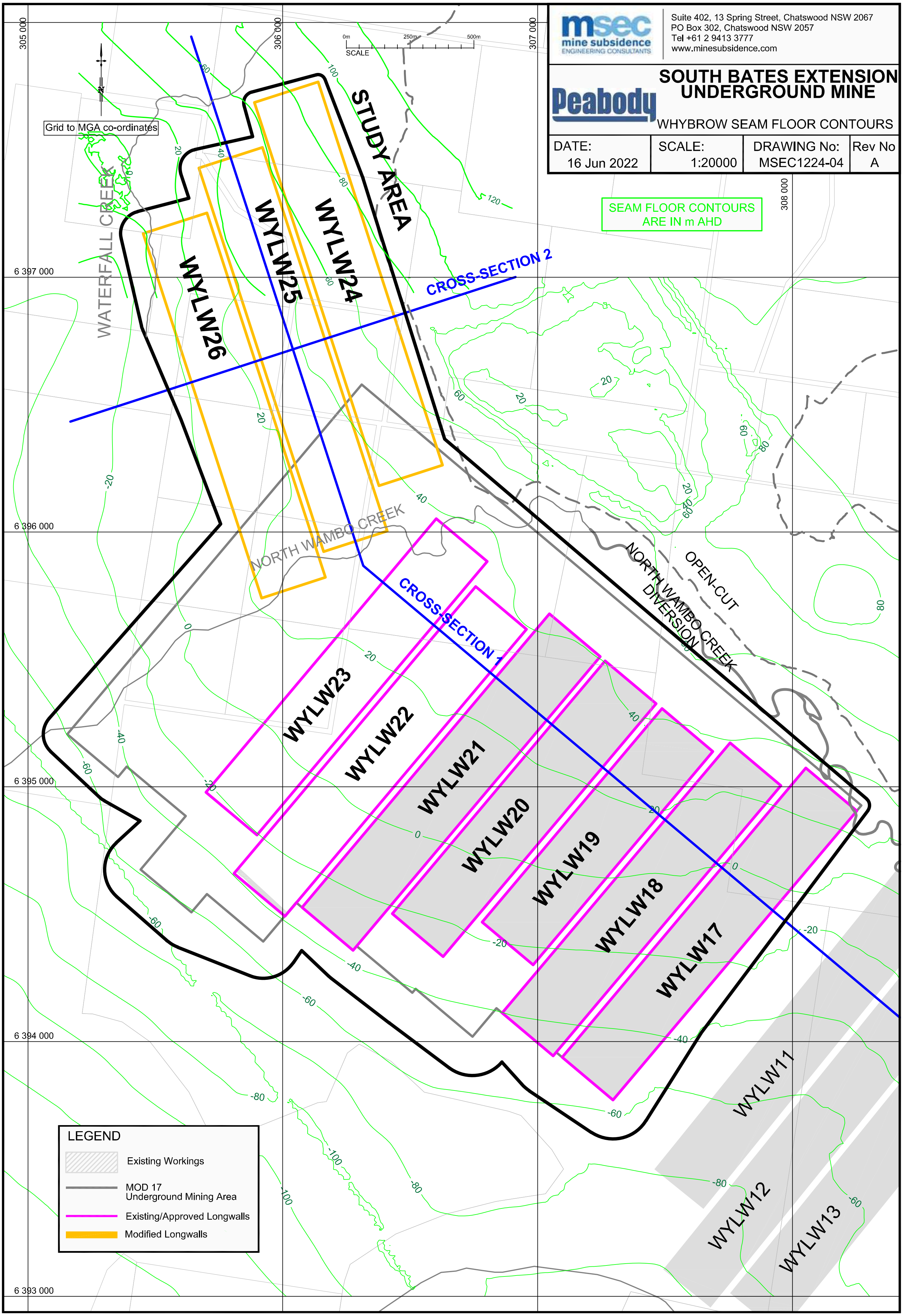

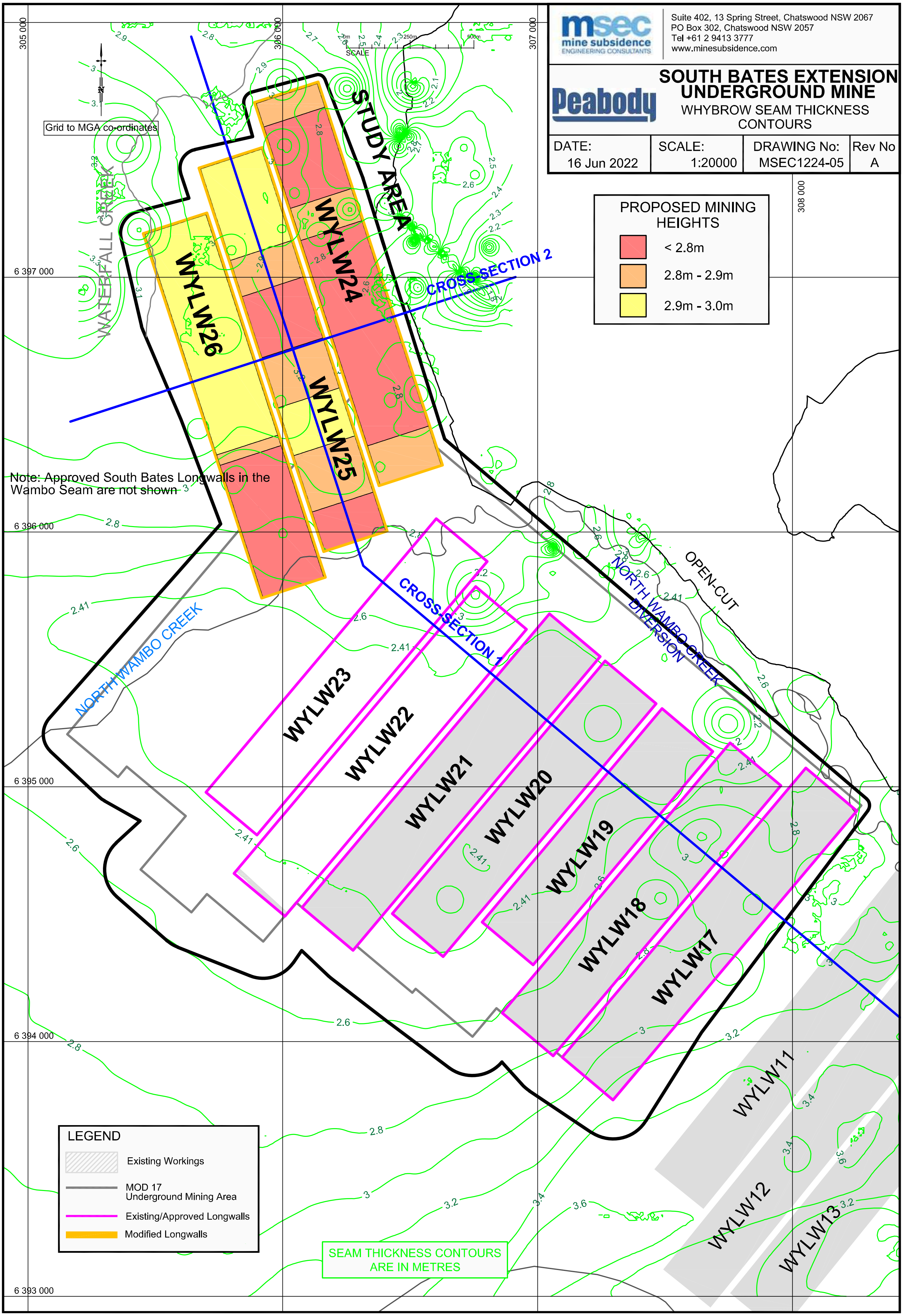
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PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
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Peabody
SOUTH BATES EXTENSION UNDERGROUND MINE
WHYBROW SEAM THICKNESS CONTOURS
DATE: 16 Jun 2022
SCALE: 1:20000
DRAWING No: MSEC1224-05
Rev No A
PROPOSED MINING HEIGHTS
< 2.8m
2.8m - 2.9m
2.9m - 3.0m
Grid to MGA co-ordinates
STUDY AREA
WATERFALL CREEK
CROSS-SECTION 2
CROSS-SECTION 1
WYLW26
WYLW25
WYLW24
WYLW23
WYLW22
WYLW21
WYLW20
WYLW19
WYLW18
WYLW17
WYLW11
WYLW12
WYLW13
NORTH WAMBO CREEK
NORTH WAMBO CREEK DIVERSION
OPEN-CUT
Note: Approved South Bates Longwalls in the Wambo Seam are not shown
305 000
306 000
307 000
308 000
6 397 000
6 396 000
6 395 000
6 394 000
6 393 000
LEGEND
Existing Workings
MOD 17 Underground Mining Area
Existing/Approved Longwalls
Modified Longwalls
SEAM THICKNESS CONTOURS ARE IN METRES

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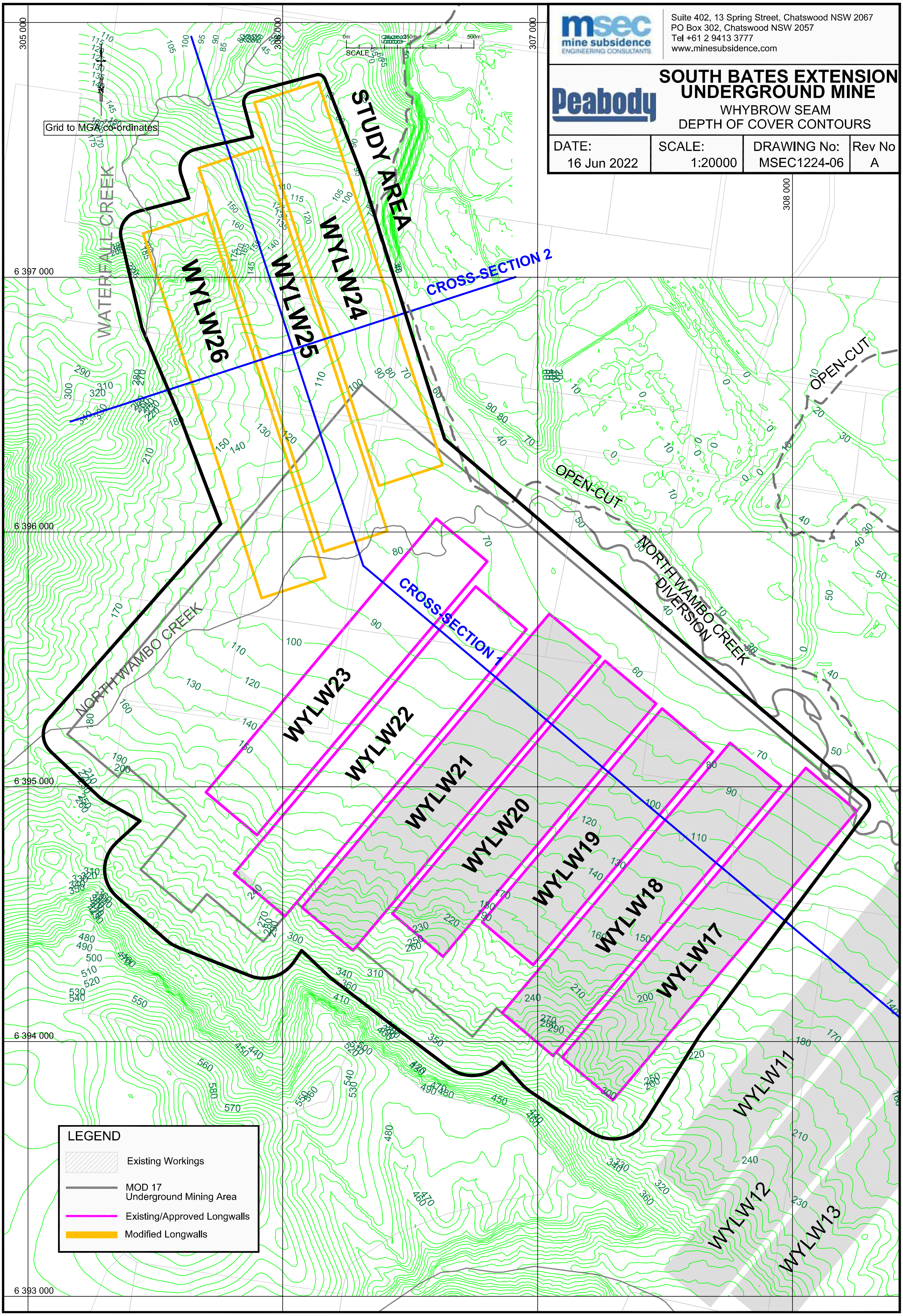

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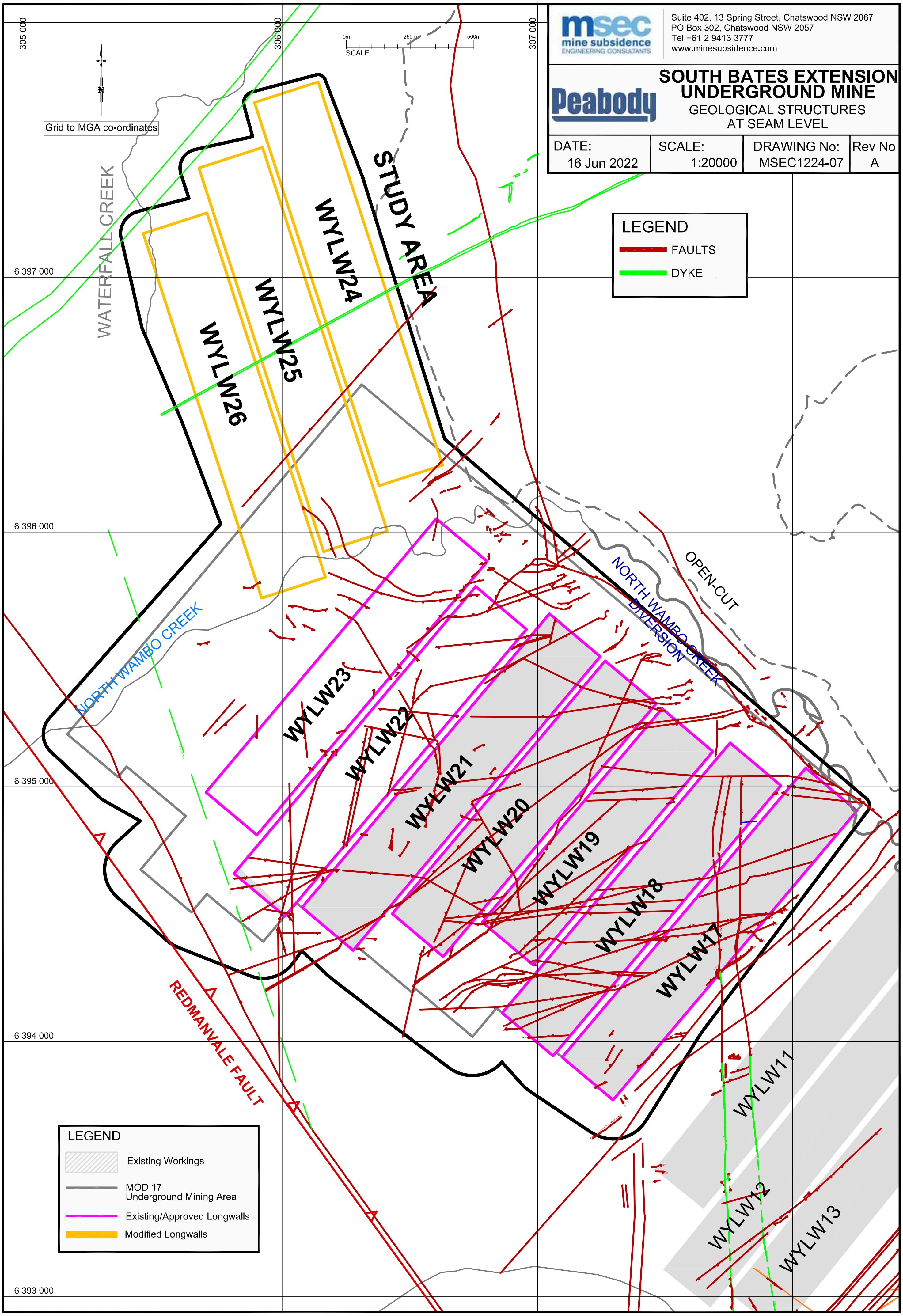

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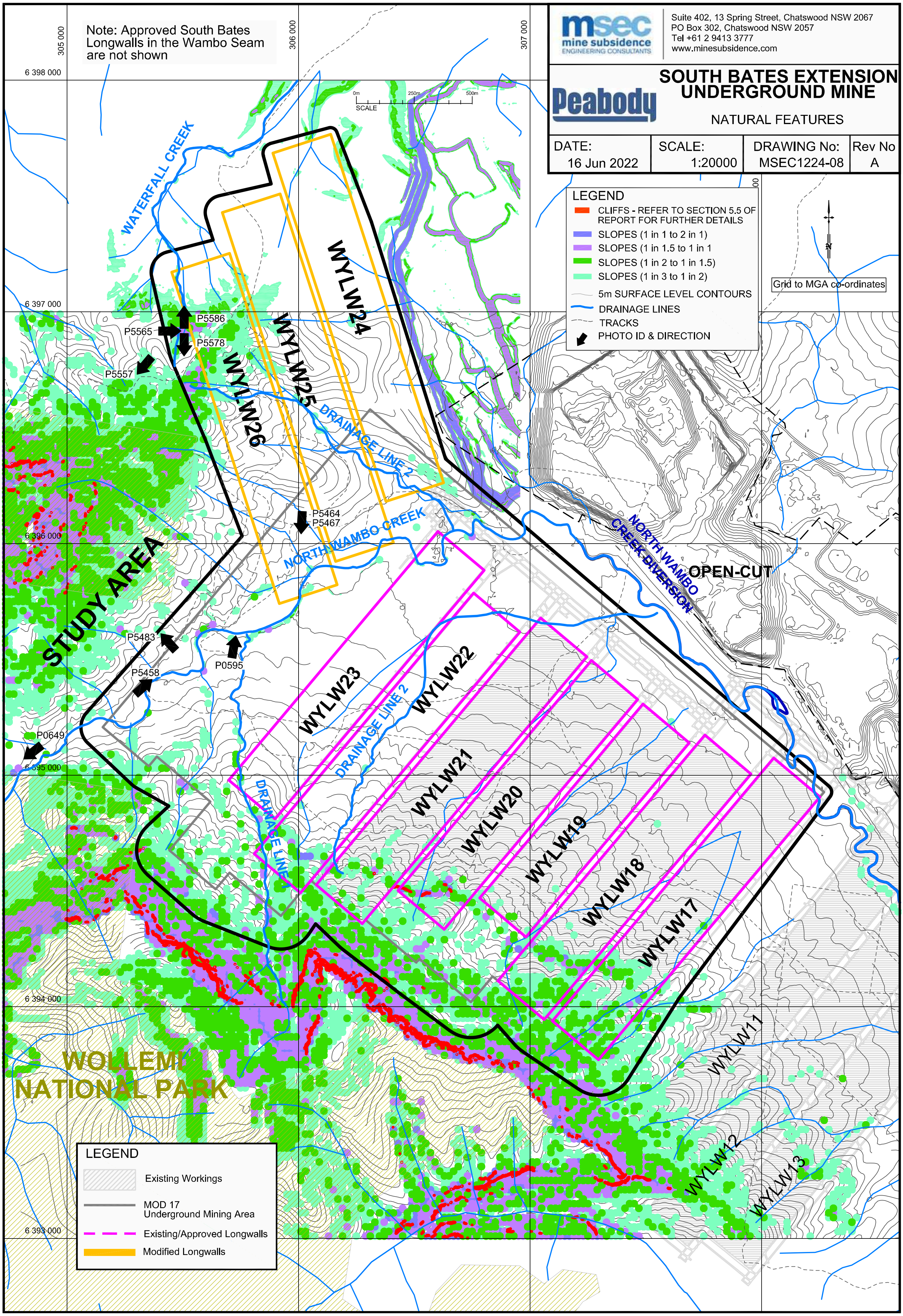

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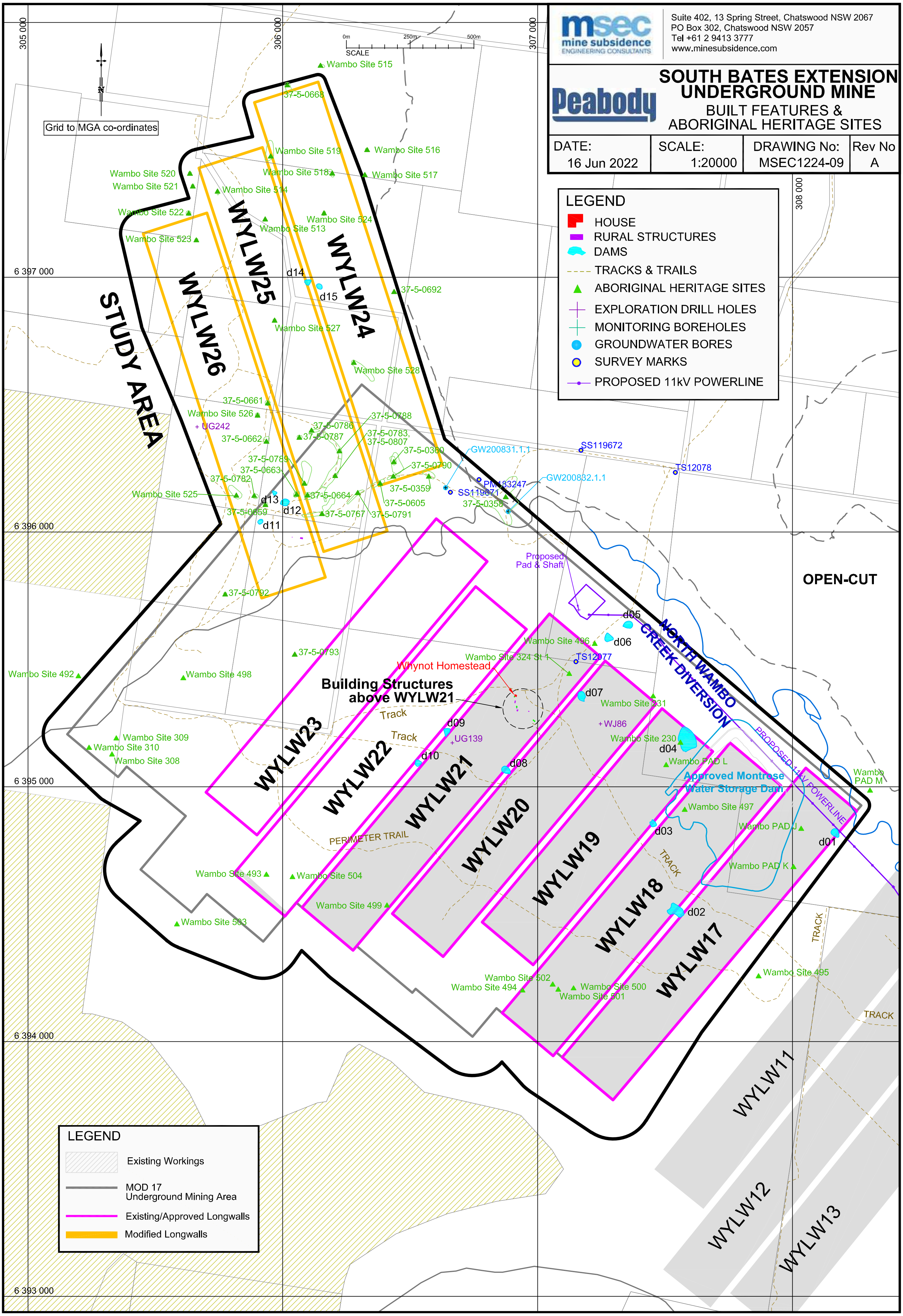

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msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

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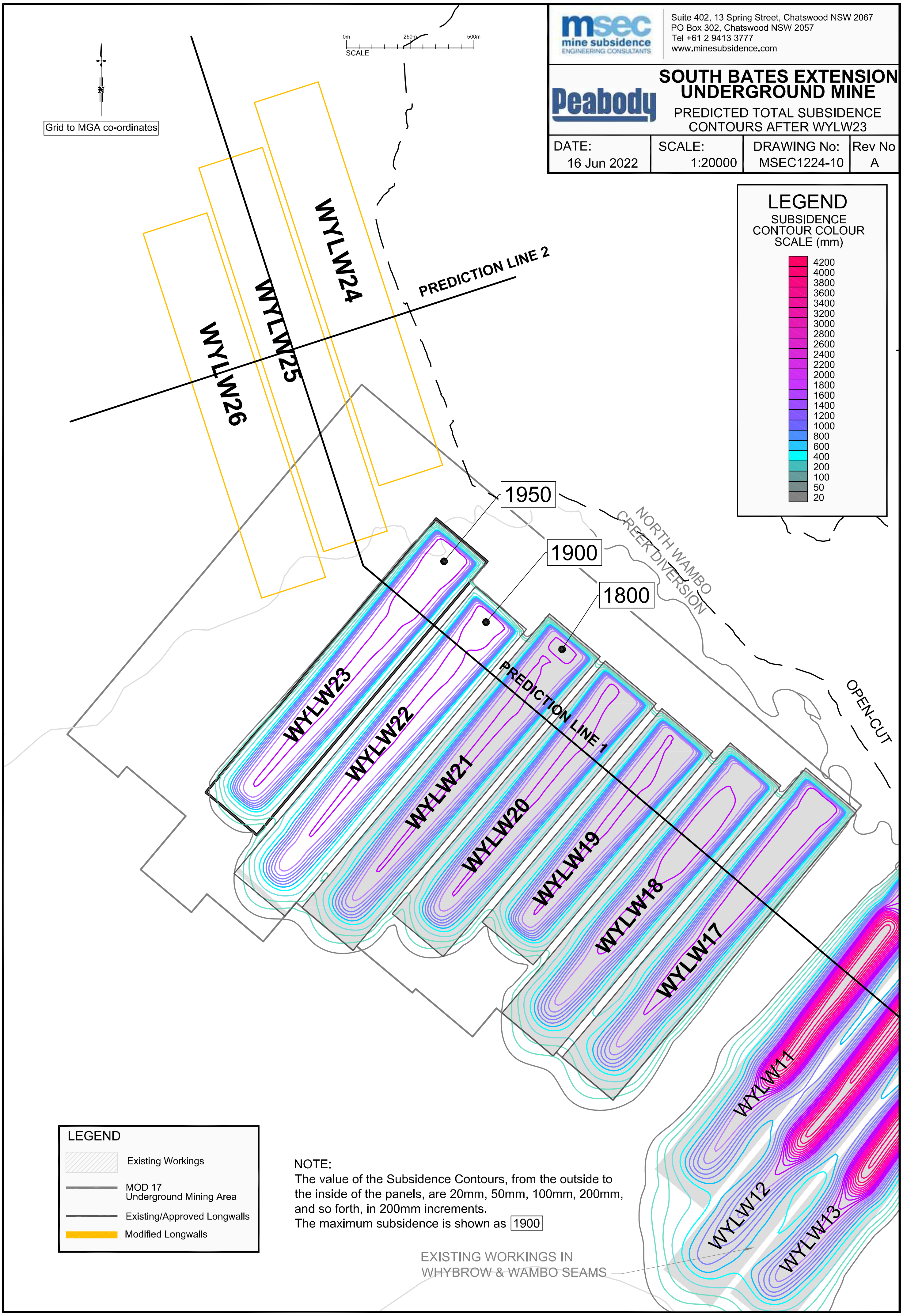
SOUTH BATES EXTENSION UNDERGROUND MINE

PREDICTED TOTAL SUBSIDENCE CONTOURS AFTER WYLW23

DATE:	SCALE:	DRAWING No:	Rev No
16 Jun 2022	1:20000	MSEC1224-10	A



LEGEND

- Existing Workings
- MOD 17 Underground Mining Area
- Existing/Approved Longwalls
- Modified Longwalls

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm, and so forth, in 200mm increments.
The maximum subsidence is shown as 1900

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Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

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SOUTH BATES EXTENSION UNDERGROUND MINE

PREDICTED TOTAL SUBSIDENCE CONTOURS AFTER WYLW24

DATE:	SCALE:	DRAWING No:	Rev No
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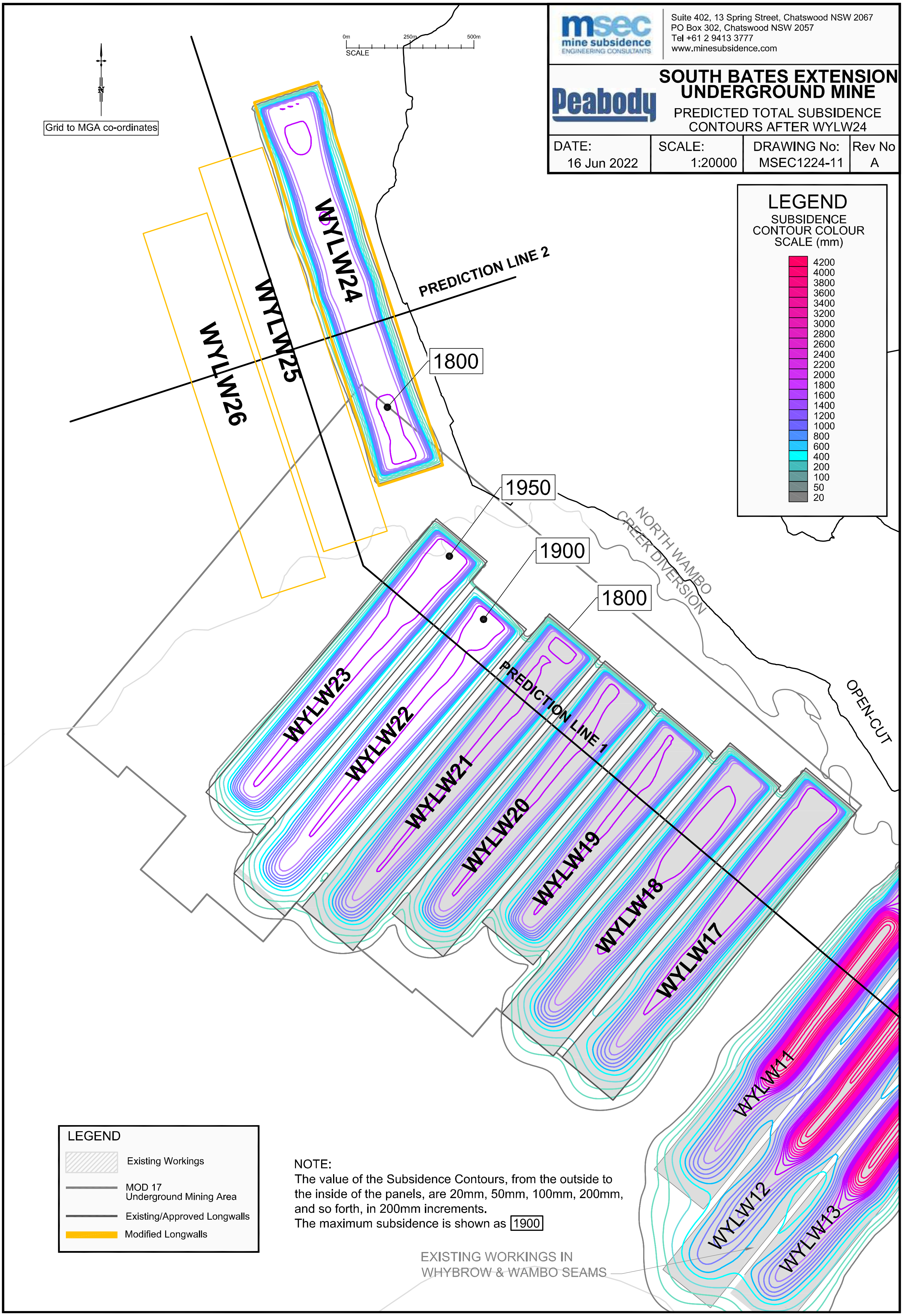

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm, and so forth, in 200mm increments.
The maximum subsidence is shown as 1900

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msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

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SOUTH BATES EXTENSION UNDERGROUND MINE

PREDICTED TOTAL SUBSIDENCE CONTOURS AFTER WYLW25

DATE:	SCALE:	DRAWING No:	Rev No
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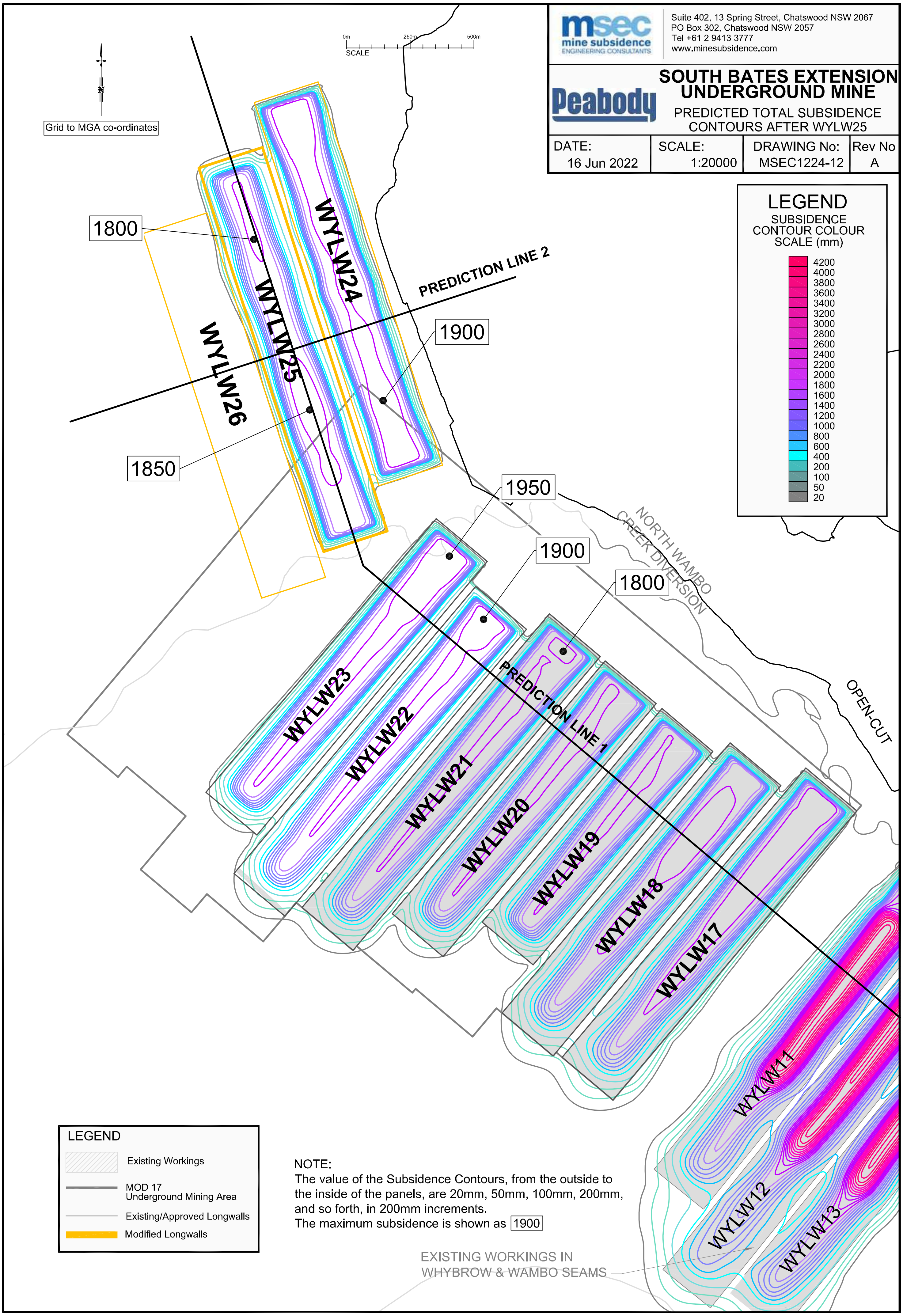

LEGEND

SUBSIDENCE CONTOUR COLOUR SCALE (mm)

4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
100
50
20

LEGEND

- Existing Workings
- MOD 17 Underground Mining Area
- Existing/Approved Longwalls
- Modified Longwalls

NOTE:
The value of the Subsidence Contours, from the outside to the inside of the panels, are 20mm, 50mm, 100mm, 200mm, and so forth, in 200mm increments.
The maximum subsidence is shown as 1900

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