ILLAWARRA METALLURGICAL COAL:

Appin – Area 9 – Longwall 905

End of Panel Subsidence Monitoring Review Report for Appin Longwall 905

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft issue	DK/JB/BM	-	29 May 23
A	Final issue	DK/JB/BM	KK	15 Jun 23

Report produced for: End of panel report for LW905

Associated reports: MSEC448 (Rev. B) – Appin Colliery – Longwalls 901 to 904 – Subsidence Predictions and Impact Assessments for Natural Features and Surface Infrastructure in Support of the Extraction Plan (June 2012)

MSEC1117 (Rev. B) – Appin – Longwalls 709, 710A, 710B, 711 and 905 – Subsidence Predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the Proposed Longwalls 709, 710A, 710B, 711 and 905 at Appin Colliery (May 2021)

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

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Figures

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Drawings

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

Drawing No.	*Description*	*Rev.*
MSEC1334-01	General layout and monitoring lines	A
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1.0 BACKGROUND

1.1. Introduction

Illawarra Metallurgical Coal (IMC) has completed the mining of LW905 which is the fifth and final longwall in the series in Area 9 at Appin Colliery. The location of the longwalls in Area 9 are shown in Drawing No. MSEC1334-01, in Appendix A. A summary of the commencement and finishing dates for the longwalls in Area 9 is provided in Table 1.1.

Table 1.1 Commencement and finishing dates for the longwalls in Area 9

Longwall	Commencement date	Finishing date
LW901	19 January 2016	8 September 2017
LW902	12 May 2018	3 April 2019
LW903	1 November 2019	7 April 2021
LW904	20 May 2021	9 August 2022
LW905	25 September 2022	28 February 2023

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IMC to prepare subsidence predictions and impact assessments for LW901 to LW904 and for LW709 to LW711 and LW905. Reports Nos. MSEC448 (Rev. B) and MSEC1117 (Rev. B) were issued in June 2012 and May 2021 in support of the Extraction Plan Applications for these longwalls.

The Department of Planning and Environment (DPE) granted approval of the Extraction Plans for LW901 to LW904 on 10 September 2014 and for LW709 to LW711 and LW905 on 29 July 2022.

This End of Panel subsidence review report provides the following information:

- comparisons between the measured and predicted subsidence effects at the monitoring lines and monitoring points in Appin Area 9 resulting from the mining of LW905; and
- comparisons between the observed and assessed impacts on the natural and built features within the mining area resulting from the mining of LW905.

Further details on the observed and assessed impacts for natural features due to the mining of LW905 are provided in the associated reports by other consultants. The observations provided in this report should be read in conjunction with those and all other relevant reports.

Chapter 2 of this report describes the locations of the ground monitoring lines and monitoring points that were surveyed during the mining of LW905. That section also provides comparisons between the measured and predicted movements resulting from the mining of this longwall.

Chapter 3 of this report describes the natural and built features near LW905. That section also provides comparisons between the observed and assessed impacts for these features due to the mining of this longwall. Further discussions on the observed and assessed impacts for the natural features are provided in the associated reports by other consultants.

Appendix A includes all drawings associated with this report.

1.2. Mining geometry

The layout of the longwalls in Area 9 at Appin Colliery is shown in Drawing No. MSEC1334-01, in Appendix A. A summary of the as-extracted dimensions for LW901 to LW905 is provided in Table 1.2.

Table 1.2 Mining geometry of the as-extracted longwalls in Area 9

Location	Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
Area 9	LW901	2028	305	-
	LW902	2153	305	45
	LW903	2297	305	45
	LW904	2038	325	45
	LW905	858	325	54

The mined lengths of the longwalls excluding the installation headings are approximately 9 m shorter than the overall void lengths provided in Table 1.2. The longwall face widths excluding the first workings are approximately 294 m for LW901 to LW903 and 314 m for LW904 and LW905.

The longwalls in Area 9 at Appin Colliery have been mined in the Bulli Seam, from the west towards the east, i.e. towards the main headings. The natural surface and seam levels across LW901 to LW905 are illustrated in Fig. 1.1 and along the centreline of LW905 are illustrated in Fig. 1.2.

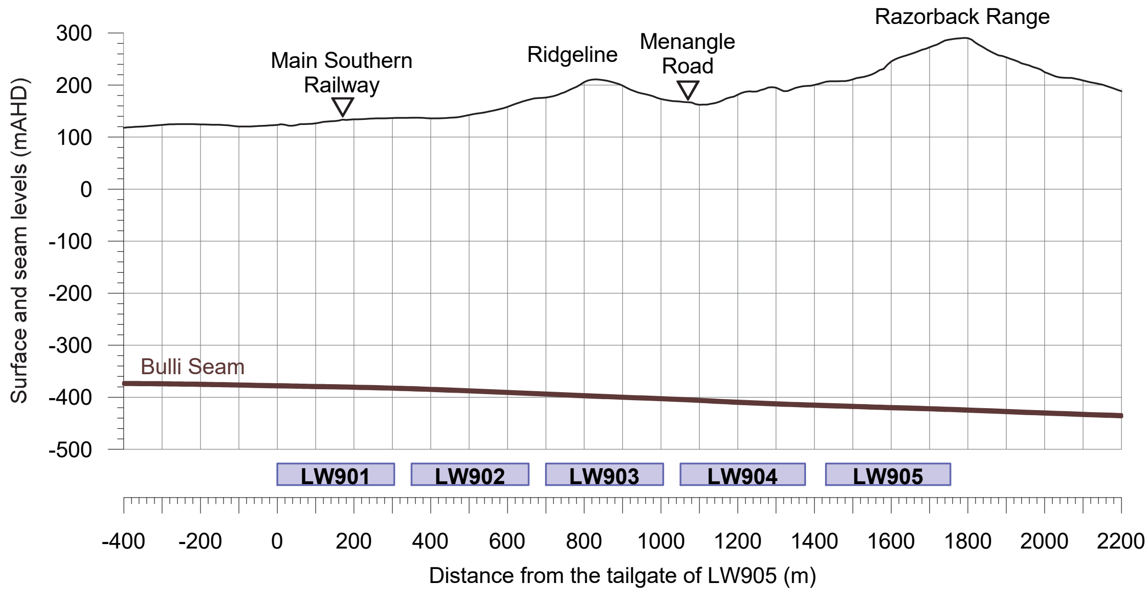

Fig. 1.1 Surface and seam levels across LW901 to LW905

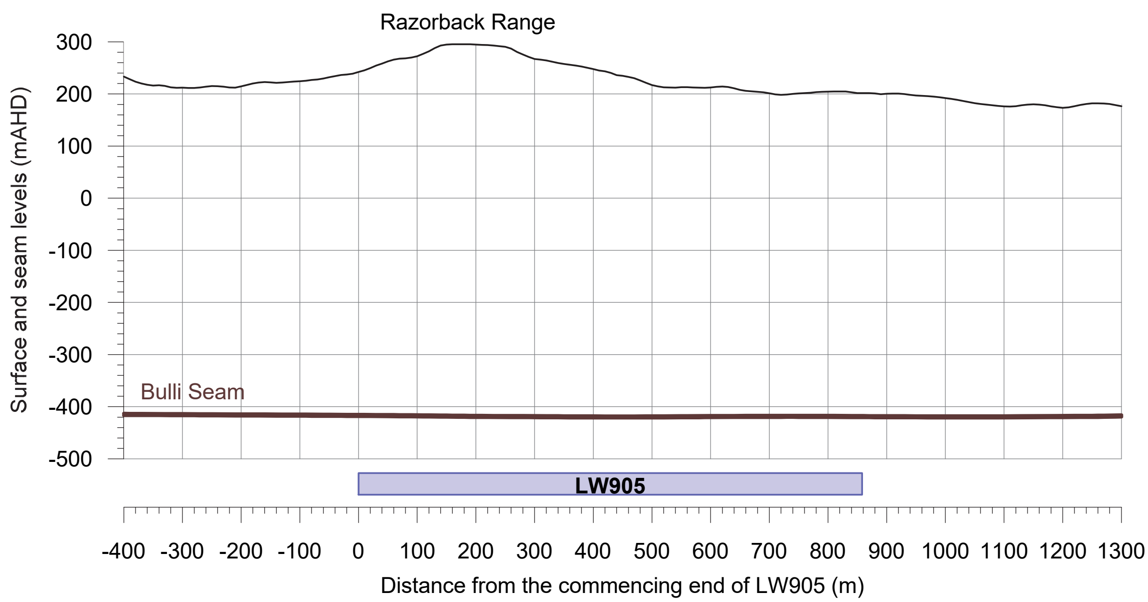

Fig. 1.2 Surface and seam levels along the centreline of LW905

The natural surface above the mining area generally falls from the north towards the south. The natural drainage lines above the western end of LW905 flow into the Nepean River which is more than 1 km south of the longwall tailgate. The drainage lines above the eastern end of LW905 flow into Harris Creek which is more than 600 m east of the finishing end of the longwall. Razorback Range is partially located above the western end of LW905 and the toe of this range extends across the eastern end of this longwall.

The depth of cover to the Bulli Seam directly above LW905 varies between a minimum of 585 m above the tailgate towards the finishing (i.e. eastern) end of the longwall, and a maximum of 715 m above the maingate near the mid-length of the longwall. The seam floor within the mining area generally dips from the south to the north, with an average dip of approximately 2 % or 1 in 50.

The thickness of the Bulli Seam varies between 2.95 m and 3.05 m within the extents of LW905. IMC mined the full thickness of the seam.

1.3. Predicted mine subsidence effects

The predicted mine subsidence effects for LW905 are provided in Report No. MSEC1117 which supported the Extraction Plan Application for LW709 to LW711 and LW905. The predicted conventional subsidence effects have been obtained using the Incremental Profile Method (IPM) based on calibrated prediction curves for Appin Colliery as described in Section 3.6 of Report No. MSEC1117.

A summary of the maximum predicted incremental vertical subsidence, tilt and curvatures due to the mining of LW901 to LW905 is provided in Table 1.3. The values provided in this table are the additional movements due to the mining of each of the longwalls.

Table 1.3 Maximum predicted incremental vertical subsidence, tilt and curvature due to each of LW901 to LW905

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})
LW901	625	4.5	0.04	0.10
LW902	825	6.5	0.08	0.15
LW903	850	6.0	0.06	0.11
LW904	875	6.0	0.06	0.10
LW905	650	4.5	0.04	0.08

A summary of the maximum predicted total vertical subsidence, tilt and curvatures after the mining of LW901 to LW905 is provided in Table 1.4. The values provided in this table are the accumulated movements due to the mining of all longwalls in Area 9.

Table 1.4 Maximum predicted total vertical subsidence, tilt and curvature after the mining of LW901 to LW905

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})
LW901 to LW905	1300	6.5	0.08	0.16

The maximum predicted total vertical subsidence after the mining of LW905 is 1300 mm and it occurs above the eastern end of LW903. The maximum value represents 43 % of the seam thickness of 3.0 m in that location.

The maximum predicted total tilt after the mining of LW905 is 6.5 mm/m (i.e. 0.65 % or 1 in 154). The maximum predicted total curvatures are 0.08 km^{-1} hogging and 0.16 km^{-1} sagging and represent minimum radii of curvature of 13 km and 6 km, respectively.

The predicted conventional (i.e. typical) strains, based on applying a factor of 15 to the predicted conventional curvatures (and rounding to the nearest 0.5 mm/m), are 1.5 mm/m tensile and 2.5 mm/m compressive. However, the measured strains can exceed these conventional values due to irregular movements or localised effects.

The predicted strains (including the potential for non-conventional anomalous movement) for the longwalls in Area 9 were determined using a statistical analysis of ground monitoring data from Appin and other nearby collieries, as described in Section 4.3 of Report No. MSEC1117.

The maximum predicted total strains above the mining area based on the 95 % confidence levels are 1.0 mm/m tensile and 1.6 mm/m compressive. The maximum predicted total strains above the mining area based on the 99 % confidence levels are 1.5 mm/m tensile and 3.3 mm/m compressive.

The predicted valley-related effects along the streams have been determined using the methods outlined in ACARP Research Project No. C9067, which were published in the handbook entitled "*Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems*", issued in September 2002. Details on the ACARP 2002 Prediction Method are provided in the background report entitled "*General Discussion on Mine Subsidence Ground Movements*" which can be obtained from *www.minesubsidence.com*.

2.1. Introduction

The mine subsidence effects due to the mining of LW905 were monitored using ground monitoring lines, ground monitoring points and other systems including the following:

- Main Southern Railway, including monitoring associated with the track, embankments, cuttings, culverts and Douglas Park Station;
- Hawkey Road private extension monitoring line;
- Menangle Road monitoring line;
- Steep slopes monitoring lines (SSD Line and SSE Line only);
- Indara Razorback Complex;
- Nepean River closure lines (Nep X 9I and Nep X 9J Lines only);
- Harris Creek Cliff Line closure lines;
- Blades Bridge monitoring points;
- Far-field monitoring points and Razorback Range 3D;
- Nepean Twin Bridges monitoring points and bridge joint monitoring;
- Moreton Park Road Bridge South monitoring points;
- Global Navigation Satellite System (GNSS) monitoring; and
- ALS / LiDAR surveys.

The locations of the ground monitoring lines and ground monitoring points are shown in Drawing No. MSEC1334-01, in Appendix A. Comparisons between the measured and predicted subsidence effects at these monitoring lines and monitoring points are provided in the following sections. The predicted subsidence effects have been obtained using the IPM based on the calibrated prediction curves for Appin Colliery as described in Section 3.6 of Report No. MSEC1117.

2.2. Main Southern Railway

The Main Southern Railway crosses directly above the previously mined LW901, as shown in Drawings Nos. MSEC1334-01 to MSEC1334-04, in Appendix A. Monitoring associated with the railway includes the:

- Global Navigation Satellite System (GNSS) monitoring along the railway;
- ARTC monitoring line;
- embankment monitoring points;
- cutting monitoring points;
- culvert monitoring points; and
- Douglas Park Station monitoring points.

IMC and the Australian Rail Track Corporation (ARTC) agreed to cease automated track monitoring along the railway during the mining of LW905. GNSS units were, however, installed along the railway to provide a continuous monitoring presence along the railway.

The monitoring results and discussions are provided in weekly subsidence monitoring review reports for the railway (Reports Nos. MSEC1295-R01 to MSEC1295-R30), which were issued during the mining of LW905, between September 2022 and April 2023.

A summary of the monitoring results for the Main Southern Railway is provided in the following sections.

2.2.1. GNSS monitoring and ARTC monitoring line

The ARTC monitoring line follows the Main Southern Railway directly above the previously mined LW901. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the ARTC monitoring line during the mining of LW905 is provided in Table 2.1.

Table 2.1 Survey dates for the ARTC monitoring line during LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start and end of LW905 and monthly long bay surveys during LW905	26 September 2017 (end of LW901) 20 May 2019 (end of LW902) 19 May 2021 (end of LW903) 16 August 2022 (end of LW904) 4 April 2023 (end of LW905)	None

The measured and predicted incremental vertical subsidence along the ARTC monitoring line due to the mining of LW905 only are illustrated in Fig. 2.1. Measurements from the GNSS units along the rail corridor are also plotted in the figure.

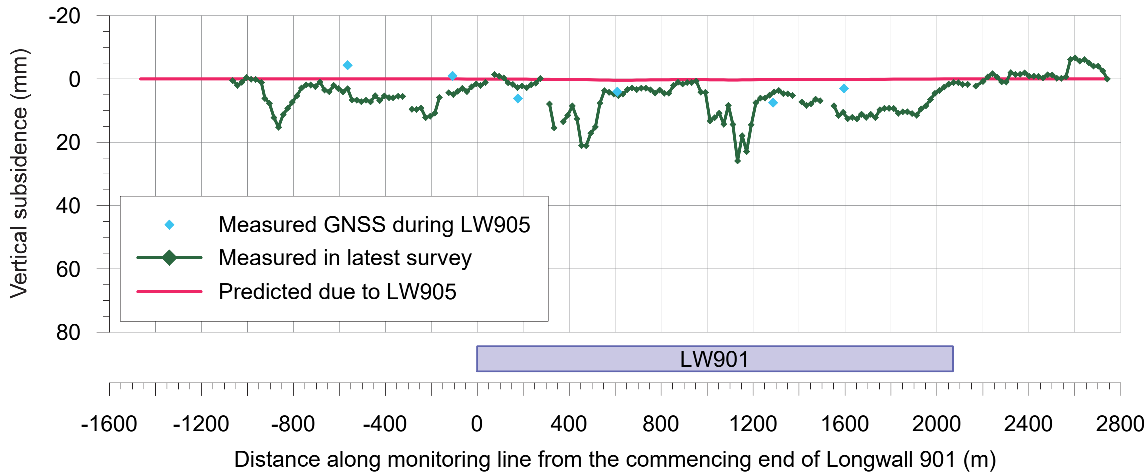

Fig. 2.1 Measured and predicted incremental vertical subsidence along the ARTC line due to the mining of LW905 only

The maximum measured and predicted incremental vertical subsidence occur directly above the extracted LW901 where the monitoring line is located closest to the active LW905. There is some variability in the measured profile which could be partly due to localised movements of the survey marks, mostly associated with railway embankments. Low-level uplift was observed at the eastern end of the monitoring line; however, this movement is in the order of survey tolerance for absolute level, or may reflect swelling of soils following heavy rainfall events.

There was a reasonable correlation between changes in height measured by the GNSS units and the results from the ground surveys.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strain for the ARTC monitoring line is provided in Table 2.2. The values are the maximum additional movements due to the mining of LW905 only.

Table 2.2 Maximum measured and predicted incremental subsidence effects for the ARTC monitoring line due to the mining of LW905 only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm)	Maximum incremental tensile strain (mm/m)	Maximum incremental compressive strain (mm/m)
Measured	26	0.6	0.2	0.2
Predicted	< 20	< 0.5	*- Refer to discussions below -*	

The accuracies of the measured relative eastings, northings and levels along the ARTC monitoring line are in the order of ±5 mm. The accuracies of the measured absolute eastings, northings and levels are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum measured incremental vertical subsidence of 26 mm is very small and within the same order of magnitude as the prediction of less than 20 mm.

The maximum measured incremental tilt of 0.6 mm/m is greater than the maximum predicted value of less than 0.5 mm/m. However, the greatest measured tilts are partly due to localised movements of the survey marks, mostly associated with railway embankments. Away from these locations, the measured macro/global tilt is similar to that predicted.

The maximum measured strains are 0.2 mm/m tensile and 0.2 mm/m compressive which are similar to the order of survey tolerance. That is, the strains were not measurable outside of the survey tolerance.

The vectors of horizontal movement along the ARTC monitoring line are shown in Drawing No. MSEC1334-04. Discussions on these movements have been included in Section 2.10.

2.2.2. Embankment monitoring points

Embankment monitoring points in Appin Area 9 are located at railway chainages 74.7 km, 75.7 km and 76.2 km. The embankment at 74.7 km is located directly above the previously mined LW901 and the embankments at 75.7 km and 76.2 km are located at minimum distances of approximately 0.3 km and 0.7 km, respectively, to the west of the previously mined LW902.

The subsidence effects at the embankments were measured by IMC using 3D ground monitoring lines along the crests and toes. Only minor differential vertical and horizontal movements were measured along the embankments, typically similar to the order of survey tolerance. Some pegs were lost or disturbed following rainfall events or due to livestock or other activities. No adverse impacts were observed along the embankments.

2.2.3. Cutting monitoring points

Cuttings in Appin Area 9 are located at railway chainages 74.0 km and 75.3 km. Both cuttings are located directly above the previously mined LW901. The cuttings at 74.0 km and 75.3 km are located at minimum distances of approximately 200 m and 50 m to the south of the previously mined LW902.

The subsidence effects at the cuttings were measured by IMC using 3D ground monitoring lines along their crests and toes. Minor changes were observed during the mining of LW905, with no adverse impacts observed on the cuttings themselves. Some pegs were lost or disturbed following rainfall events.

2.2.4. Culvert monitoring points

The culvert monitoring points in Appin Area 9 are located at the crossing of Harris Creek and on the embankments at railway chainages 74.7 km and 75.7 km. The culvert at 74.7 km is located directly above the previously mined LW901 and the culvert at 75.7 km is located at a distance of approximately 400 m to the west of the previously mined LW902.

The subsidence effects at the culvert monitoring points were measured by IMC using 3D ground monitoring lines along their main axes. Only minor differential vertical and horizontal movements were measured along the culverts, typically similar to the order of survey tolerance.

2.2.5. Douglas Park Station monitoring points

Douglas Park Station is located immediately to the east of the finishing end of the previously mined LW901 and south of the finishing end of the previously mined LW902. The subsidence effects at the station platform were measured by IMC using 3D ground monitoring points along its length. Only minor differential vertical and horizontal movements were measured along the platform, typically similar to the order of survey tolerance.

2.3. Hawkey Road private extension monitoring line

The Hawkey Road private road extension monitoring line is located to the east of LW905 at a minimum distance of approximately 25 m from the longwall finishing end. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Hawkey Road private extension monitoring line during LW905 is provided in Table 2.3.

Table 2.3 Survey dates for the Hawkey Road private extension monitoring line during LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly 3D and fortnightly 2D surveys during LW905 and final survey after completion of LW905	28 March 2022 (base survey) 4 May 2022, 29 September 2022, then approximate monthly surveys to 19 January 2023, then fortnightly surveys to 17 March 2023 and then 30 March 2023 (end of LW905)	None

The measured incremental vertical subsidence along the Hawkey Road private extension monitoring line due to the mining of LW905 only is illustrated in Fig. 2.2. Positive values are net downward movements and negative values are net uplift.

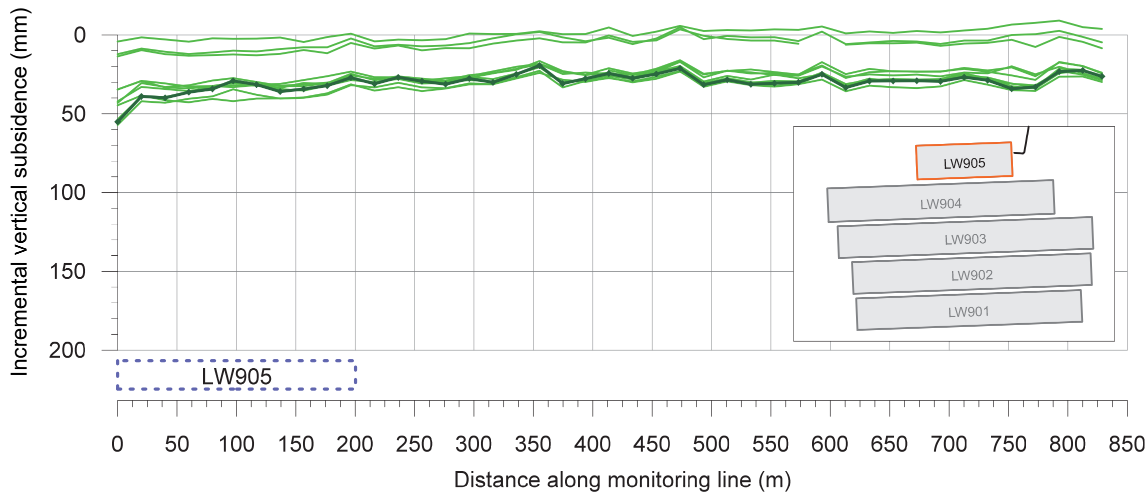

Fig. 2.2 Measured incremental vertical subsidence along the Hawkey Road private extension monitoring line due to the mining of LW905 only

The measured incremental vertical subsidence along the Hawkey Road private extension monitoring line due to the mining of LW905 is 55 mm at Mark HX01 nearest to the longwall. The measured vertical subsidence is less than the maximum predicted incremental vertical subsidence of 75 mm.

The maximum measured strains along the Hawkey Road extension private monitoring line are 0.5 mm/m tensile between Marks HX31 and HX32 and 0.6 mm/m compressive between Marks HX39 and HX40. The measured strains are likely to include components due to survey tolerance in the order of ±0.3 mm/m. Only low-level strains were predicted along this monitoring line because it is located outside the mining area.

The 95th percentiles of the measured incremental strains along the Hawkey Road extension private monitoring line are 0.4 mm/m tensile and 0.4 mm/m compressive. The maximum predicted strains based on the 95 % confidence levels (i.e. considering the potential for anomalous movement) outside the mining area are 0.6 mm/m tensile and 0.4 mm/m compressive. The measured strains based on the 95th percentiles, therefore, are the same or less than the predicted strains based on the 95 % confidence levels.

It is considered that the movements measured along the Hawkey Road private extension monitoring line are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

The vectors of horizontal movement along the Hawkey Road private extension monitoring line are shown in Drawing No. MSEC1334-04. Discussions on these movements have been included in Section 2.10.

2.4. Menangle Road monitoring line

The Menangle Road monitoring line follows the alignment of that road and it crosses above the western end of LW903 and above the eastern end of LW904. The road and monitoring line are located at a minimum distance of 150 m south of the finishing end of LW905 at its closest point.

The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Menangle Road monitoring line during LW905 is provided in Table 2.4.

Table 2.4 Survey dates for the Menangle Road monitoring line during LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly 3D and weekly 2D surveys during LW905 and final survey after completion of LW905	3 May 2018 (base survey) 16 May 2019 (end of LW902) 13 May 2021 (end of LW903) 11 August 2022 (end of LW904) 11 October 2022, 2 November 2022, then approximate weekly surveys to 27 March 2023 and then 3 April 2023 (end of LW905)	None

The measured and predicted total vertical subsidence along the Menangle Road monitoring line due to the mining of LW902 to LW905 are illustrated in Fig. 2.3. The accumulated movements measured during the mining of LW902, LW903, LW904 and LW905 are shown by the blue, khaki, orange and green lines, respectively.

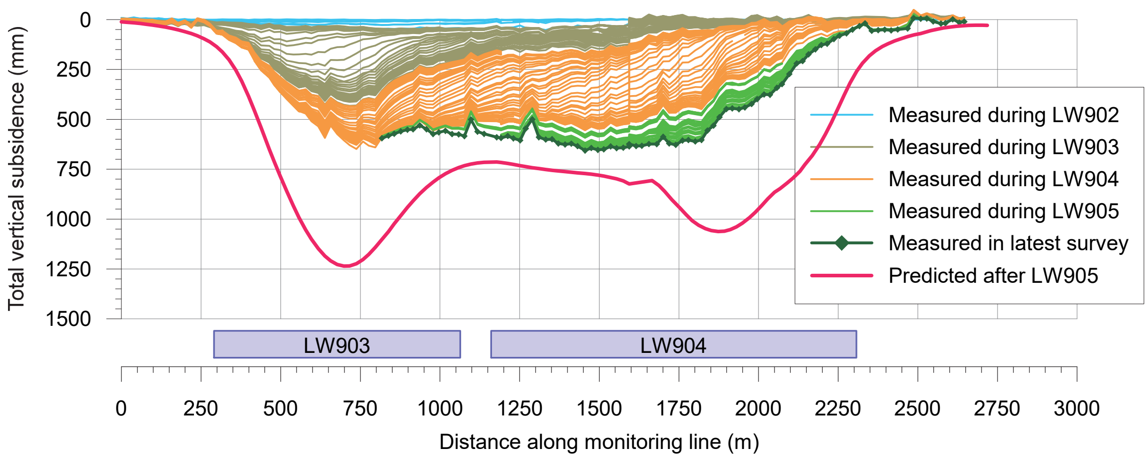

Fig. 2.3 Measured and predicted total vertical subsidence along the Menangle Road monitoring line due to the mining of LW902 to LW905

The maximum measured and predicted total vertical subsidence occurs directly above the previously mined LW903 and LW904. Low-level additional subsidence was measured above LW904 due to the mining of LW905. Only very low-level subsidence was measured outside the mining area, which is less than that predicted.

A summary of the maximum measured and predicted total vertical subsidence, tilt and strain for the Menangle Road monitoring line is provided in Table 2.5. The values are the maximum accumulated movements due to the mining of LW902 to LW905.

Table 2.5 Maximum measured and predicted total subsidence effects for the Menangle Road monitoring line due to the mining of LW902 to LW905

Type	Maximum total vertical subsidence (mm)	Maximum total tilt (mm)	Maximum total tensile strain (mm/m)	Maximum total compressive strain (mm/m)
Measured	656	4.4	1.6	1.4
Predicted	1250	4.5	*- Refer to discussions below -*	

The accuracies of the measured relative eastings, northings and levels along the Menangle Road monitoring line are in the order of ±5 mm. The accuracies of the measured absolute eastings, northings and levels are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum measured total vertical subsidence of 656 mm is approximately half and the maximum predicted value of 1250 mm. The maximum measured tilt of 4.4 mm/m is similar to but slightly less than the maximum predicted value of 4.5 mm/m. The maximum measured tilt is due to the localised bump in the subsidence profile above the chain pillar between LW903 and LW904 and, therefore, it does not represent the overall/macro movements above the mining area.

The measured total strain along the Menangle Road monitoring line due to the mining of LW902 to LW905 is illustrated in Fig. 2.4. The movements measured during the mining of LW902, LW903 and LW905 are shown by the blue, khaki, orange and green lines, respectively.

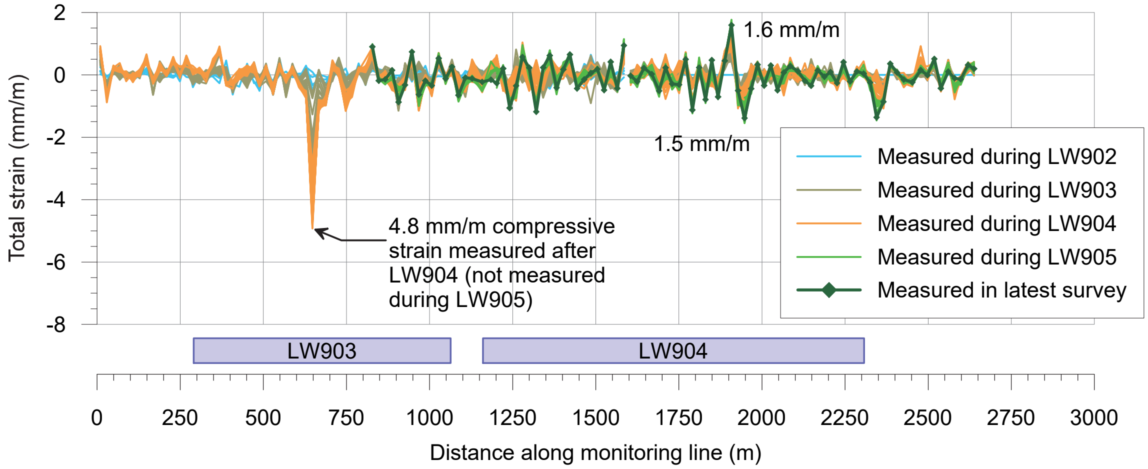

Fig. 2.4 Measured total strain along the Menangle Road monitoring line due to the mining of LW902 to LW905

The maximum measured total strains along the section of road monitored during LW905 are 1.6 mm/m tensile and 1.4 mm/m compressive. The monitoring line previously measured compressive strain of 4.8 mm/m after LW904; however, that section of road was not measured during LW905. The maximum predicted total conventional strains, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.5 mm/m tensile and 2.5 mm/m compressive.

The maximum measured total tensile strain after LW905 of 1.6 mm/m is similar to but slightly greater than the maximum predicted conventional strain of 1.5 mm/m. The maximum measured total compressive strain for LW905 of 1.6 mm/m is less than the maximum predicted conventional strain of 2.5 mm/m.

The 95th percentiles for the total strains measured at any time during the mining of LW902 to LW905 for the survey bays located directly above the mining area are 0.8 mm/m tensile and 1.2 mm/m compressive. The maximum predicted total strains based on the 95 % confidence levels (i.e. considering the potential for anomalous movement) above the mining area are 1.0 mm/m tensile and 1.6 mm/m compressive. The measured total strains due to the mining of LW902 to LW905 based on the 95th percentiles, therefore, are less than the predicted strains based on the 95 % confidence levels.

It is considered that the movements measured along the Menangle Road monitoring line are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

The vectors of horizontal movement along the Menangle Road monitoring line are shown in Drawing No. MSEC1334-04. Discussions on these movements have been included in Section 2.10.

2.5. Steep slopes monitoring lines

The steep slopes monitoring lines are located partly above LW904 and they extend up the lower part of Razorback Range. Only the SSD and SSE monitoring lines were surveyed during the mining of LW905 and they are located to the west and to the south, respectively, of this longwall.

The steep slope monitoring lines were measured using 2D and 3D survey techniques. A summary of the survey dates for the SSD and SSE monitoring lines during LW905 is provided in Table 2.6.

Table 2.6 Survey dates for the SSD and SSE monitoring lines during LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly 3D and weekly 2D surveys during LW905 and final survey after completion of LW905	27 April 2021 (base survey) 18 August 2022 (end of LW904) 12 October 2022, then approximate weekly surveys to 2 February 2023 and then 3 April 2023 (end of LW905)	None

The measured incremental vertical subsidence for the SSD and SSE monitoring lines are illustrated in Fig. 2.5 and Fig. 2.6, respectively. The profiles represent the additional movements due to the mining of LW905 only.

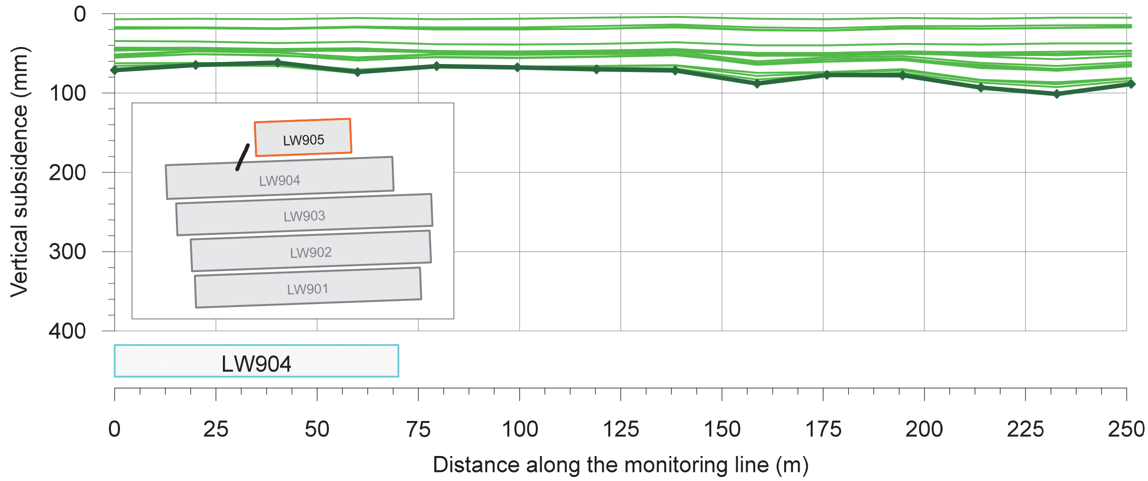

Fig. 2.5 Measured incremental vertical subsidence along the SSD monitoring line due to the mining of LW905 only

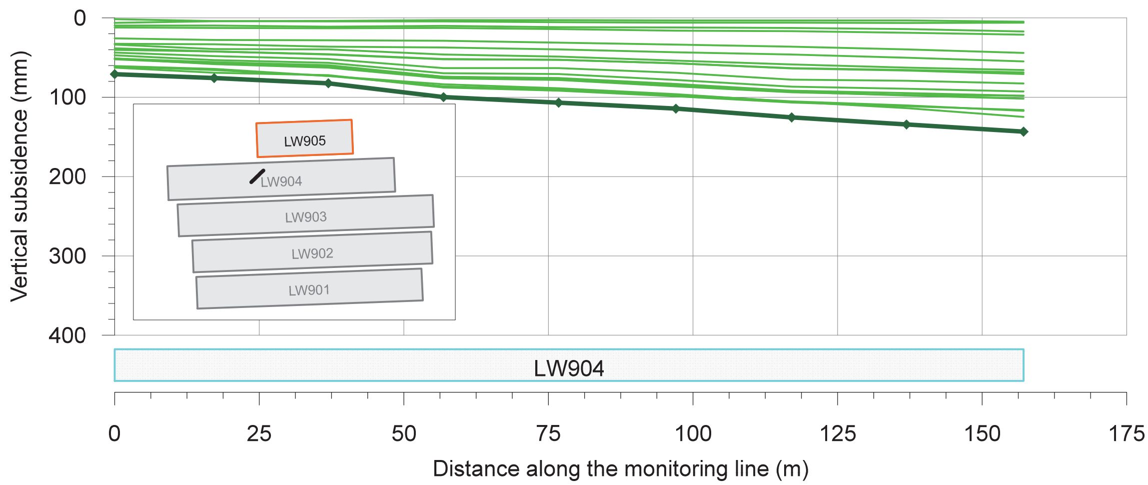

Fig. 2.6 Measured incremental vertical subsidence along the SSE monitoring line due to the mining of LW905 only

The maximum measured values of incremental vertical subsidence are 101 mm for the SSD Line and 143 mm for the SSE Line. Only low-level vertical subsidence was measured along the monitoring lines as they are located outside the extent of LW905.

The measured vertical subsidence is similar to or greater than the maximum predicted incremental vertical subsidence of 100 mm. However, the measured incremental subsidence is within ±50 mm of the predicted incremental vertical subsidence which is the order of accuracy of the prediction method for monitoring lines located outside the extents of the active longwall.

The maximum measured incremental strains for the SSD and SSE monitoring lines are 0.5 mm/m tensile and 0.7 mm/m compressive. The maximum measured strains occur where the monitoring lines are located directly above LW904 and they are within the range expected based on conventional movements.

It is considered that the movements measured along the SSD and SSE monitoring line are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

2.6. Indara Razorback Complex

The Indara Razorback Complex is located above the maingate of LW905. The complex was monitored using a north-south orientated 3D ground monitoring line and 3D monitoring points on the tower structure. A summary of the survey dates for the ground monitoring line and points during LW905 is provided in Table 2.7.

Table 2.7 Survey dates for the Indara Razorback Complex monitoring line and points during LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly 3D during LW905, then weekly 3D when mining 100 m from the complex until 400 m beyond the complex and then final survey after completion of LW905	19 January 2022 (base survey), 15 July 2022, 29 September 2022, then approximate monthly surveys to 11 November 2022, then approximate weekly surveys to 27 March 2023 (end of LW905)	None

The measured and predicted incremental vertical subsidence along the Indara Razorback Complex is illustrated in Fig. 2.7. The profiles represent the additional movements due to the mining of LW905 only.

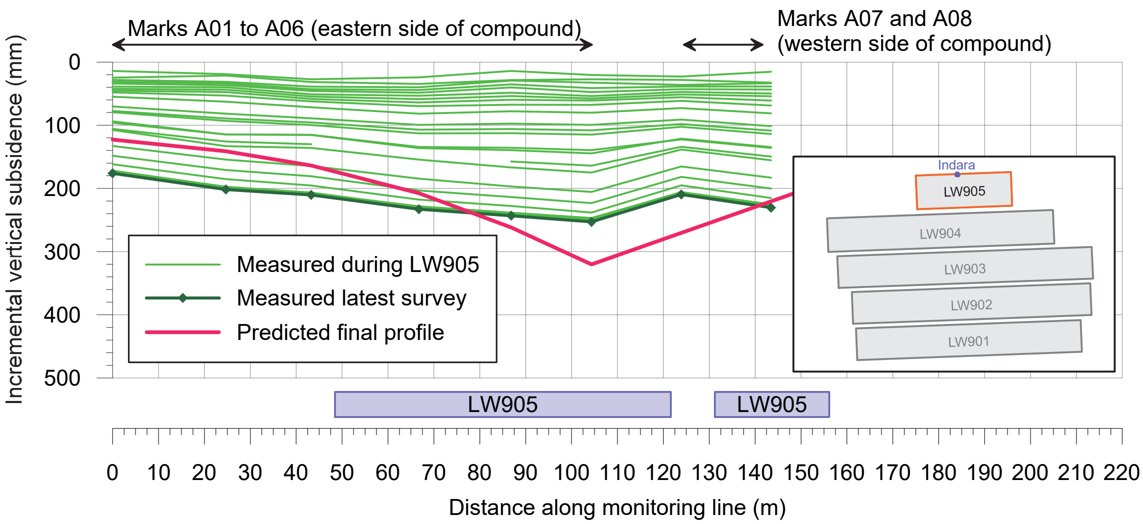

Fig. 2.7 Measured and predicted incremental vertical subsidence along the Indara Razorback Complex monitoring line due to the mining of LW905

The maximum measured and predicted incremental vertical subsidence occurs directly above LW905. The measured vertical subsidence outside LW905 is slightly greater than predicted; however, it is within ±50 mm which is the order of the accuracy of the prediction method outside the active longwall.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strain for the Indara Razorback Complex monitoring line is provided in Table 2.8. The values are the maximum additional movements due to the mining of LW905 only.

Table 2.8 Maximum measured and predicted incremental subsidence effects for the Indara Razorback Complex monitoring line due to the mining of LW905

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm)	Maximum incremental tensile strain (mm/m)	Maximum incremental compressive strain (mm/m)
Measured	253	1.1	0.8	0.8
Predicted	320	3.5	*- Refer to discussions below -*	

The accuracies of the measured relative eastings, northings and levels along the Indara Razorback Complex monitoring line are in the order of ±5 mm. The accuracies of the measured absolute eastings, northings and levels are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum measured incremental vertical subsidence of 253 mm is less than the maximum predicted value of 320 mm. The maximum measured tilt of 1.1 mm/m is also less than the maximum predicted value of 3.5 mm/m.

The measured incremental strain along the Indara Razorback Complex monitoring line is illustrated in Fig. 2.8. The profiles represent the additional movements due to the mining of LW905 only.

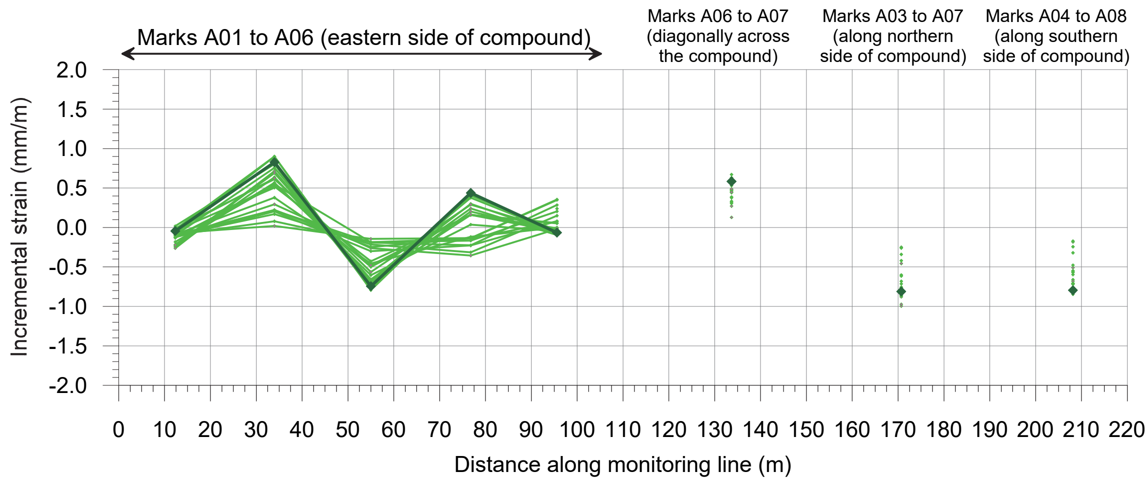

Fig. 2.8 Measured incremental strain along the Indara Razorback Complex monitoring line due to the mining of LW905

The maximum measured incremental strains along the monitoring line are 0.8 mm/m tensile and 0.8 mm/m compressive. The maximum measured strains occur where the monitoring line is located directly above LW905 and they are within the range expected based on conventional movements.

It is considered that the movements measured along the Razorback Range Complex monitoring line are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

2.7. Nepean River closure lines

The Nepean River is located approximately 1.8 km south of the tailgate of LW905 at its closest point. The Nepean River 9A to 9J closure lines (Nep X 9A-Line to Nep X 9J-Line) are 2D monitoring lines across the Nepean River Valley, apart from the Nep X 9E-Line which is across Allens Creek near the confluence with the Nepean River. The monitoring lines each comprise two survey prisms on either side of the valley, with lengths varying between 110 m and 225 m.

There were no monitoring commitments for the Nepean River monitoring lines during the mining of LW905. However, the Nepean Nep X 9I-Line and Nep X 9J-Line were monitored as part of the HCCL monitoring program. The monitoring frequency for the Nep X 9I-Line and Nep X 9J-Line during the mining of LW905 was the same as the HCCL closure lines, which are summarised in Table 2.9.

The development of the measured incremental closure at the Nep X 9I-Line and 9J-Line during the mining of LW905 is illustrated in Fig. 2.9. The profiles represent the additional movements due to the mining of LW905 only.

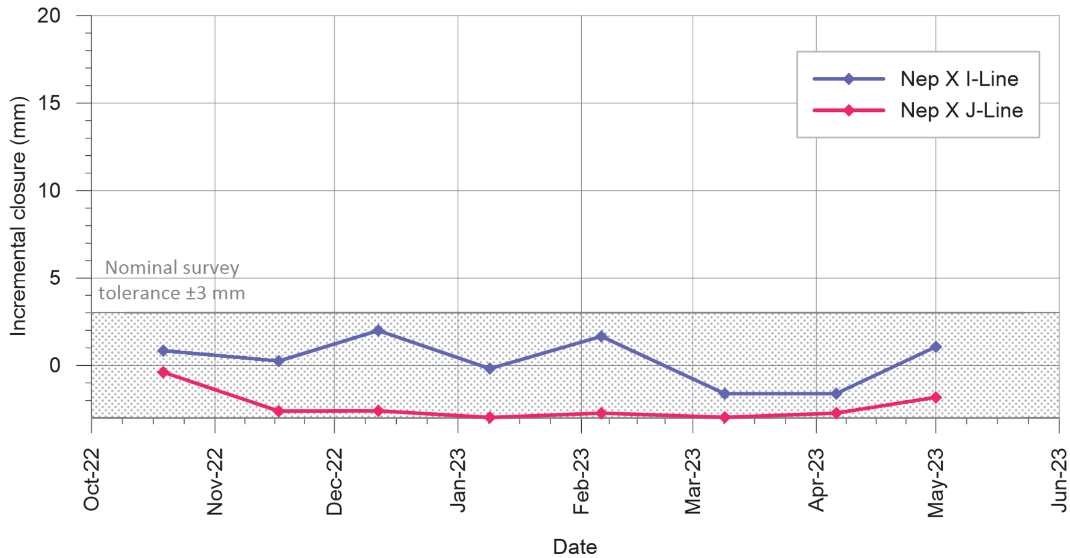

Fig. 2.9 Development of measured incremental closure at the Nep X 9I-Line and 9J-Line during the mining of LW905

The measured incremental movements were in the order of survey tolerance of ±3 mm. That is, the mining-related movements were not measurable outside of the survey tolerance. No measurable movements were predicted due to the mining of LW905 due to the distance from that longwall.

It is considered that the movements measured using the Nepean River closure lines are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

2.8. Harris Creek Cliff Line closure lines

The Harris Creek Cliff Line (HCCL) is located more than 2 km south-east of the finishing end of LW905 at its closest point. The HCCL A-Line to E-Line are 2D monitoring lines across the valley of Harris Creek. The monitoring lines each comprise two survey prisms on either side of the valley, with lengths varying between 60 m and 110 m. A summary of the survey dates for the HCCL closure lines during LW905 is provided in Table 2.9.

Table 2.9 Survey dates for the HCCL closure lines during LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Base survey prior to the commencement of LW905; monthly surveys during mining; and final survey after completion of LW905	10 April 2018 (end of LW901) 7 June 2019 (end of LW902) 11 May 2021 (end of LW903) 19 September 2022 (end of LW904) 19 October 2022 and then approximate monthly surveys to 1 May 2023 (end of LW905)	Monthly surveys until Technical Committee agree to cessation of monitoring

The development of the measured incremental movements for the HCCL closure lines due to the mining of LW905 is illustrated in Fig. 2.10. Positive values represent net closure and negative values represent net opening.

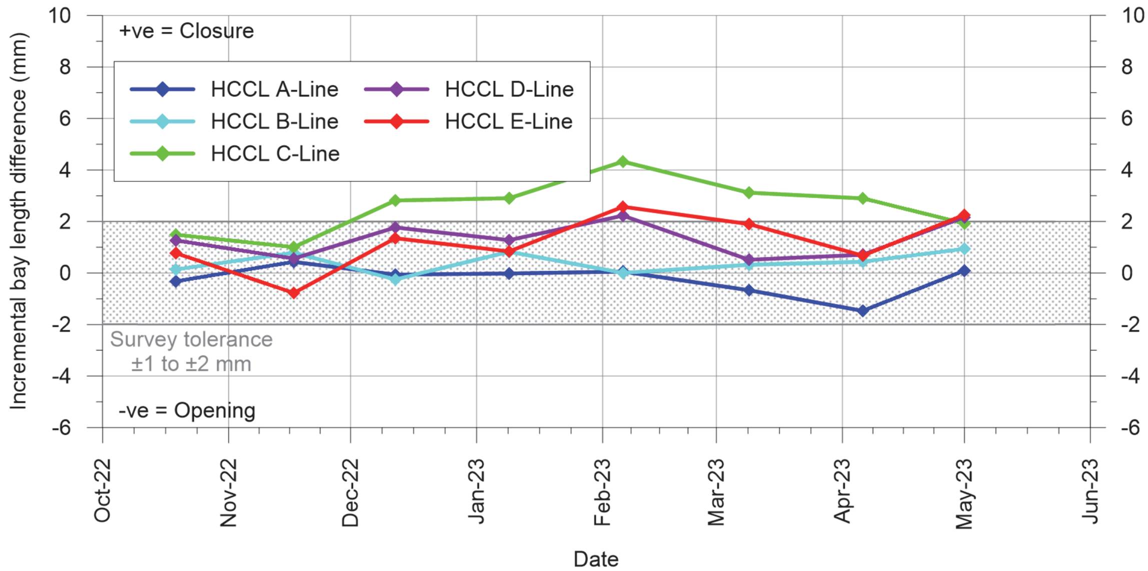

Fig. 2.10 Development of measured incremental movements for the HCCL closure lines due to the mining of LW905

The measured incremental movements in the final survey for LW905 are ±2 mm or less. These movements are therefore in the order of the nominal tolerance for survey accuracy and environmental effects. That is, the mining-related movements are not measurable outside of the nominal tolerance.

There are transient movements during the mining of LW905 that are greater than ±2 mm that are likely to include survey accuracy and environmental effects. The HCCL C-Line measured incremental closure of up to 4 mm in early-February 2023 which then reduced to 2 mm in early-May 2023. These movements are consistent with environmental effects where natural valley closure develops during and shortly after the summer period and natural valley opening develops during and shortly after the winter period.

The development of the measured total closure for the HCCL closure lines due to the mining of LW901 to LW905 is illustrated in Fig. 2.11. Positive values represent net closure and negative values represent net opening.

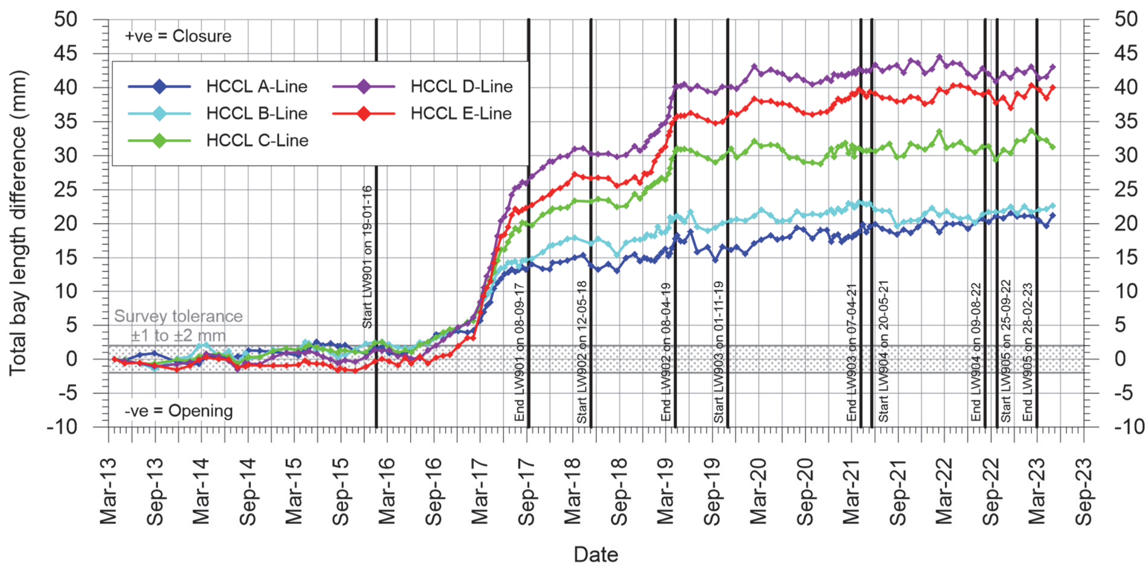

Fig. 2.11 Development of measured total closure for the HCCL due to the mining of LW901 to LW905

A summary of the measured and predicted total closure movements for each of the HCCL closure lines is provided in Table 2.10. The values are the maximum accumulated movements due to the mining of LW901 to LW905.

Table 2.10 Measured and predicted total closure for the HCCL closure lines due to LW901 to LW905

Location	Measured total closure (mm)	Predicted total closure (mm)
HCCL A-Line	21	50
HCCL B-Line	23	
HCCL C-Line	31	
HCCL D-Line	43	
HCCL E-Line	40	

The maximum measured total closure due to the mining of LW901 to LW905 is 43 mm at the HCCL D-Line. The greatest closures have developed towards the southern end of the cliffline (i.e. towards the confluence with the Nepean River) and generally reduce towards the northern end. The total closure movements measured after the completion of LW905 are less than the maximum predicted value of 50 mm.

It is considered that the movements measured using the HCCL closure lines are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

2.9. Blades Bridge monitoring points

Blades Bridge crosses Harris Creek and it is located more than 2 km south of the finishing end of LW905 at its closest point. The horizontal distance across Blades Bridge has been measured using two prisms fixed to the bridge abutments, located on its northern side. A summary of the survey dates for Blades Bridge during LW905 is provided in Table 2.11.

Table 2.11 Survey dates for Blades Bridge during LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Base survey prior to the commencement of LW905; monthly surveys during mining; and final survey after completion of LW905	11 May 2018 (end of LW901) 7 June 2019 (end of LW902) 11 May 2021 (end of LW903) 19 September 2022 (end of LW904) 19 October 2022 and then approximate monthly surveys to 1 May 2023 (end of LW905)	Monthly surveys until Technical Committee agree to cessation of monitoring

The measured incremental movement at Blades Bridge due to the mining of LW905 only is illustrated in Fig. 2.12. The measured movement at the nearby HCCL A-Line is also shown in this figure for comparison.

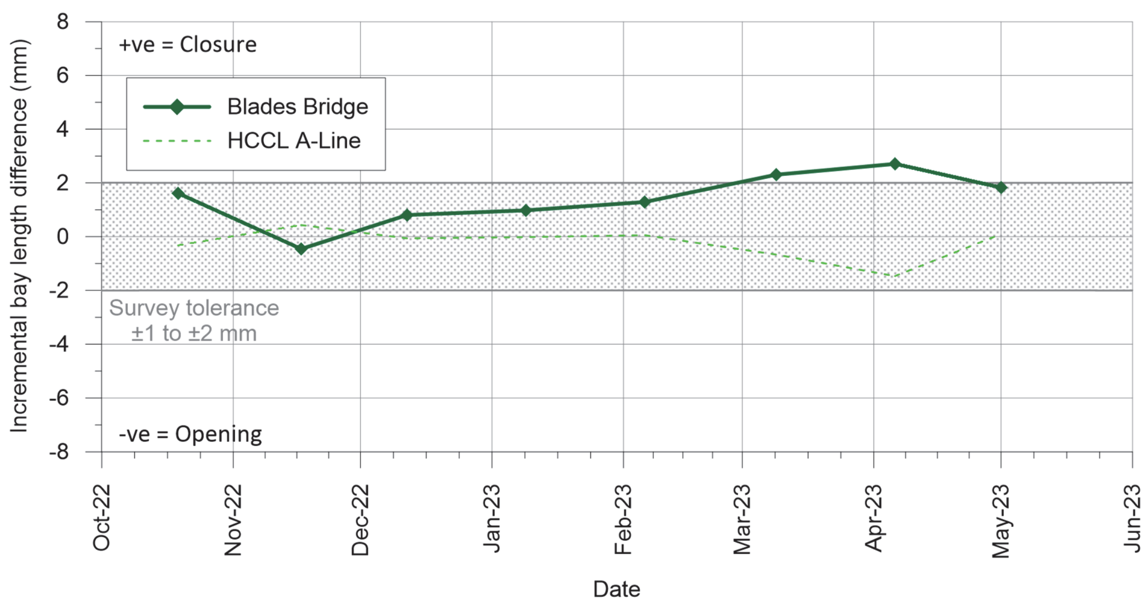

Fig. 2.12 Measured incremental closure at Blades Bridge due to the mining of LW905 only

The measured incremental closure at Blades Bridge due to the mining of LW905 only is +2 mm (closure). The final incremental movement at the completion of LW905 is similar the order of survey tolerance and, therefore, it is not measurable.

It is considered that the movements measured using the Blades Bridge monitoring line are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

2.10. Far-field monitoring points

The far-field horizontal movements in Area 9 have been measured by IMC using the Appin Area 9 (AA9) far-field marks, Razorback Range (3D), Menangle Road, Hawkey Road, HCCL, Indara Razorback Complex and Steep Slopes monitoring lines.

The survey dates for the AA9 far-field marks during the mining of LW905 are provided in Table 2.12. The survey dates for the ARTC monitoring line are provided in Sections 2.2.

Table 2.12 Survey dates for the AA9 far-field marks for LW905

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Base survey prior to the commencement of LW905; monthly surveys during mining; and final survey after completion of LW905	12 September 2017 (end of LW901) 2 May 2019 (end of LW902) 7 May 2021 (end of LW903) 19 August 2022 (end of LW904) 11 November 2022 and then monthly surveys to 6 April 2023 (end of LW905)	None

The measured incremental horizontal movement vectors for the AA9 far-field marks and the Menangle Road, Hawkey Road, HCCL, Indara Razorback Complex, Razorback Range and Steep Slopes monitoring lines are shown in Drawing No. MSEC1334-04. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±10 mm.

The vectors of incremental horizontal movement are generally orientated towards the mining area. The greatest movements occur directly above the mining area and along Razorback Range to the north of the mining area.

A comparison between the measured incremental far-field horizontal movements due to the mining of LW905 and those measured elsewhere in the Southern Coalfield is provided in Fig. 2.13. The x-axis represents the distance from the active longwall.

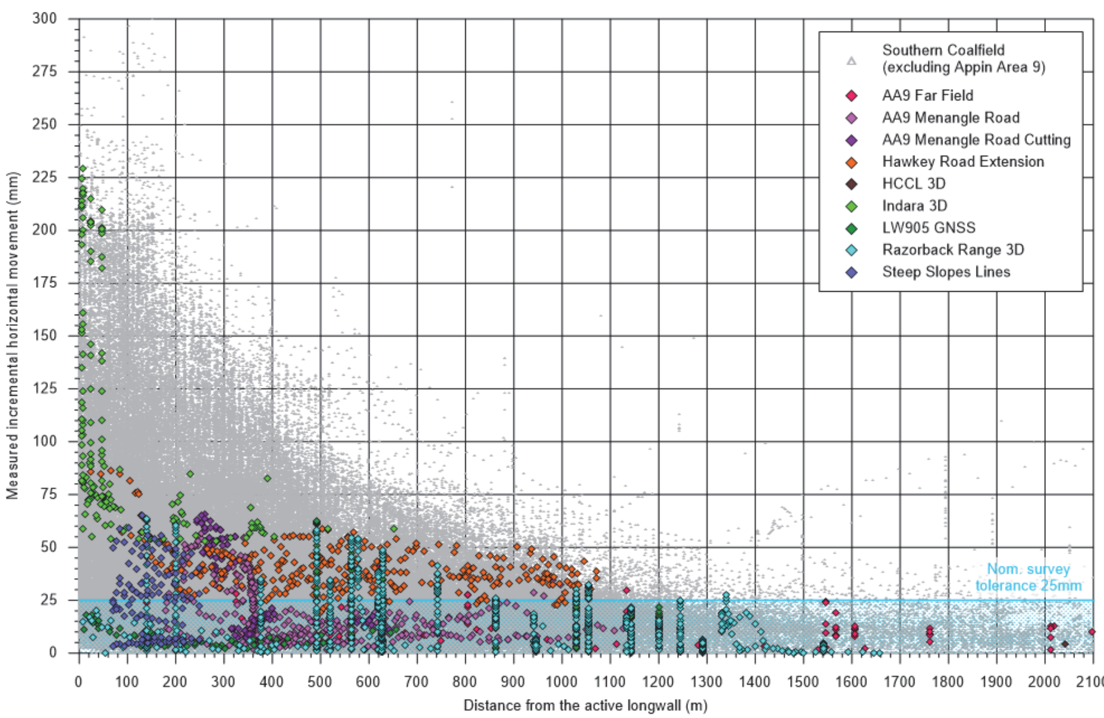

Fig. 2.13 Measured incremental far-field horizontal movements due to the mining of LW905

The measured incremental horizontal movements due to the mining of LW905 (i.e. coloured diamonds in Fig. 2.13) are within the range of movements that have been measured elsewhere in the Southern Coalfield (i.e. grey diamonds in that figure) at similar distances from the active longwall.

The greatest incremental far-field horizontal movements were measured at the Indara 3D monitoring points that were located adjacent to the maingate of LW905. The maximum measured incremental movement outside the extent of LW905 was 230 mm.

Elsewhere, the measured incremental far-field horizontal movements were less than 100 mm. The movements measured at distances greater than 1.1 km from LW905 were typically less than 25 mm and therefore were in the order of survey tolerance.

The incremental far-field horizontal movements due to the mining of LW905 are within the range of movements measured elsewhere in the Southern Coalfield at similar distances from the active longwall.

It is considered that the movements measured using the 3D monitoring points are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

2.11. Nepean Twin Bridges monitoring points

The Nepean Twin Bridges are located approximately 2.5 km southeast of the finishing end of LW905. These bridges experienced far-field movements due to the mining in Appin Area 9 and the concurrent mining in the adjacent Appin Area 7. The monitoring associated with the Nepean Twin Bridges included:

- absolute 3D monitoring points;
- relative 3D monitoring points;
- bridge joint monitoring; and
- visual monitoring.

Descriptions of the monitoring results are provided in the following sections.

2.11.1. Absolute 3D monitoring points

The absolute 3D horizontal movements at the Nepean Twin Bridges have been monitored at Marks DPBN and DPBS, which are located at the northern and southern ends, respectively, of the twin bridges. These marks were measured as part of the far-field monitoring, as described in Section 2.10.

The absolute horizontal movements at Marks DPBN and DPBS have been measured since 15 October 2007 during the mining in Appin Area 7 and during the mining of LW901 to LW905 in Area 9. The development of total horizontal movements for these marks, plotted from the start of April 2014, is shown in Fig. 2.14.

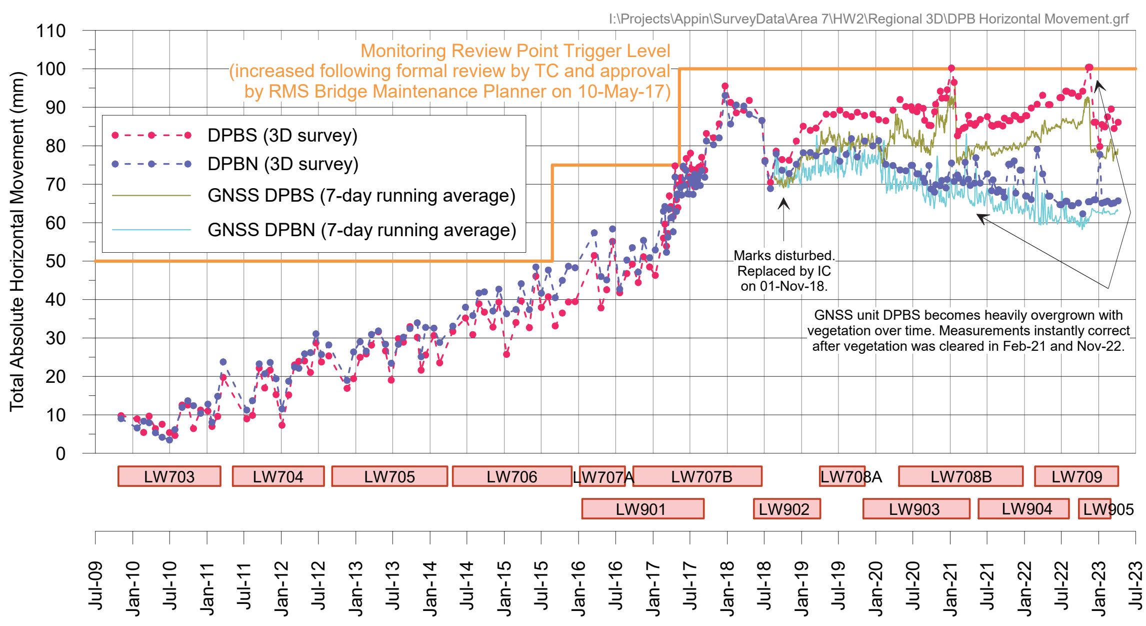

Fig. 2.14 Measured total absolute movements at Marks DPBN and DPBS due to the concurrent mining in Appin Areas 7 and 9

Global Navigation Satellite System (GNSS) units were installed at the ends of the Nepean Twin Bridges in late 2018 and they replaced the fixed survey marks DPBN and DPBS. The results have been overlaid with absolute 3D ground surveys in Fig. 2.14. Greater variation was initially observed at DPBS. A site inspection found that the results were influenced by heavy vegetation growth, which, when removed, returned readings to previously observed trends.

The vectors of incremental horizontal movement at Marks DPBN and DPBS are shown in Drawing No. MSEC1334-04, in Appendix A. The measured incremental horizontal movements at Marks DPBN and DPBS, at the completion of LW905, are 3 mm and 13 mm, respectively. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of measurement tolerance for absolute position of ±20 mm. The orientations of the vectors are therefore not reliable since the magnitudes are not measurable.

The absolute horizontal movements at Marks DPBN and DPBS remained below the Monitoring Review Point Trigger, as shown in Fig. 2.14. A summary of the maximum measured absolute horizontal movements at Marks DPBN and DPBS, measured on 6 April after the completion of LW905, is provided in Table 2.13.

Table 2.13 Measured absolute movements and trigger for the Nepean Twin Bridges

Location	Maximum measured absolute horizontal movement (mm)	Level 1 Trigger (mm)
Marks DPBN and DPBS	86	100

The maximum measured absolute horizontal movement at Marks DPBN and DPBS was less than the Level 1 Trigger at the completion of LW905.

The 2D horizontal distance across the Nepean River valley at the Nepean Twin Bridges has also been measured using the Marks DPBN and DPBS. The measured total valley closure at the Nepean Twin Bridges is illustrated in Fig. 2.15. The nominal survey accuracy is ±3 mm.

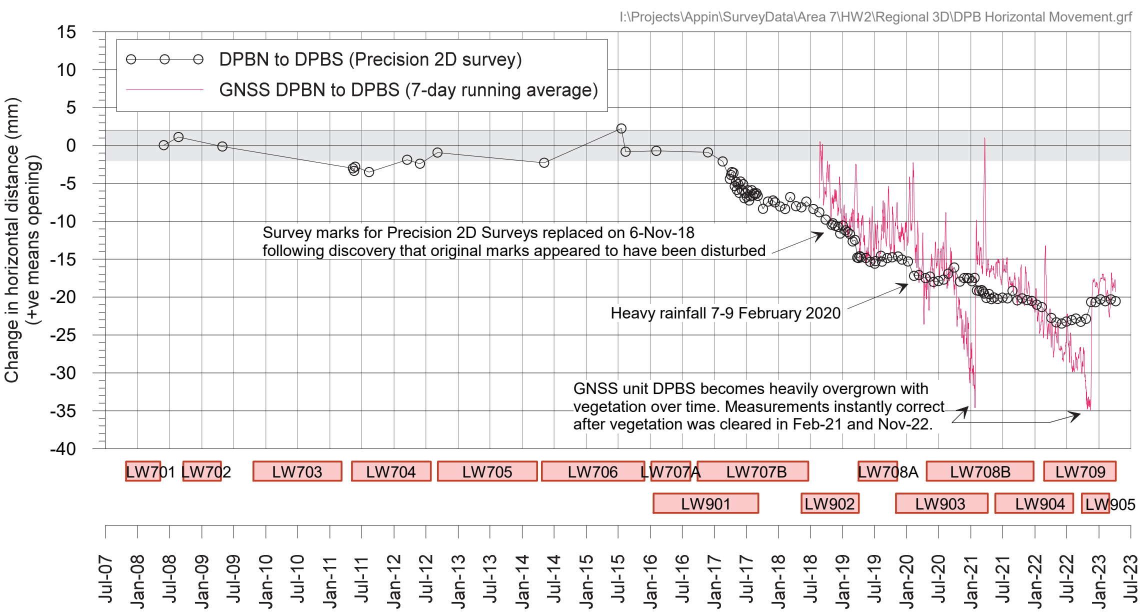

Fig. 2.15 Measured total valley closure at the Nepean Twin Bridges

The measured incremental closure at the completion of LW905 was 2 mm, which is within survey tolerance. The results of the GNSS units have been overlaid with the absolute 3D and precision 2D survey results in in Fig. 2.15. There appears to be reasonable agreement between the results, though greater variation is observed from the GNSS units, even when a 7-day running average is displayed.

2.11.2. Relative 3D monitoring points

The subsidence effects at the Nepean Twin Bridges were measured by IMC using relative 3D marks fixed directly to the bridges' structure. The locations of the monitoring points on the Southbound and Northbound carriageways of the bridges are shown in Fig. 2.16 and Fig. 2.17 (Source: IMC).

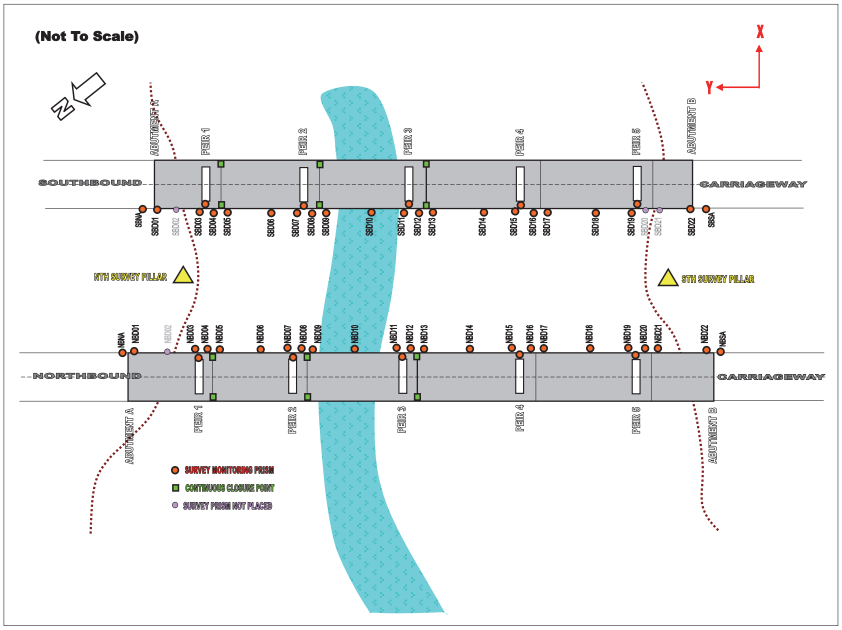

Fig. 2.16 Plan of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IMC)

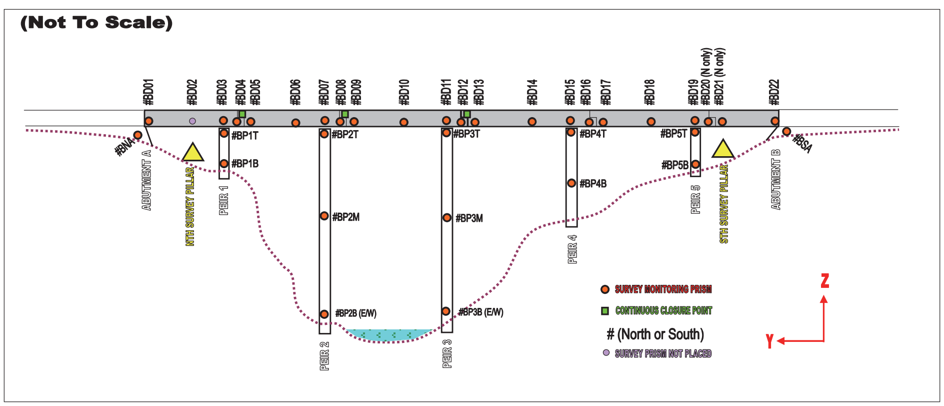

Fig. 2.17 Elevation of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IMC)

The changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges have been measured since 15 October 2007 during mining in Appin Area 7 and continued during LW901 to LW905 in Area 9. The development of total changes in horizontal distance between the marks, plotted from 2007, is shown in Fig. 2.18. The nominal survey accuracy is ±2 mm.

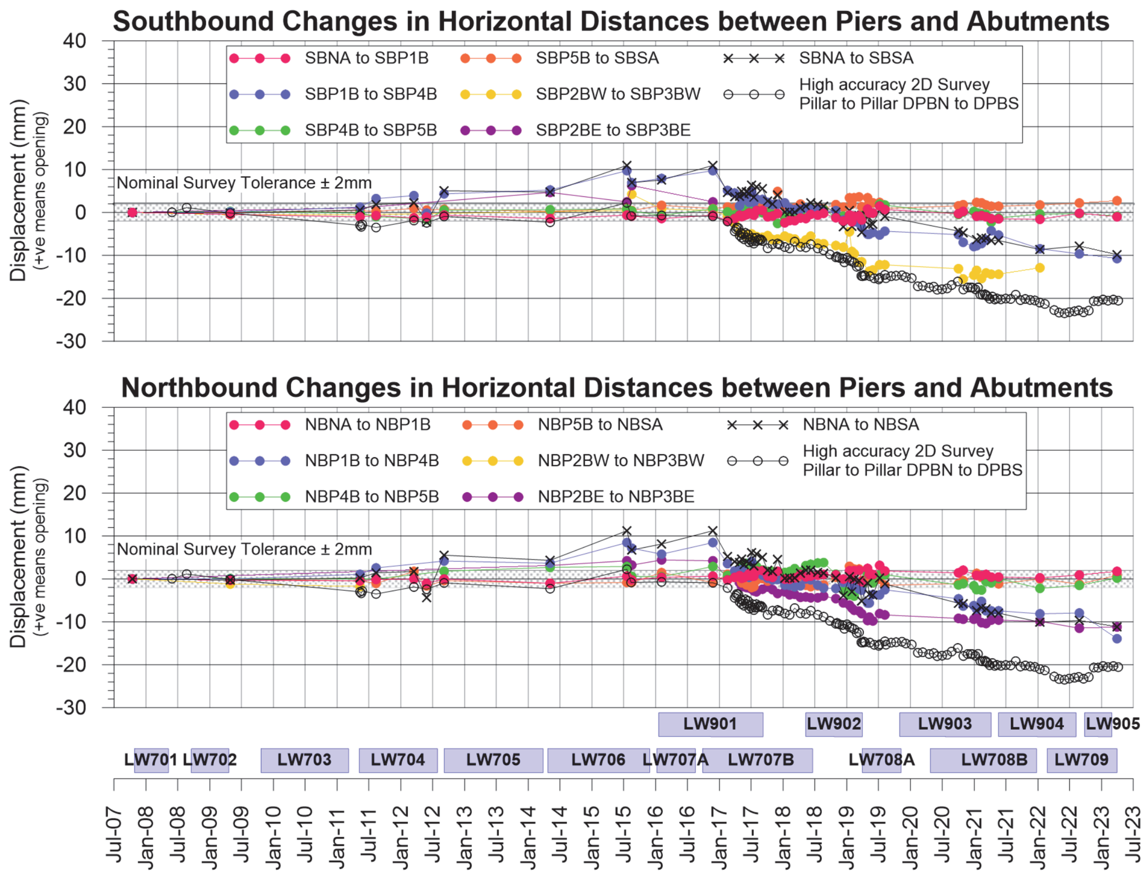

Fig. 2.18 Measured total changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges

It can be seen that the total closure measured across the ends of the bridges has concentrated between Piers 2 and 3 at the bases of the bridges. Very little incremental changes in the distances were measured between the piers and abutments during the mining of LW905.

The measured changes in the lateral direction of the base of the Southbound and Northbound Bridges are close to survey tolerance, as shown in Fig. 2.19. It is noted that a lateral shift was observed in the positions of the base of Piers 2 and 3 relative to the upper levels of the bridges at the end of mining of LW902, with a small recovery measured during the mining of LW905. Minimal change in lateral alignment has been observed in the bridge deck.

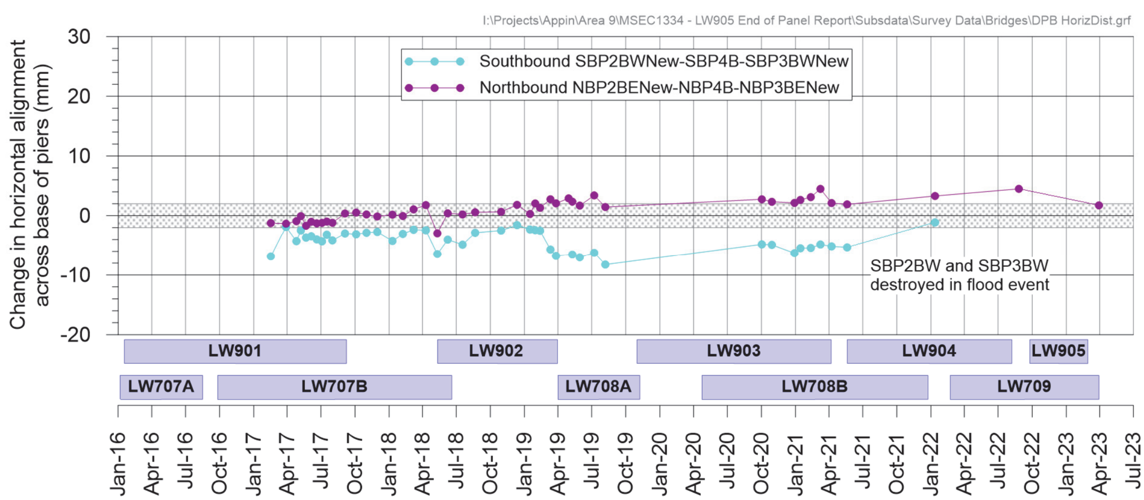

Fig. 2.19 Changes in horizontal alignment across the base of the piers

2.11.3. Joint monitoring

Differential movements across the movement joints in the Nepean Twin Bridges were measured by PSM during the mining of LW905 and the concurrent mining in the adjacent Appin Area 7. The bridge movement joints are referred to as Joint 1 (adjacent to Pier 1), Joint 2 (adjacent to Pier 2) and Joint 3 (main expansion joint adjacent to Pier 3).

The bridge joint monitoring readings commenced on 29 November 2007 (during the mining of LW701 in Appin Area 7) and measurements have been taken at 5 or 10-minute intervals. Further details on the bridge joint monitoring and the results are provided in monitoring reports by PSM, numbers PSM883-472L (dated 5 December 2022 and PSM883-473L (dated 27 February 2023).

The TARP for the Nepean Twin Bridges, which was developed by the RMS chaired Technical Committee, provided a trigger for the differential movements across the bridge movement joints. A summary of the Level 1 Triggers and the maximum measured differential movements across the bridge movement joints, at any time during the extraction of LW905, is provided in Table 2.14.

Table 2.14 Measured differential movements and triggers for the Nepean Twin Bridges joints

Type	Maximum measured differential movement across bridge joint (mm)	Level 1 Trigger (mm)
Joint 1 (northern joint)	+0.19 (northbound carriageway) +0.52 (southbound carriageway)	2
Joint 2 (middle joint)	-0.80 (northbound carriageway) -0.41 (southbound carriageway)	2
Joint 3 (main expansion joint)	-4.11 (northbound carriageway) -1.25 (southbound carriageway)	10

The measured differential movements at the bridge joints did not exceed the Level 1 Triggers during the mining of LW905.

2.12. Moreton Park Road Bridge (South) monitoring points

Moreton Park Road Bridge (South) is located approximately 2.2 km south-east of the finishing end of LW905. The bridge has experienced far-field movements due to the mining in Area 9 and the concurrent mining in the adjacent Appin Area 7. The monitoring associated with Moreton Park Road Bridge (South) included the following:

- absolute 3D monitoring points; and
- relative 3D monitoring points.

Descriptions of the monitoring results are provided in the following sections.

2.12.1. Absolute 3D monitoring points

The absolute 3D horizontal movements at Moreton Road Bridge South have been monitored at Marks MPBE and MPBW, which are located adjacent to the eastern and western ends, respectively, of the bridge. These marks were measured as part of the far-field monitoring, as described in Section 2.10.

The vectors of incremental horizontal movement at Marks MPBE and MPBW are shown in Drawing No. MSEC1334-04, in Appendix A. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±20 mm. The measured incremental horizontal movement at Marks MPBE and MPBW, at the completion of LW905, were less than 10 mm. The measured movements, therefore, are in the order of survey tolerance.

The absolute horizontal movements at Marks MPBE and MPBW have been measured since 15 October 2007 during the mining in Appin Area 7 and during the mining of LW901 to LW905 in Area 9. The development of total horizontal movements for these marks, plotted since the start of 2010, is shown in Fig. 2.20.

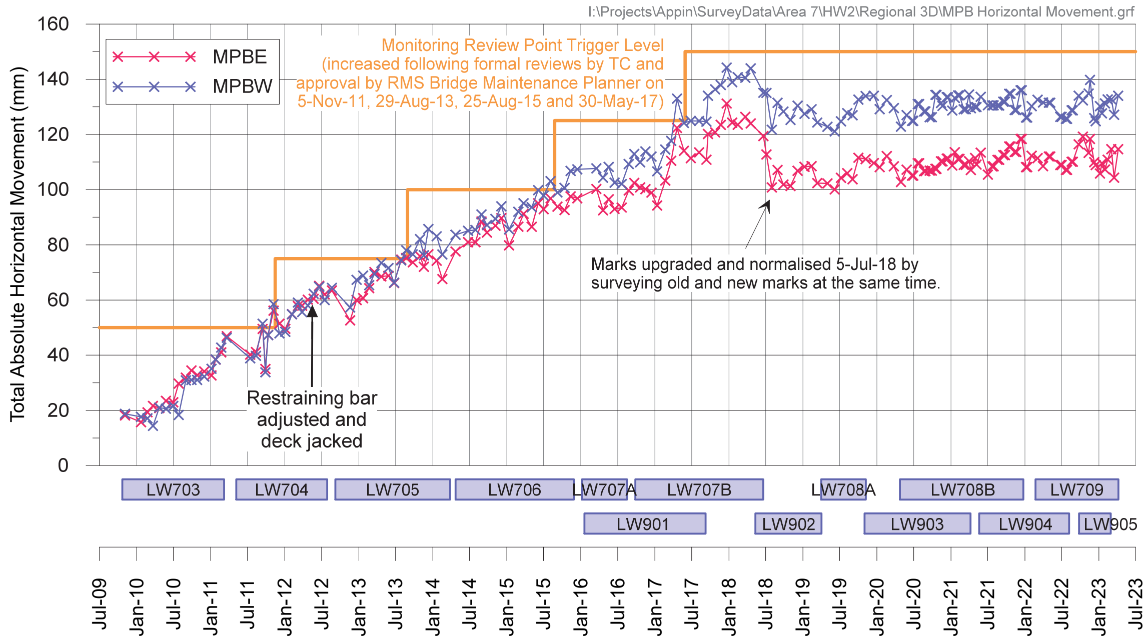

Fig. 2.20 Measured total absolute movements at Marks MPBE and MPBW due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks MPBE and MPBW did not exceed the Monitoring Review Point Trigger during the mining of LW905, as shown in Fig. 2.20.

A summary of the maximum measured absolute horizontal movements at Marks MPBE and MPBW, measured on 6 April 2023 after the completion of LW905, is provided in Table 2.15.

Table 2.15 Measured absolute movements and trigger for Moreton Road Bridge (South)

Location	Maximum measured absolute horizontal movement (mm)	Level 1 Trigger (mm)
Marks MPBE and MPBW	134	150

The maximum measured absolute horizontal movement at Marks MPBE and MPBW was less than the Level 1 Trigger at the completion of LW905.

2.12.2. Relative 3D monitoring points

The mine subsidence movements of the Moreton Park Road Bridge (South) were measured by IMC using relative 3D marks fixed directly to the bridge structure. The locations of the monitoring points on the bridges are shown in Fig. 2.21 and Fig. 2.22 (Source: IMC).

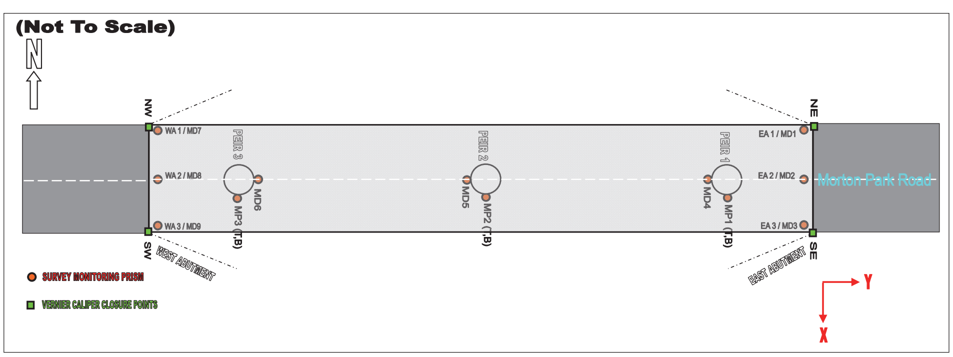

Fig. 2.21 Plan of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

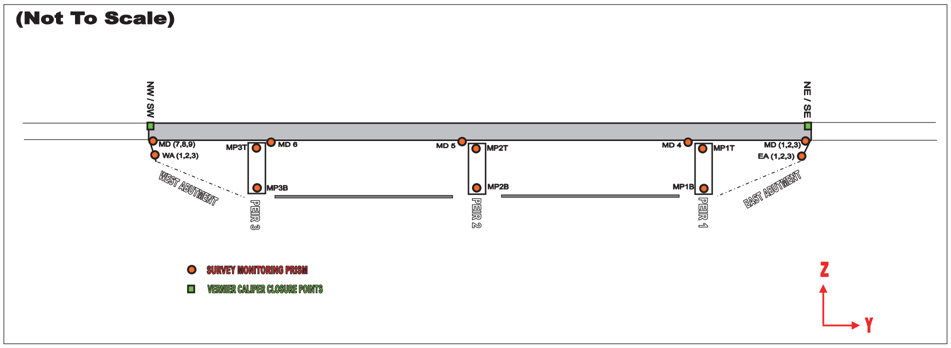

Fig. 2.22 Elevation of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

The changes in horizontal distance between the bridge abutments have been measured since 15 October 2007 during the mining in Appin Area 7 and during the mining LW901 to LW905 in Area 9. Marks have been established on the eastern abutment (EA1 to EA3) and on the western abutment (WA1 to WA3). The development of total changes in horizontal distance between the abutments, plotted since 2007 is shown in Fig. 2.23. The nominal survey accuracy is ±2 mm.

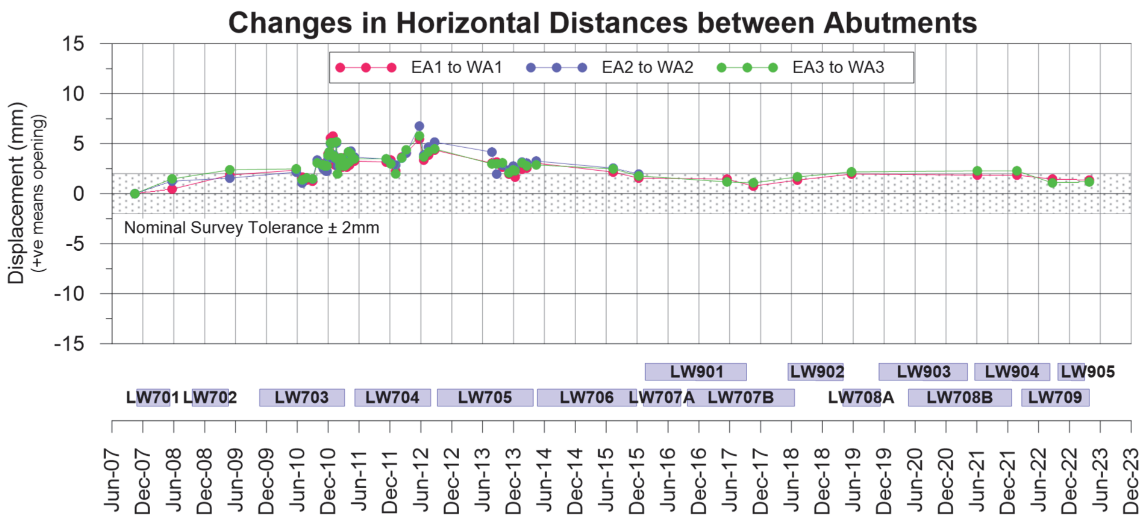

Fig. 2.23 Measured total changes in horizontal distance between the abutments of Moreton Park Road Bridge (South)

The total changes in horizontal distance between the bridge abutments were less than ±2 mm at the completion of LW905. The total measured movements, therefore, were in the order of survey tolerance at the completion of the longwall.

2.13. GNSS monitoring

Global Navigation Satellite System (GNSS) units have been installed above the mining area and on Razorback Range. The absolute positions (vertical and horizontal) are measured at regular intervals (nominally 10 seconds) and these are used to calculate four-hour running averages.

The GNSS units include those located on the private properties at the top of Razorback Range (SSGNSS01 to SSGNSS06), on the side of Razorback Range (SSGNSS07 and SSGNSS08) and on and downslope of the Indara Razorback Compound (SSGNSS09 to SSGNSS12). The locations of these units are shown in Drawing No. MSEC1334-01.

The measured absolute incremental horizontal movements (four-hour running averages) for SSGNSS01 to SSGNSS12 are shown in Fig. 2.24 to Fig. 2.29. These figures show the additional movements due to the mining of LW905 only.

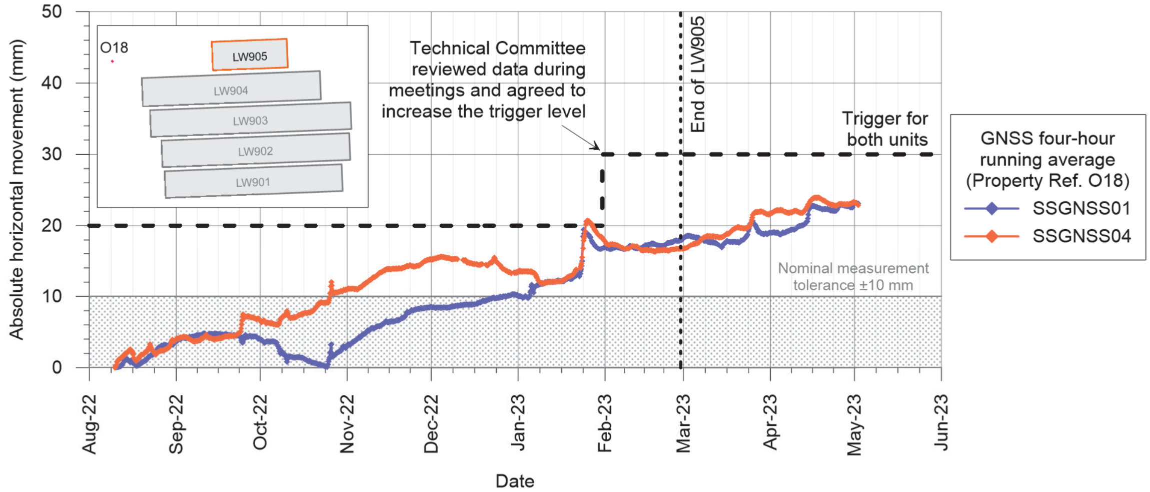

Fig. 2.24 Measured absolute horizontal movements at SSGNSS01 and SSGNSS04 (Property O18)

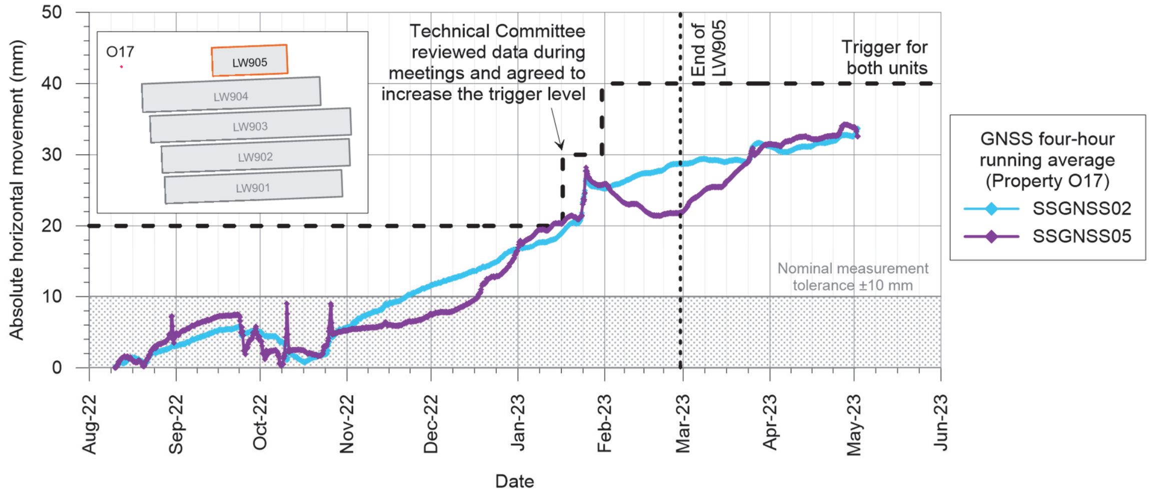

Fig. 2.25 Measured absolute horizontal movements at SSGNSS02 and SSGNSS05 (Property O17)

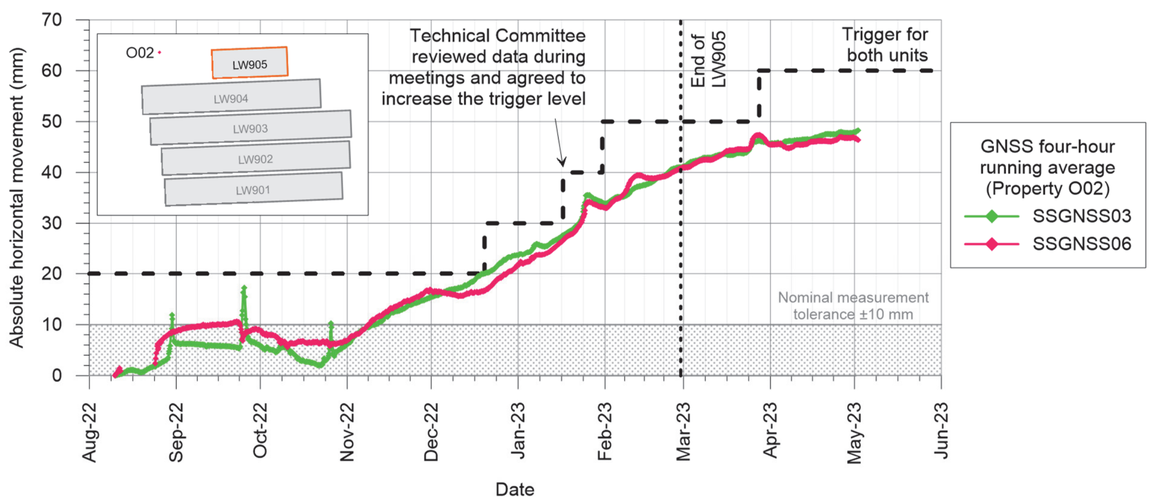

Fig. 2.26 Measured absolute horizontal movements at SSGNSS03 and SSGNSS06 (Property O02)

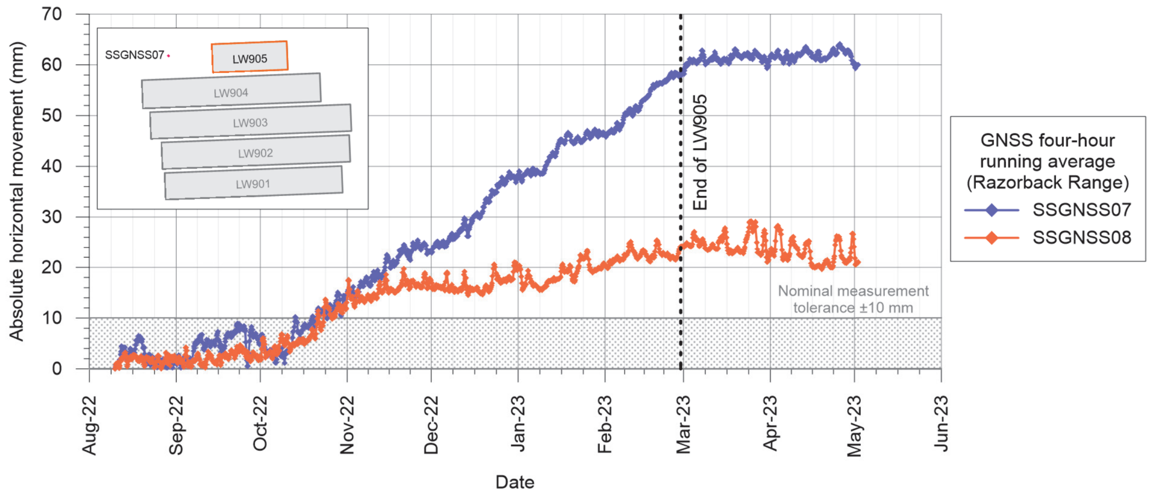

Fig. 2.27 Measured absolute horizontal movements at SSGNSS07 and SSGNSS08 on the side of Razorback Range north of LW904 and west of LW905

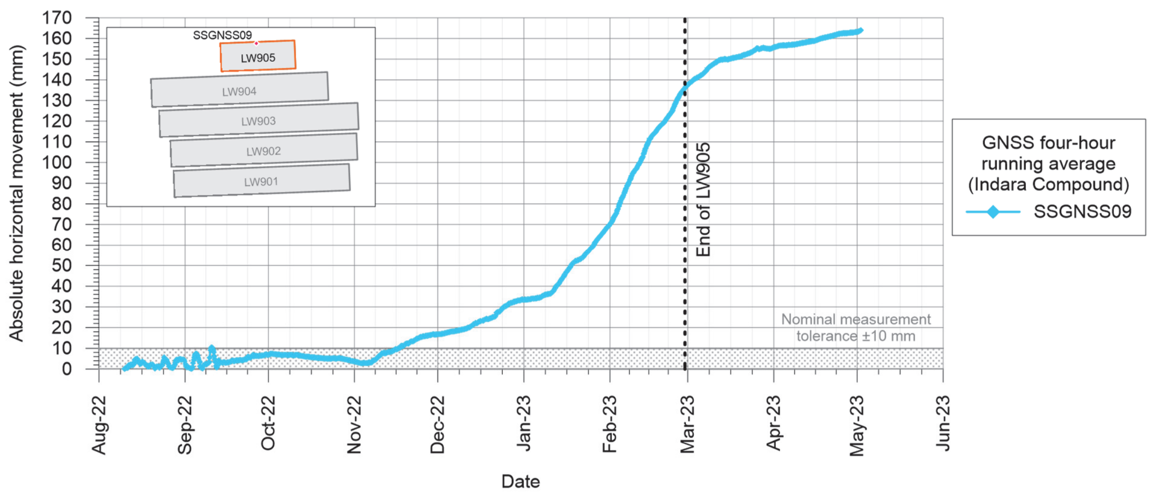

Fig. 2.28 Measured absolute horizontal movements at SSGNSS09 on the Indara Razorback Compound

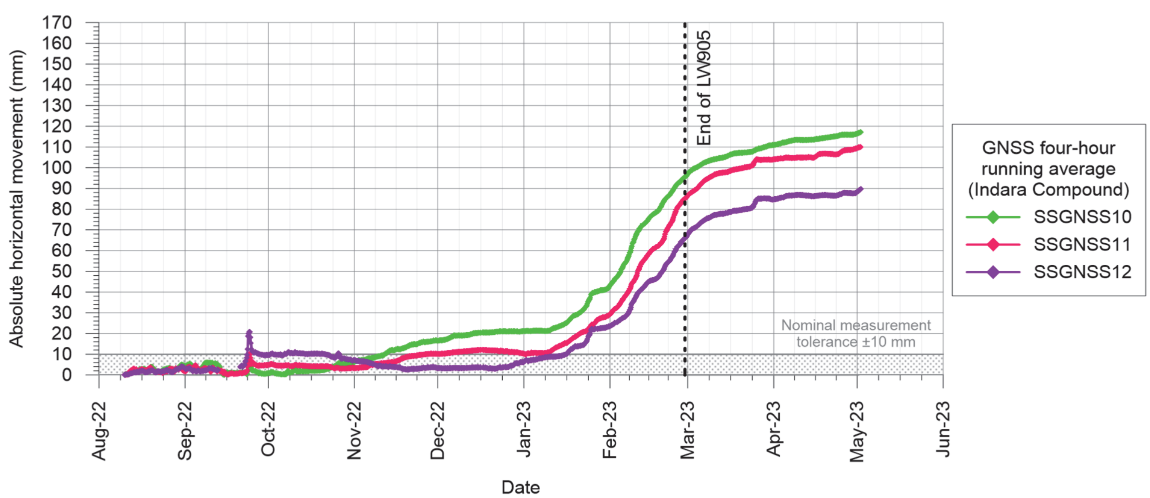

Fig. 2.29 Measured absolute horizontal movements at SSGNSS10 to SSGNSS12 on the steep slopes below the Indara Razorback Compound

The GNSS results were included in the subsidence review reports (MSEC1294, Rev. R01 to R33) which were issued during and after the mining of LW905. The Technical Committee reviewed the monitoring data and made recommendations on the management of the building structures.

The absolute incremental horizontal movements at the GNSS units developed gradually during the mining of LW905. The horizontal movements at GNSS01 to GNSS05 reached the trigger levels during mining and IMC carried out visual observations of the steep slopes. The Technical Committee reviewed the data in the regular meetings and made further recommendations and revised the triggers accordingly.

2.14. ALS / LiDAR surveys

The changes in surface level due to the mining in Area 9 have been measured using Airbourne Laser Scan (ALS) / Light Detection and Ranging (LiDAR) surveys.

ALS surveys have been carried out in June 2007 (before the commencement of LW901), November 2017 (after the completion of LW901), late-March 2019 (around the completion of LW902), mid-April 2021 (after the completion of LW903), mid-September 2022 (after the completion of LW904) and mid-April 2023 (after the completion of LW905).

The measured incremental changes in surface level due to the mining of LW905 only are shown in Fig. 2.30. These contours have been determined by taking the differences between the surface levels measured before and after the mining of this longwall. The data located outside the predicted limit of vertical subsidence (i.e. incremental 20 mm subsidence contour) have been removed for clarity.

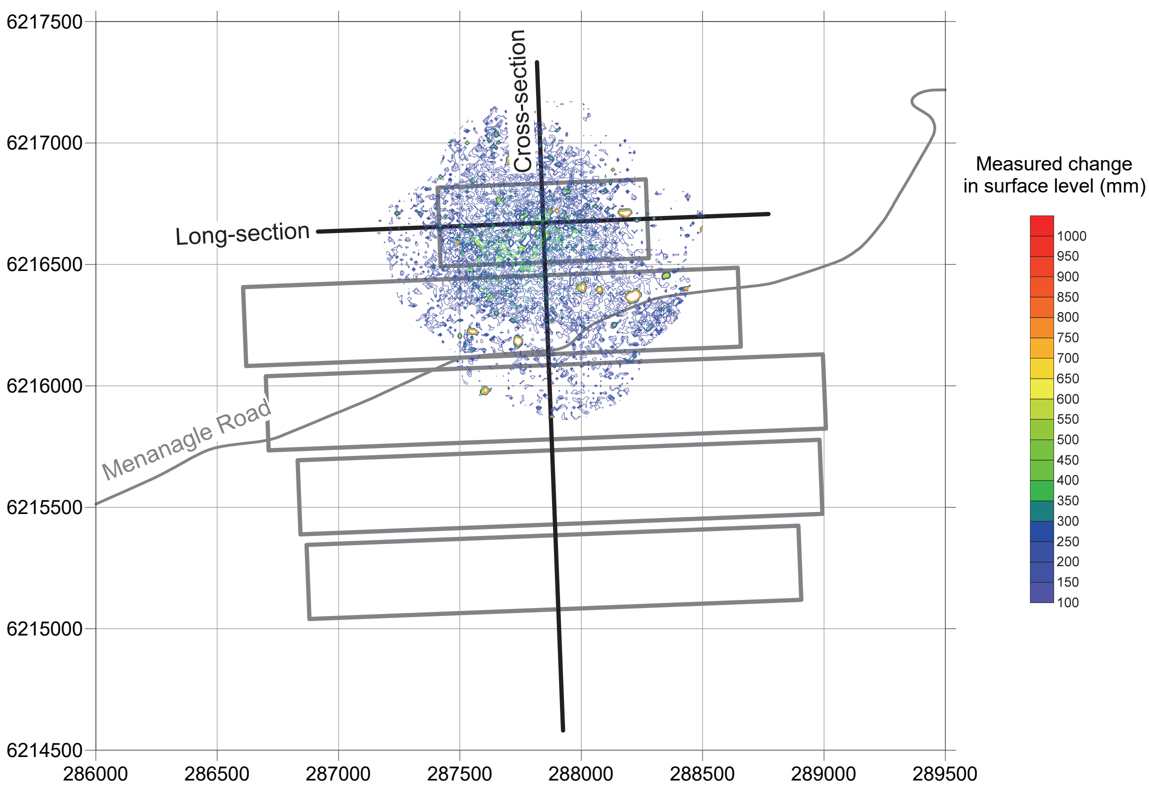

Fig. 2.30 Measured incremental changes in surface level due to the mining LW905 only

The LiDAR surveys after LW903, LW904 and LW905 have an accuracy for absolute level in the order of ±100 mm. The accuracy of the measured incremental changes in surface level (i.e. the difference between these two surveys) due to the mining of LW905, therefore, is in the order of ±200 mm.

The measured total changes in surface level due to the mining of LW901 to LW905 are shown in Fig. 2.31. These contours have been determined by taking the differences between the surface levels measured before the commencement of LW901 and after the completion of LW905. The data located outside the predicted limit of vertical subsidence (i.e. total 20 mm subsidence contour) have been removed for clarity.

The LiDAR survey before LW901 has a lower point density and is affected more by vegetation compared with the more recent surveys. Hence, there is more variability in the measured total changes in surface level due to the mining of LW901 to LW905 and the accuracy is in the order of ±250 mm or greater.

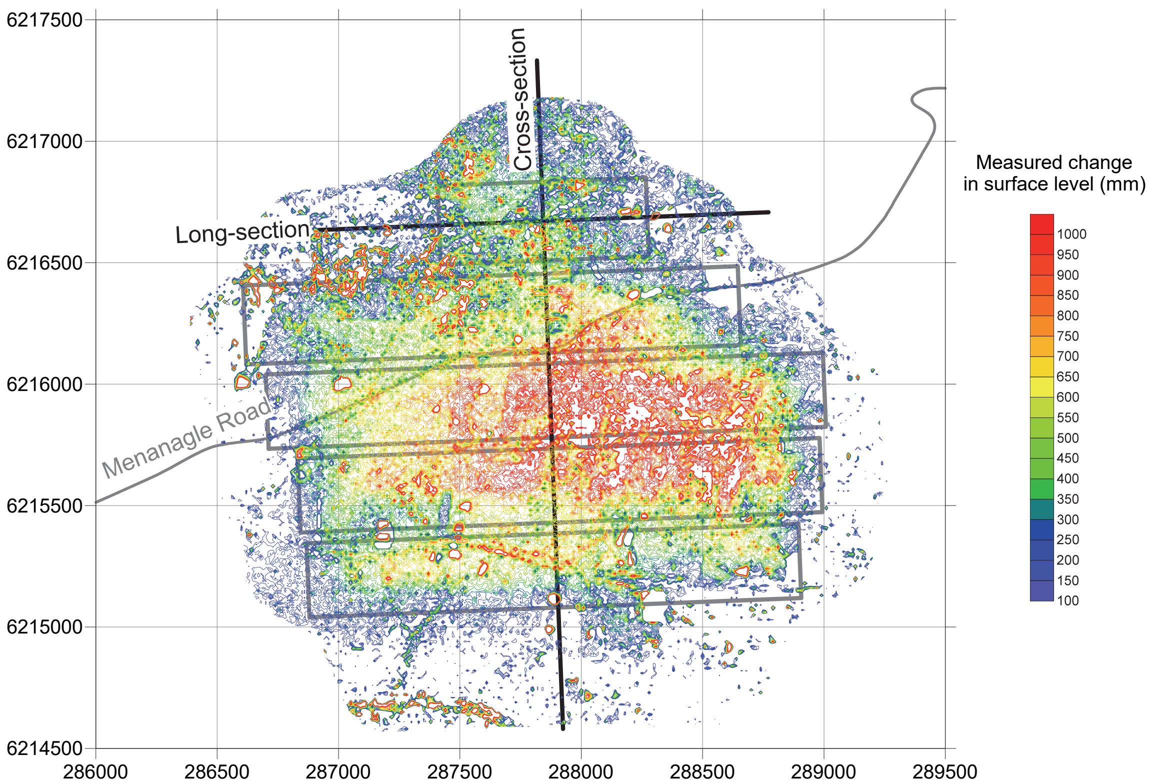

Fig. 2.31 Measured total changes in surface level due to the mining of LW901 to LW905

The contours of the measured changes in surface level, developed from the LiDAR surveys, show the changes in the heights of points at fixed positions in space (i.e. eastings and northings). This differs from traditional subsidence contours that include both the vertical and horizontal components of the movements of points fixed to the surface. Horizontal movements are usually included in the subsidence profiles, as traditional ground monitoring data is based on the movements of survey marks that are fixed to the ground.

The contours can contain artefacts (i.e. locally increased or decreased movements), particularly in the locations of steeply incised terrain. These artefacts can be seen in Fig. 2.30 and Fig. 2.31 as the areas of dark red contours outside the extents of the mined longwalls, such as along Razorback Range to the north of the mining area.

The change in surface level at a fixed position in space (i.e. easting and northing), therefore, can be large in the locations of steep slopes and does not provide a true indication of the actual vertical subsidence at a point on the ground. However, where the ground is reasonably flat, the contours of the measured changes in surface level should provide a good indication of the actual vertical subsidence.

The comparisons of the measured changes in surface level and the predicted vertical subsidence along a Cross-section and a Long-section are provided in Fig. 2.32 and Fig. 2.33, respectively. The locations of these sections are indicated in Fig. 2.30 and Fig. 2.31. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report No. MSEC1117 which supported the Extraction Plan Application.

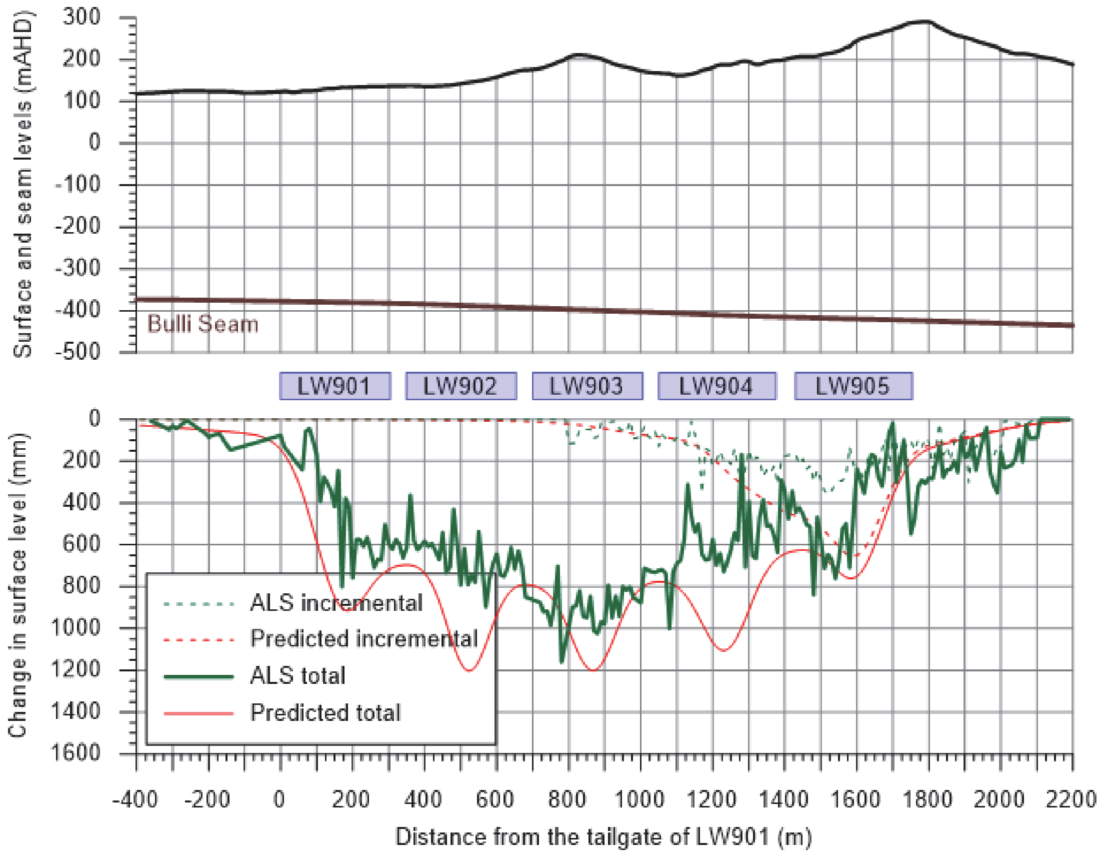

Fig. 2.32 Measured changes in surface level and predicted vertical subsidence along the Cross-section

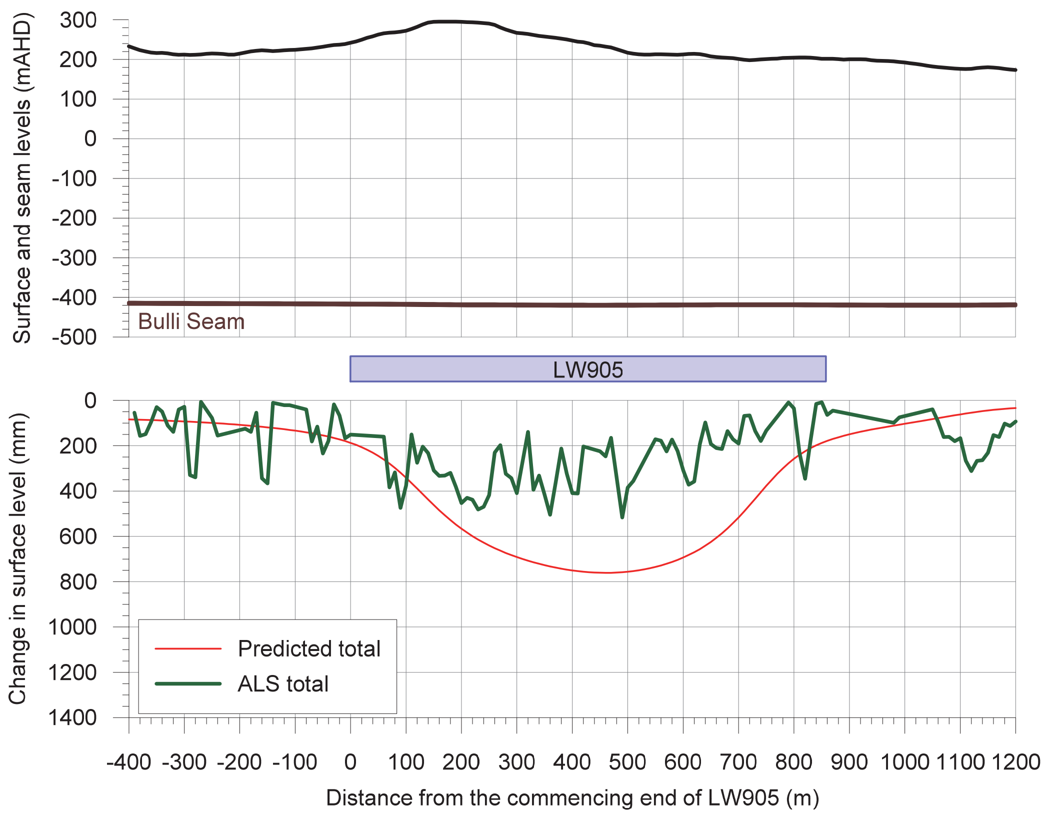

Fig. 2.33 Measured changes in surface level and predicted vertical subsidence along the Long-section

The profiles of the measured incremental changes in surface level (i.e. dashed lines) reasonably match the predicted profiles of incremental vertical subsidence along the Cross-section and Long-section. There is more variability in the measured total changes in surface level (i.e. solid lines) due to the lower accuracy of the LiDAR survey before LW901.

The maximum measured changes in surface level above each of the longwalls are generally similar to or less than the maximum predicted values. There are localised areas where the measured movements exceed the predictions; however, these are likely due to artefacts within the LiDAR surveys.

There are localised areas outside of the longwalls where the measured changes in surface level exceed the predicted vertical subsidence. However, these are artefacts of the LiDAR surveys and are not real movements. Elsewhere, the low-level movements are in the order of accuracy of the measurement method.

It is considered that the ground movements measured using the LiDAR surveys are consistent with the predictions provided in Report No. MSEC1117 which supported the Extraction Plan Application.

3.0 COMPARISONS BETWEEN THE OBSERVED AND ASSESSED IMPACTS FOR THE NATURAL AND BUILT FEATURES

3.1. Natural features

The natural features in the vicinity LW905 are shown in Drawing No. MSEC1334-02, in Appendix A, and include:

- Nepean River – located more than 2 km south of LW905 at its closest point;
- Harris Creek – upper reaches located more than 1 km east of LW905 at its closest point;
- tributaries to the Nepean River and Harris Creek – upper reaches located directly above LW905;
- cliffs along Razorback Range – two cliffs (RR-CL6 and RR-CL7) located directly above LW905;
- cliffs along the Nepean River and Harris Creek – located more than 2 km from LW905;
- rock outcrops – located along on side of Razorback Range directly above LW905; and
- steep slopes – located along on side of Razorback Range directly above LW905.

The MSEC assessed impacts for the natural features due to the mining of LW901 to LW905 are provided in Reports Nos. MSEC448 and MSEC1117 which supported the Extraction Plan Applications. More detailed assessments for the natural features are also provided in other consultants' reports on the project.

Comparisons between the MSEC assessments and the reported impacts for the natural features listed above, resulting from the mining of LW905, are provided in Table 3.1. The impacts are based on those recorded by the IMC Environmental Field Team and are described in the accompanying Landscape Report entitled "*Appin Mine Longwall 905 Landscape Report 2023*".

Table 3.1 Assessed and reported impacts for the natural features due to LW905

Natural feature	MSEC assessed impacts	Reported impacts
Nepean River	Unlikely that increased **ponding**, **flooding** or **changes in stream alignment** would occur.	No reported impacts.
	Minor **fracturing** of the bedrock within or beyond 400 m of the longwalls.	No visible fracturing observed; however, the flooded river valley and sediment profile limits observations of the river bed.
	Unlikely that **surface water flow diversions** would occur.	No reported impacts.
	Likely that **gas emissions** would develop along the river.	No new gas release zones were observed along the Nepean River during the mining of LW905. However, there were 11 active gas release zones that developed during the mining of previous longwalls in Area 9 and continued during the mining of LW905. Refer to the IMC Landscape Report.
	Water quality – refer to the surface water report by HGEO. **Terrestrial ecology** – no reported impacts, refer to the IMC Landscape Report.	
Harris Creek	Adverse impacts unlikely.	No reported impacts.
Tributaries to the Nepean River	Unlikely that increased **ponding**, **flooding** or **scouring** would occur.	No reported impacts.
	Cracking of natural surface soils and **fracturing** of exposed bedrock directly above the longwalls. Minor fracturing could occur within 400 m of the longwalls.	No reported impacts.
	Unlikely that **surface water flow diversions** would occur.	No reported impacts.
Cliffs along Razorback Range	Rock falls could occur at the cliffs located above the mining area representing 3 % and 5 % of the total length, or between 1 % and 3 % of the total face area of these cliffs.	No reported mining-related impacts. There was minor erosion of the soil cover at the crest of a cliffline located north of LW905 likely due to heavy rainfall and not related to mining.

Natural feature	MSEC assessed impacts	Reported impacts
Cliffs along the Nepean River	Rock falls could occur close to mining area (LW901 to LW905), representing less than 0.5 % of the total face area within the mining domain.	No reported impacts.
Cliffs along Harris Creek	Likelihood of mining-induced rock falls considered to be extremely low.	No reported mining-related impacts. Minor rock falls were observed during mining that were considered to be associated with existing instabilities and after heavy rainfall.
Other cliffs and rock outcrops	Fracturing of exposed bedrock which could result in **rockfalls** where the rock is marginally stable.	No reported impacts.
Steep slopes	Surface **cracking** typically between 25 mm and 50 mm, with localised cracking in the order of 100 mm to 150 mm directly above the longwalls.	No reported mining-related impacts. Several shallow slides reported along Razorback Range after heavy rainfall, not related to mining.

No mining-related physical impacts (i.e. surface cracking, rock fracturing, etc.) for the natural features were reported during the mining of LW905. Impacts not related to mining included minor rockfalls along Harris Creek Cliff Line and Razorback Range and several shallow slides along Razorback Range which occurred after heavy rainfall periods and are associated with existing or natural instabilities.

The reported impacts on the natural features due to the mining of LW905 are therefore less than the MSEC assessments provided in Reports Nos. MSEC448 and MSEC1117 which supported the Extraction Plan Applications. Further assessments of natural features have been provided by other specialist consultants, and these are described in the relevant reports attached to the *End of Panel* report.

3.2. Built features

The built features in the vicinity LW905 are shown in Drawing No. MSEC1334-03, in Appendix A, and include the:

- Main Southern Railway and associated infrastructure;
- Menangle and Hawkey Roads;
- Nepean Twin Bridges;
- Moreton Road Bridge (South) and Blades Bridge;
- Water and sewer pipelines;
- 66 kV and 11 kV powerlines;
- Optical fibre and copper telecommunications cables;
- survey control marks;
- heritage sites (railway cottage); and
- houses and associated structures.

The MSEC assessed impacts for the built features resulting from the mining of LW901 to LW905 are provided in Reports Nos. MSEC448 and MSEC1117 which supported the Extraction Plan Applications. Comparisons between the MSEC assessments and the reported impacts for the built features listed above, resulting from the mining of LW905, are provided in Table 3.2.

Table 3.2 Assessed and reported impacts for the built features due to LW905

Built feature	MSEC assessed impacts	Reported impacts
Main Southern Railway	No impacts on the safety or serviceability of the railway after the implementation of the monitoring and management strategies.	No reported impacts on safety or serviceability.
Menangle Road	Minor cracking and localised heaving of the road surface directly above the mining area.	Localised mining-related impacts to the road pavement and fretting of the cutting. Minor dip and wear in eastbound lane occurred near MR9078. A bump and minor cracking of the road pavement developed within the cutting between Marks MR9085 and MR9086. Minor deterioration of the road pavement elsewhere. The impacts developed gradually during the mining of LW905 with no impacts to safety.
Hawkey Road private extension	Impacts unlikely.	No reported impacts.
Nepean Twin Bridges	Impacts unlikely after the implementation of the preventive, monitoring and management strategies.	No reported impacts.
Moreton Park Road Bridge (South) and Blades Bridge	Impacts unlikely.	No reported impacts.
Water and sewer pipelines	Minor leakages could occur.	No reported impacts.
66 kV and 11 kV powerlines	Minor impacts possible requiring some adjustments of cables and poles.	No reported impacts.
Optical fibre and copper telecommunications cables	Impacts unlikely with the implementation of monitoring and management strategies.	No reported impacts.
Survey control marks	Vertical and horizontal movements which could require re-establishment.	No reported damage to survey control marks. The marks to be re-established after completion of mining.
Rural structures	Minor impacts on rural structures located directly above longwalls.	IMC reported moderate settlement and loss of subgrade beneath one shed (Property Ref. N15) which was not related to the mining of LW905.
Pools	Assessed impacts for approximately 15 % of pools above the mining area including cracking and loss of water.	IMC reported impacts for one pool (Property Ref. N14) where several coping pavers had lifted off.
Farm dams	Incidence of impact (cracking and leakage) expected to be extremely low.	No reported impacts including the dam on Property Ref. N13 above the eastern end of LW905.
Groundwater bores	Impacts likely including lowering of piezometric surface, blockage and change in groundwater quality.	Refer to the groundwater assessment and the IMC Landscape Report.
Aboriginal heritage sites	Adverse impacts unlikely.	No Aboriginal heritage sites located within the Study Area for LW905.
Heritage sites	Adverse impacts unlikely.	No reported impacts.
Houses	Houses expected to remain safe and serviceable, assessed impacts: 92 % for no claim or Category R0, 6 % for Category R1 or R2, 2 % for Category R3 or R4, and < 0.5 % for Category R5.	Houses have remained in safe and serviceable conditions. No mining-related impacts reported for the houses along Gibraltar Drive at the top of Razorback Range (Property Refs. O02, O17 and O18). IMC reported minor impacts not related to mining including very slight internal wall cracking, movements of the driveway, retaining walls and poly tanks. IMC reported very slight to slight internal and external wall, ceiling and cornice cracking (Category R1 and R2) of eight houses during LW905 that were associated with the current or previous longwalls in Area 9.

Localised mining-related heaving and cracking of the road pavement along Menangle Road was reported during the mining of LW905. These impacts developed gradually and they did not affect safety or serviceability of the road. There were also several existing and non-mining related defects along Menangle Road including potholes, slumping and deterioration due to heavy rainfall and traffic loads. The road pavement was re-sheeted in several locations to maintain ride quality. Examples of the mining-related impacts observed along Menangle Road during the mining of LW905 are provided in Fig. 3.1 to Fig. 3.3.

IMC reported that there was potential impact (lifting of several coping tiles) for one pool during the mining of LW905. The assessed (i.e. predicted) impacts were that approximately 15 % of pools located above the mining area could experience cracking and loss of water.

IMC advised MSEC that there were eight claims submitted for damage to houses during the mining of LW905 which included very slight to slight impacts (Categories R1 and R2). However, some of these damage claims may be associated with the mining of earlier longwalls in the series. The End of Panel reports for the previously mined longwalls in Area 9 state that there were three damage claims submitted to SA NSW relating to the houses for each of LW901 to LW904, i.e. 12 claims in total for LW901 to LW904, for very slight to slight impacts (Categories R1 and R2) on the houses.

MSEC therefore understands that there have been approximately 20 claims for damage to houses during the mining of LW901 to LW905 relating to very slight to slight impacts (Category R1 and R2) and no moderate or greater impacts (Category R3 to R5). There is a total of 255 houses located within the Study Area for these longwalls in Area 9.

The observed rates of impacts for the houses within the Study Area for LW901 to LW905 therefore are 8 % Category R1 and R2 impacts and zero Category R3 to R5 impacts. The latest assessed rates of impacts for the houses are provided in Table 6.38 of Report No. MSEC1117 and they were 17 % to 23 % Category R1 and R2 impacts, 7 % to 11 % Category R3 and R4 impacts and 2 % to 3 % Category R5 impacts. The observed rates of impacts for the houses in Area 9 therefore are less than the assessed impacts provided in Report No. MSEC1117.

The recorded mining-related impacts on the built features due to the mining of LW905 are similar to or less than the MSEC assessments provided in Reports Nos. MSEC1117 and MSEC1318 which supported the Extraction Plan and Modification Applications. The built features and infrastructure were maintained in safe and serviceable conditions during mining with the implementation of the monitoring and management strategies.

Fig. 3.1 Bump in eastbound lane and compression in shoulder along Menangle Road between Marks MR9085 and MR9086 (Source: SLR, photograph taken on 2 March 2023)

Fig. 3.2 Deterioration of pavement between MR9097 and MR9098 likely due to heavy rainfall and traffic load (Source: SLR, photograph taken on 2 March 2023)

Fig. 3.3 Minor fretting and dislodgment of small rocks in rock cutting between MR9083 and MR9088 (Source: SLR, photograph taken on 2 March 2023)

APPENDIX A. DRAWINGS

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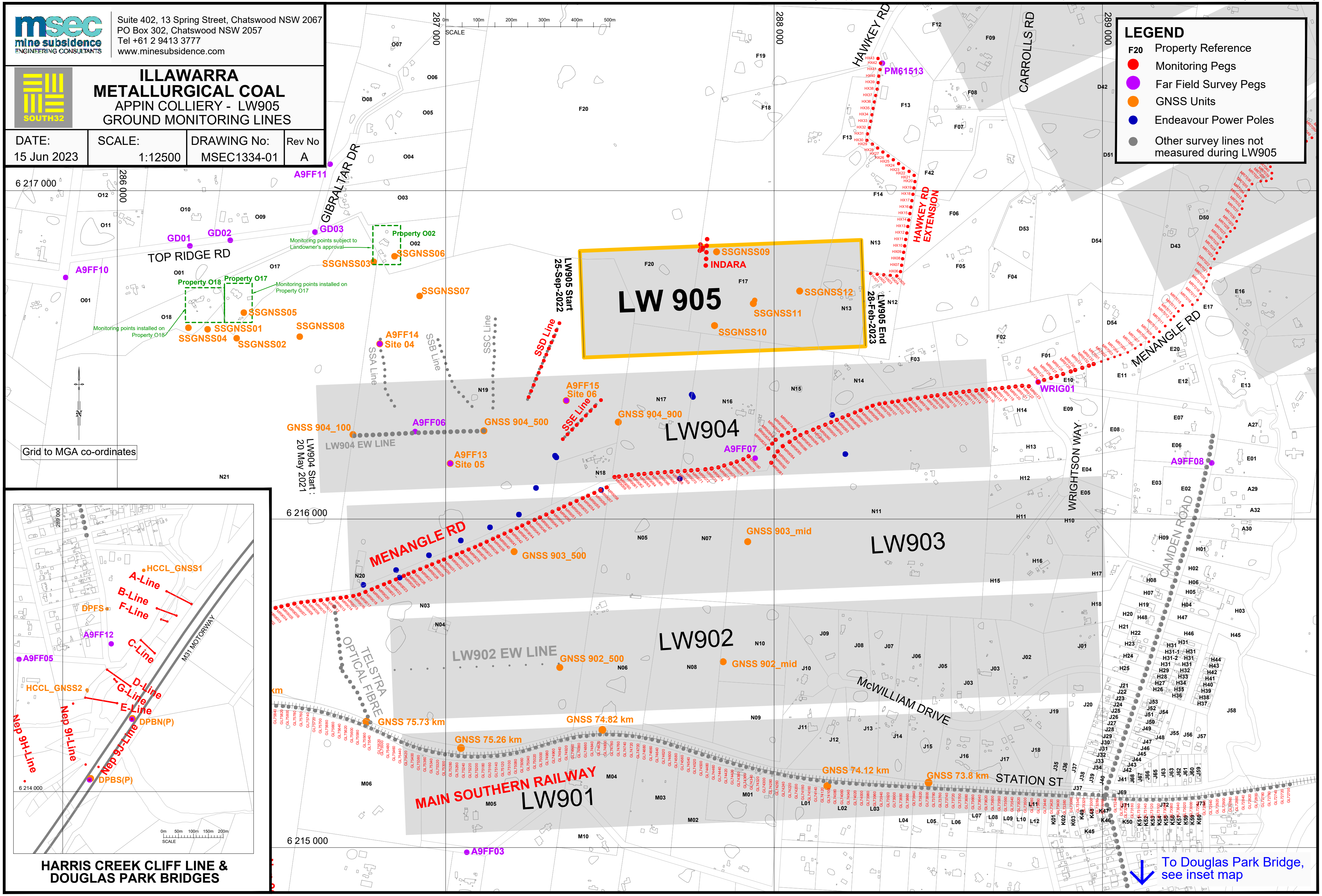
SOUTH32

ILLAWARRA METALLURGICAL COAL
APPIN COLLIERY - LW905
GROUND MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
15 Jun 2023	1:12500	MSEC1334-01	A



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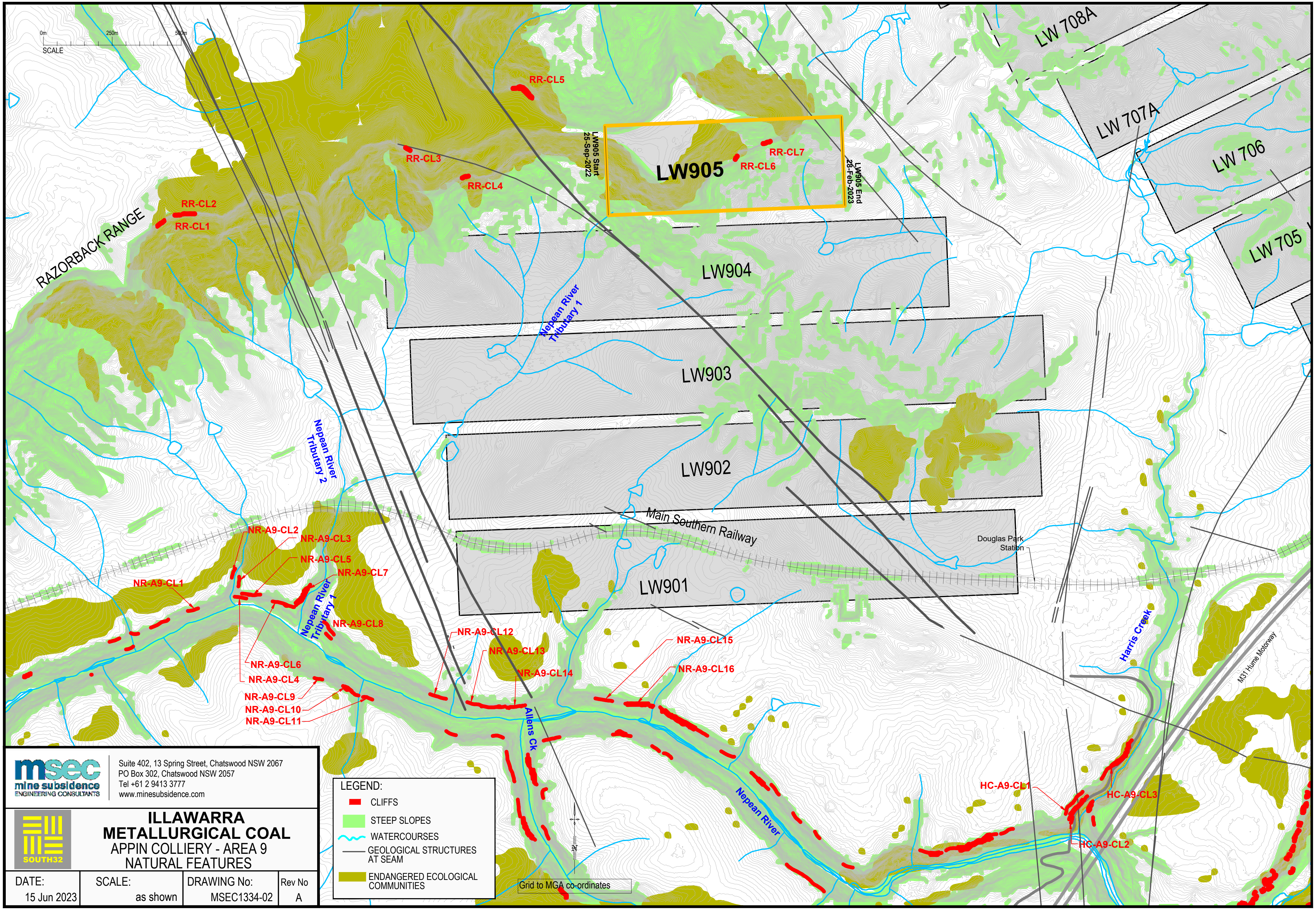

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ILLAWARRA METALLURGICAL COAL
APPIN COLLIERY - AREA 9
NATURAL FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
15 Jun 2023	as shown	MSEC1334-02	A

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ILLAWARRA METALLURGICAL COAL
APPIN COLLIERY - AREA 9
BUILT FEATURES

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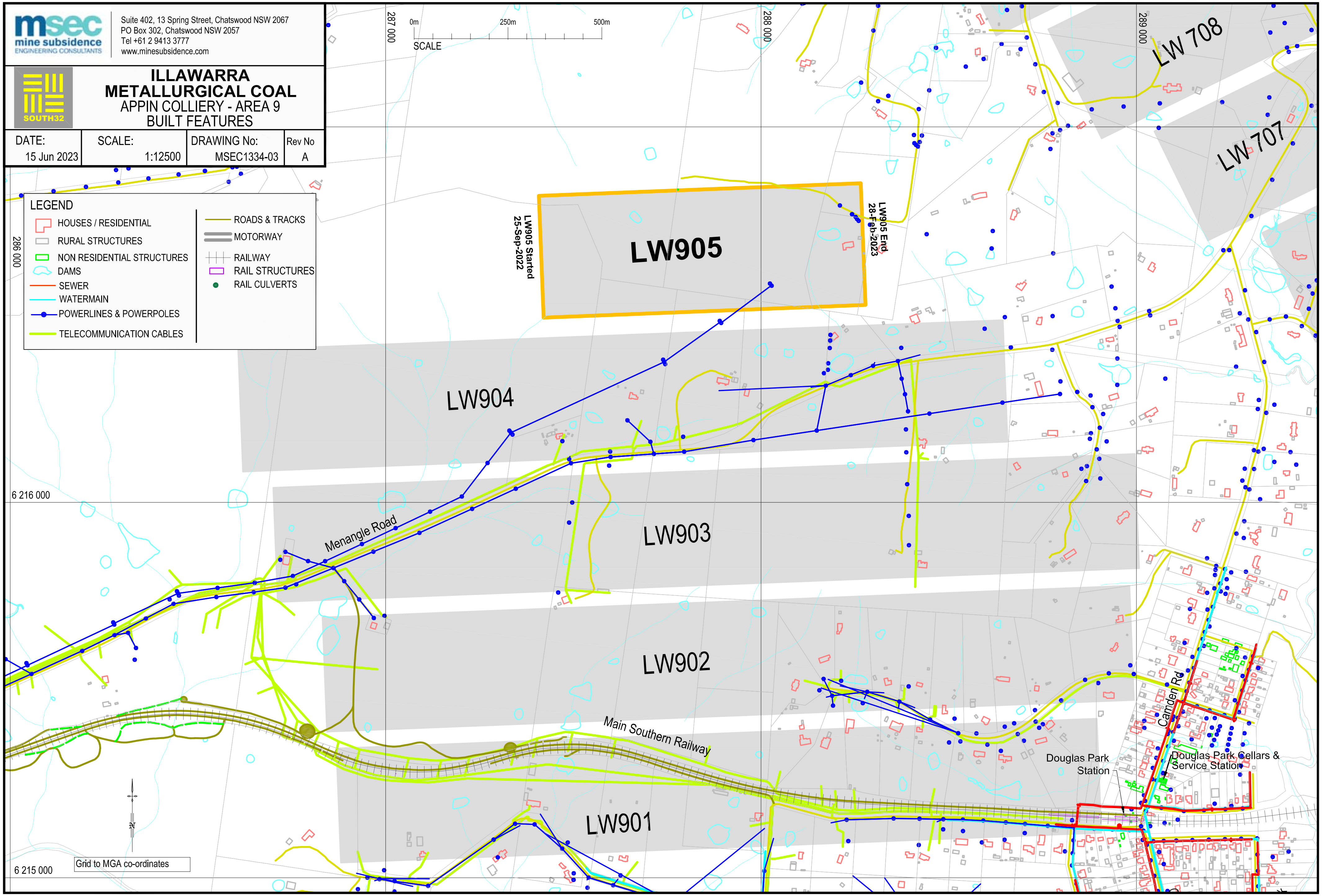

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APPIN COLLIERY - AREA 9
VECTORS OF INCREMENTAL HORIZONTAL MOVEMENT DUE TO LW905

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