mine subsidence ENGINEERING CONSULTANTS

ILLAWARRA METALLURGICAL COAL:

Appin – Area 9 – Longwall 903

End of Panel Subsidence Monitoring Review Report for Appin Longwall 903

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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)

MSEC829 (Rev. A) – Appin Colliery – Longwalls 902 to 904 – The Effects of the Proposed Modified Longwalls 902 to 904 on Previous Subsidence Predictions and Impact Assessments (May 2016)

MSEC1005 (Rev. A) – Appin Colliery – Area 9 – The Effects of the Proposed Modified Commencing Ends of Longwalls 903 and 904 at Appin Colliery on the Subsidence Predictions and Impact Assessments (December 2018)

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

Drawings

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

Drawing No.	***Description***	***Revision***
MSEC1176-01	General layout and monitoring lines	A
MSEC1176-02	Natural features	A
MSEC1176-03	Built features	A
MSEC1176-04	Vectors of incremental horizontal movement due to LW903	A

1.1. Introduction

Illawarra Metallurgical Coal (IMC) has approval for the extraction of Longwalls 901 to 904 (LW901 to LW904) in Area 9 at Appin Colliery. IMC has completed the extraction of LW903 which is the third longwall in the series. The location of the longwalls in Area 9 are shown in Drawing No. MSEC1176-01, in Appendix A. A summary of the commencement and finishing dates for LW901, LW902 and LW903 is provided in Table 1.1.

Table 1.1 Commencement and finishing dates for LW901, LW902 and LW903

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

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IMC to prepare subsidence predictions and impact assessments for LW901 to LW904. Report No. MSEC448 (Rev. B) was issued in June 2012 in support of the Extraction Plan Application for these longwalls. The Department of Planning, Industry and Environment (DPIE) granted approval for the Extraction Plan on 10 September 2014.

IMC subsequently shortened the commencing (i.e. western) and finishing (i.e. eastern) ends of LW903 by 1156 m and 50 m, respectively, from the extents indicated in the Extraction Plan Application. Reports Nos. MSEC829 (Rev. A) and MSEC1005 (Rev. A) were issued in May 2016 and December 2018, respectively, in support of the application for these modifications. The modified commencing and finishing ends of LW903 were approved by the DPIE on 21 March 2019 and 19 March 2021, respectively.

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 extraction of LW903; and
- Comparisons between the observed and assessed impacts on the natural and built features within the mining area resulting from the extraction of LW903.

Further details on the observed and assessed impacts for natural features due to the extraction of LW903 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 extraction of LW903. That section also provides comparisons between the measured and predicted movements resulting from the extraction of this longwall.

Chapter 3 of this report describes the natural and built features near LW903. That section also provides comparisons between the observed and assessed impacts for these features due to the extraction 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. MSEC1176-01, in Appendix A. A summary of the as-extracted dimensions for LW901, LW902 and LW903 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

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.

The longwalls in Area 9 are being extracted from the Bulli Seam, from the west towards the east, i.e. towards the main headings. The natural surface and the seam levels along the centreline of LW903 are illustrated in Fig. 1.1.

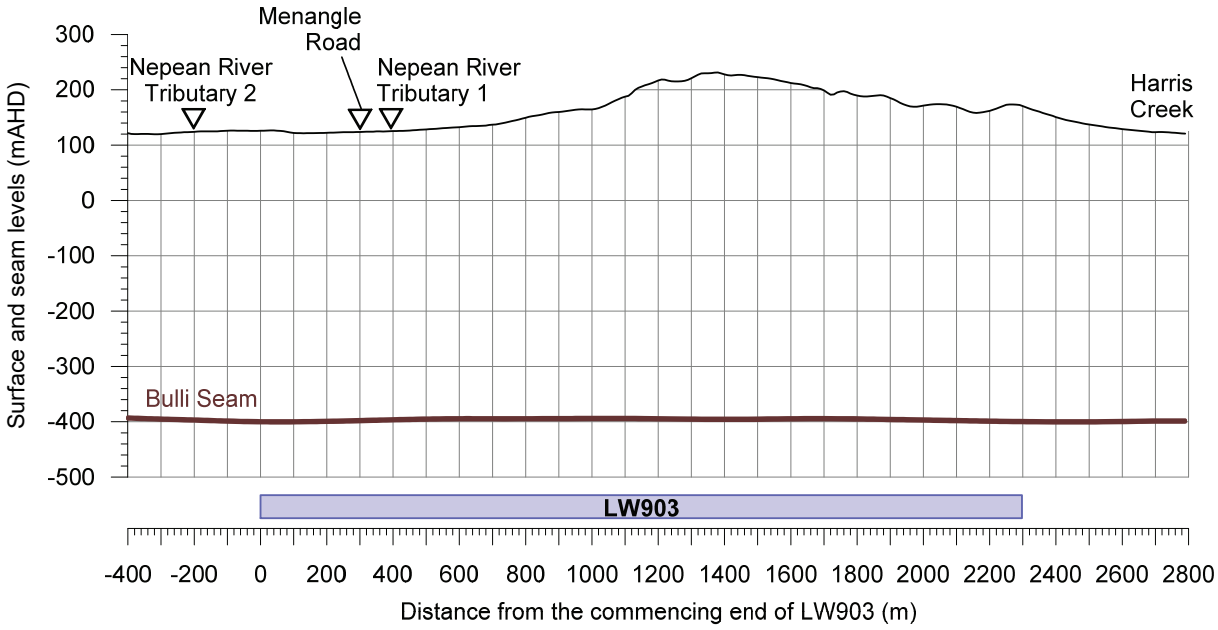

Fig. 1.1 Surface and seam levels along the centreline of LW903

The natural surface above the mining area generally falls from the north towards the south. The natural drainage lines above the western end of LW903 flow into the Nepean River which is located approximately 630 m south of the longwall tailgate. The drainage lines above the eastern end of LW903 flow into Harris Creek which is located approximately 450 m east of the finishing end of the longwall. Razorback Range is located to the north of the LW903.

The depth of cover to the Bulli Seam directly above LW903 varies between a minimum of 510 m above the commencing end of the longwall, and a maximum of 630 m above the eastern end of the longwall. The seam floor within the mining area generally dips from the south to the north, with an average dip approximately 2 %, or 1 in 50.

The thickness of the Bulli Seam varies between 2.8 m and 3.0 m within the extents of LW903. IMC extracted the full thickness of the seam.

1.3. Predicted mine subsidence effects

The predicted mine subsidence effects for LW903 are provided in Reports Nos. MSEC448, MSEC829 and MSE1005 which supported the Extraction Plan and Modification Applications. The predicted conventional subsidence effects have been obtained using the Incremental Profile Method (IPM) based on the standard prediction curves for the Southern Coalfield Bulli Coal Seam.

A summary of the maximum predicted incremental vertical subsidence, tilt and curvatures due to each of LW901 to LW903 is provided in Table 1.3. The values provided in this table are the additional movements due to the extraction of each of the longwalls.

Table 1.3 Maximum predicted incremental vertical subsidence, tilt and curvature due to each of LW901 to LW903

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	600	3.0	0.03	0.04
LW902	825	6.0	0.06	0.12
LW903	800	5.5	0.05	0.11

A summary of the maximum predicted total vertical subsidence, tilt and curvatures after the mining of LW901 to LW903 is provided in Table 1.4. The values provided in this table are the accumulated movements due to the extraction of all longwalls.

Table 1.4 Maximum predicted total vertical subsidence, tilt and curvature after the extraction of LW901 to LW903

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 LW903	1100	6.5	0.06	0.12

The maximum predicted total tilt after the extraction of LW903 is 6.5 mm/m (i.e. 0.65 %, or 1 in 154). The maximum predicted total curvatures are 0.06 km^{-1} hogging and 0.12 km^{-1} sagging, which represents minimum radii of curvature of 17 km and 8 km, respectively.

The predicted conventional (i.e. typical) strains, based on applying a factor of 15 to the predicted conventional curvatures, are 1 mm/m tensile and 2 mm/m compressive. However, the measured strains can exceed these conventional values due to irregular movements or localised effects.

The predicted strains for the longwalls in Area 9 were determined based on a statistical analysis of ground monitoring data from Appin and other nearby collieries. The maximum predicted strains were 1.0 mm/m tensile and 1.7 mm/m based on the 95 % confidence levels, and 1.7 mm/m tensile and 3.4 mm/m compressive based on the 99 % confidence levels.

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 extraction of Appin LW903 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, sewer horizontal bore and Douglas Park Station;
- Camden Road monitoring line;
- Menangle Road monitoring line;
- Telstra optical fibre cable monitoring line;
- Nepean River closure lines;
- Harris Creek Cliff Line closure lines;
- Blades Bridge monitoring points;
- Far-field monitoring points;
- Nepean Twin Bridges monitoring points and bridge joint monitoring;
- Moreton Park Road Bridge South monitoring points; and
- ALS / LiDAR surveys.

The locations of the ground monitoring lines and ground monitoring points are shown in Drawing No. MSEC1176-01, in Appendix A. Comparisons between the measured and predicted subsidence effects at these monitoring lines and points are provided in the following sections. The predicted subsidence effects have been obtained using the IPM based on the standard prediction curves for the Southern Coalfield Bulli Coal Seam.

2.2. Main Southern Railway

The Main Southern Railway crosses directly above the previously extracted LW901, as shown in Drawings Nos. MSEC1176-01 to MSEC1176-03, in Appendix A. Monitoring associated with the railway includes the:

- ARTC monitoring line;
- automated track monitoring;
- embankment monitoring points;
- cutting monitoring points;
- culvert monitoring points;
- sewer horizontal bore monitoring points; and
- Douglas Park Station monitoring points.

The monitoring results and discussions are provided in weekly subsidence monitoring review reports for the railway (Reports Nos. MSEC1070-R01 to MSEC1070-R81), which were issued during the extraction of LW903, between November 2019 and June 2021.

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

2.2.1. ARTC monitoring line

The ARTC monitoring line follows the Main Southern Railway directly above the previously extracted LW901. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the ARTC monitoring line during LW903 is provided in Table 2.1.

Table 2.1 Survey dates for the ARTC monitoring line during LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Start and end of LW903, with monthly 3D surveys, and weekly 2D focused surveys	26 September 2017 (end of LW901) 20 May 2019 (end of LW902) 4 Nov 2019; then approximate weekly surveys to 19 May 2021 (end of LW903)	As per approved LW904 monitoring program

The measured and predicted incremental vertical subsidence along the ARTC monitoring line due to the mining of LW903 only are illustrated in Fig. 2.1.

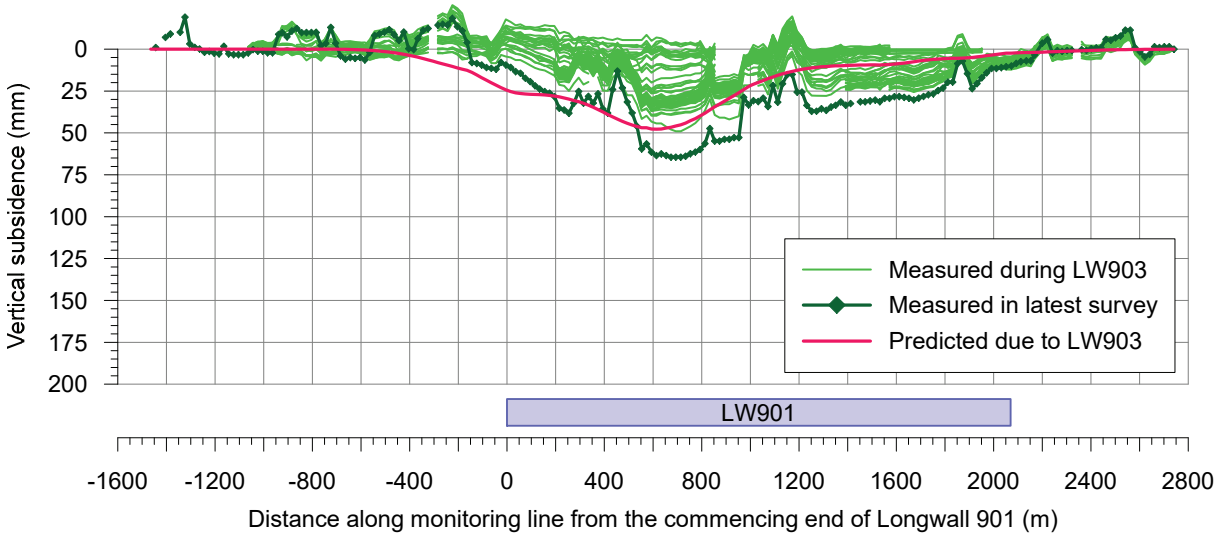

Fig. 2.1 Measured and predicted incremental vertical subsidence along the ARTC line due to the mining of LW903 only

The maximum measured and predicted vertical subsidence occur directly above the existing LW901 where the monitoring line is located closest to the active LW903. There is some variability in the measured profile which could be partly due to disturbed survey marks. Low level uplift was observed west of the commencing end of LW901; however, this movement is in the order of survey tolerance for absolute level.

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 LW903 only.

Table 2.2 Maximum measured and predicted incremental subsidence effects for the ARTC monitoring line due to the mining of LW903 only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm)	Maximum incremental tensile strain (mm/m)	Maximum incremental compressive strain (mm/m)
Measured	64	1.2	0.4	0.6
Predicted	50	< 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 64 mm is greater than the maximum predicted value of 50 mm. However, the exceedance of 14 mm is within the order of accuracy of the prediction method of ±50 mm at low levels of vertical subsidence. Away from the location of maximum vertical subsidence, elsewhere above LW901, the measured movement is greater than that predicted. However, the exceedance is in the order of accuracy of the prediction method.

The maximum measured incremental tilt of 1.2 mm/m is greater than the maximum predicted value of less than 0.5 mm/m. However, the greatest measured tilts are localised movements where there is variability in the measured vertical subsidence profile along the monitoring line. Away from these locations, the measured macro/global tilt is similar to that predicted.

The maximum measured strains are 0.4 mm/m tensile and 0.6 mm/m compressive. The 95th percentiles for the measured incremental strains for the survey bays located directly above the mining area are less than 0.25 mm/m tensile and compressive, i.e. in the order of survey tolerance.

The vectors of horizontal movement along the ARTC monitoring line are shown in Drawing No. MSEC1176-04. Discussions on these movements have been included in Section 2.9.

2.2.2. Automated track monitoring

Rail stress transducers are located along all four rails of the railway, spaced every 25 m to 60 m. The transducers measured changes in rail stress every 5 minutes during the mining of LW903. The results and discussions on rail stress were provided in the reports by Pidgeon Civil Engineering (PCE) attached to the weekly subsidence monitoring review reports. While some false alarms were triggered during mining due to malfunction or damage to transducers, actual mining-induced stress readings did not exceed trigger levels.

2.2.3. 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 extracted 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 extracted 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.

Fixed-in place inclinometers, piezometers and extensometers have also been installed at the embankments at 74.7 km and 75.7 km. The results and discussions on these monitoring systems were provided in the reports by Lambert Geotech attached to the weekly subsidence monitoring review reports. Only minor changes were recorded during the mining of LW903. While some false alarms were triggered during mining due to malfunction or damage to sensors, actual measured changes did not exceed trigger levels.

2.2.4. 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 extracted 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 extracted 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 LW903, with no adverse impacts observed on the cuttings themselves.

2.2.5. Culvert monitoring points

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

The subsidence effects at the culverts 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.

2.2.6. Douglas Park Station monitoring points

Douglas Park Station is located immediately to the east of the finishing end of the previously extracted LW901 and south of the finishing end of the previously extracted 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. Camden Road monitoring line

The Camden Road monitoring line is located to the east of LW903, at a minimum distance of approximately 200 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 Camden Road monitoring line during LW903 is provided in Table 2.3.

Table 2.3 Survey dates for the Camden Road monitoring line during LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the active subsidence; weekly surveys after longwall chainage of 400 m; and final survey after completion of LW903	3 October 2017 (end of LW901) 6 May 2019 (end of LW902) 8 December 2020, 6 January 2021, 2 February 2021, 18 February 2021, then approximate weekly surveys to 7 April 2021 and then 29 April 2021 (end of LW903)	As per approved LW904 monitoring program

The measured incremental vertical subsidence along the Camden Road monitoring line due to the mining of LW903 only is illustrated in Fig. 2.2. Positive values are net downward movements and negative values are net uplift.

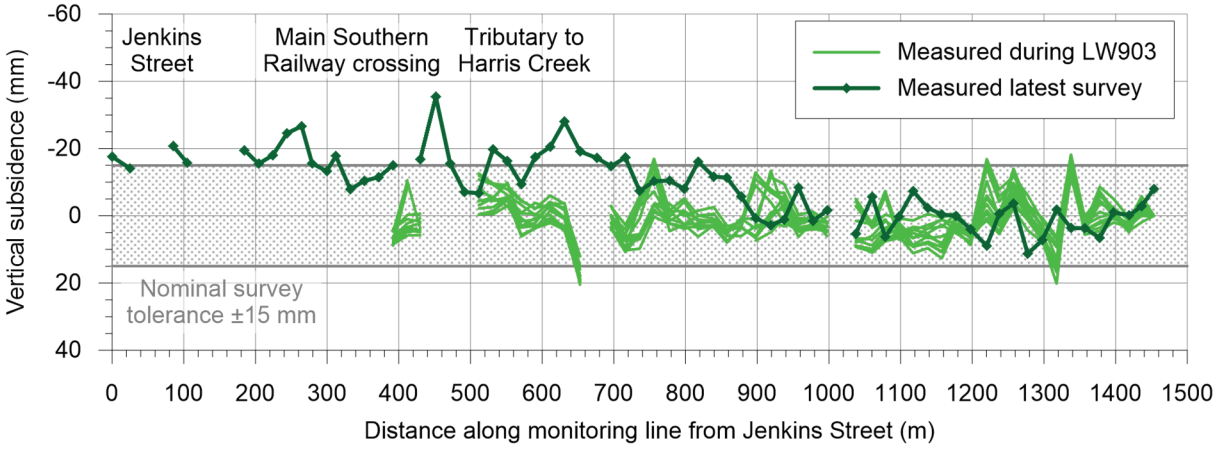

Fig. 2.2 Measured incremental vertical subsidence along the Camden Road line due to the mining of LW903 only

The measured incremental vertical subsidence along the Camden Road monitoring line is typically less than ±15 mm which is in the order of survey tolerance for absolute level. In the latest survey, uplift has been measured along the southern part of the monitoring line, i.e. between Jenkins Street and the tributary to Harris Creek. Low-level up lift was also measured during the mining of the previous LW901 and LW902. However, there is variability in these measured movements and it is possible that some survey marks have been disturbed.

The measured incremental vertical subsidence (i.e. net downward movement) along the Camden Road monitoring line due to LW903 is less than 15 mm and, therefore, is in the order of survey tolerance for absolute level. The measured incremental strains are typically less than 0.3 mm/m tensile and compressive and, therefore, are similar to the order of survey tolerance.

The vectors of horizontal movement along the Camden Road monitoring line are shown in Drawing No. MSEC1176-04. Discussions on these movements have been included in Section 2.9.

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. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Menangle Road monitoring line during LW903 is provided in Table 2.4.

Table 2.4 Survey dates for the Menangle Road monitoring line during LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the active subsidence; monthly 3D surveys from start until longwall chainage of 800 m; and final survey after completion of LW903	3 May 2018 (base survey) 16 May 2019 (end of LW902) 6 November 2019 then approximate weekly surveys to 13 May 2021 (end of LW903)	As per approved LW904 monitoring program

The measured and predicted total vertical subsidence along the Menangle Road monitoring line due to the mining of LW902 and LW903 are illustrated in Fig. 2.3. The movements measured during the mining of LW902 and LW903 are shown by the cyan and green lines, respectively. It is noted that the monitoring line was extended east of Mark MR9081 (i.e. approximate distance of 1600 m), with a baseline survey completed on 9 January 2020 and, therefore, there is a survey discontinuity in the results at that location.

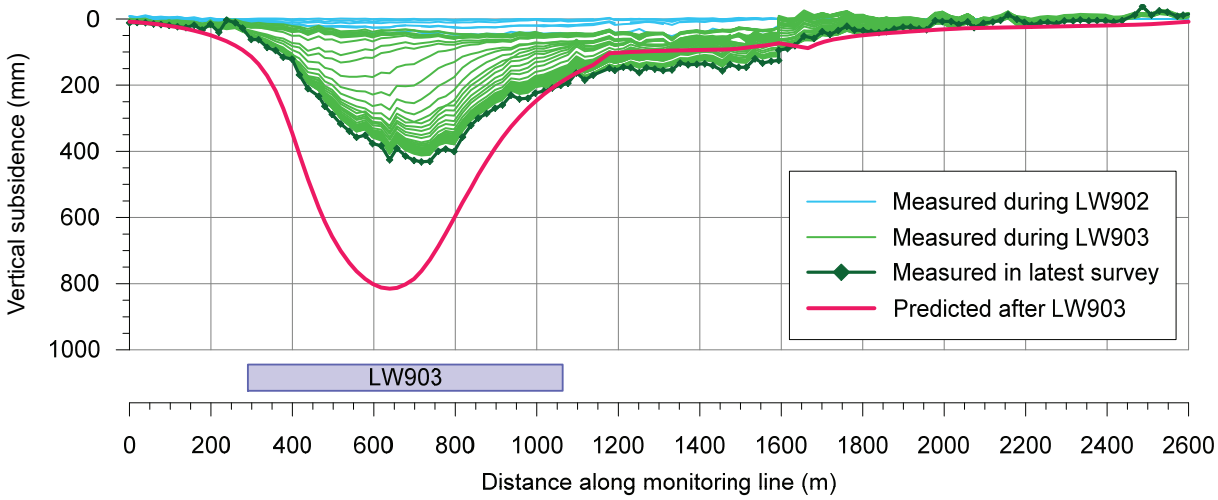

Fig. 2.3 Measured and predicted total vertical subsidence along the Menangle Road monitoring line due to the mining of LW902 and LW903

The maximum measured and predicted vertical subsidence occurs directly above LW903. The vertical subsidence measured above the longwall is less than that predicted. The measured vertical subsidence is greater than predicted north of LW903 (i.e. above solid coal); however, the exceedance is in the order of 50 mm which is in the order of accuracy of the subsidence predictions outside the mining area.

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 and LW903.

Table 2.5 Maximum measured and predicted total subsidence effects for the Menangle Road monitoring line due to the mining of LW902 and LW903

Type	Maximum total vertical subsidence (mm)	Maximum total tilt (mm)	Maximum total tensile strain (mm/m)	Maximum total compressive strain (mm/m)
Measured	432	2.6	1.0	3.0
Predicted	800	3.5	*- 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 vertical subsidence of 432 mm is approximately half and the maximum predicted value of 800 mm. The measured movement could be less than that predicted due to greater end effects where the monitoring line is located close to the longwall commencing end. The maximum measured tilt of 2.6 mm/m is less than the maximum predicted value of 3.5 mm/m. The maximum tilt occurs adjacent to the commencing end of LW903.

The maximum measured total strains are 1.0 mm/m tensile and 3.0 mm/m compressive. The maximum predicted total conventional strains, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1 mm/m tensile and 2 mm/m compressive. The maximum measured compressive strain of 3.0 mm/m is therefore greater than the maximum predicted value of 2 mm/m based on conventional ground movements. However, it was noted in Reports Nos. MSEC448, MSEC829 and MSEC1005 that the measured strains can exceed the predicted values based on conventional movements due to anomalous ground movements or valley related effects.

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

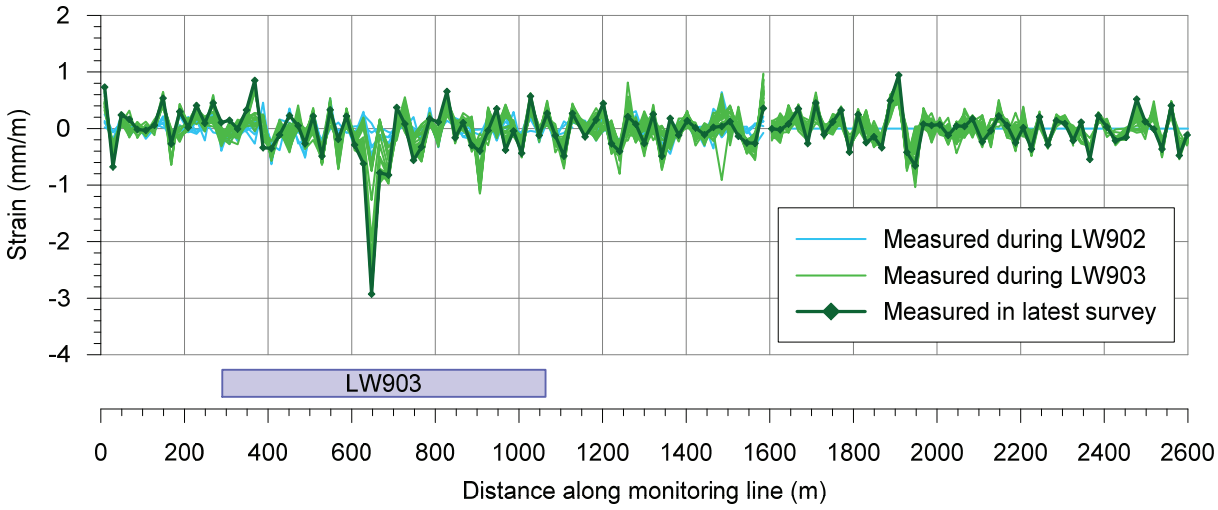

Fig. 2.4 Measured total strain along the Menangle Road monitoring line due to the mining of LW902 and LW903

The maximum measured compressive strain occurs directly above LW903. There is a drainage line close to this location and, therefore, the localised movement could include anomalous or valley-related effects. As shown in Fig. 2.5, the compressive strain developed gradually between January and February 2020.

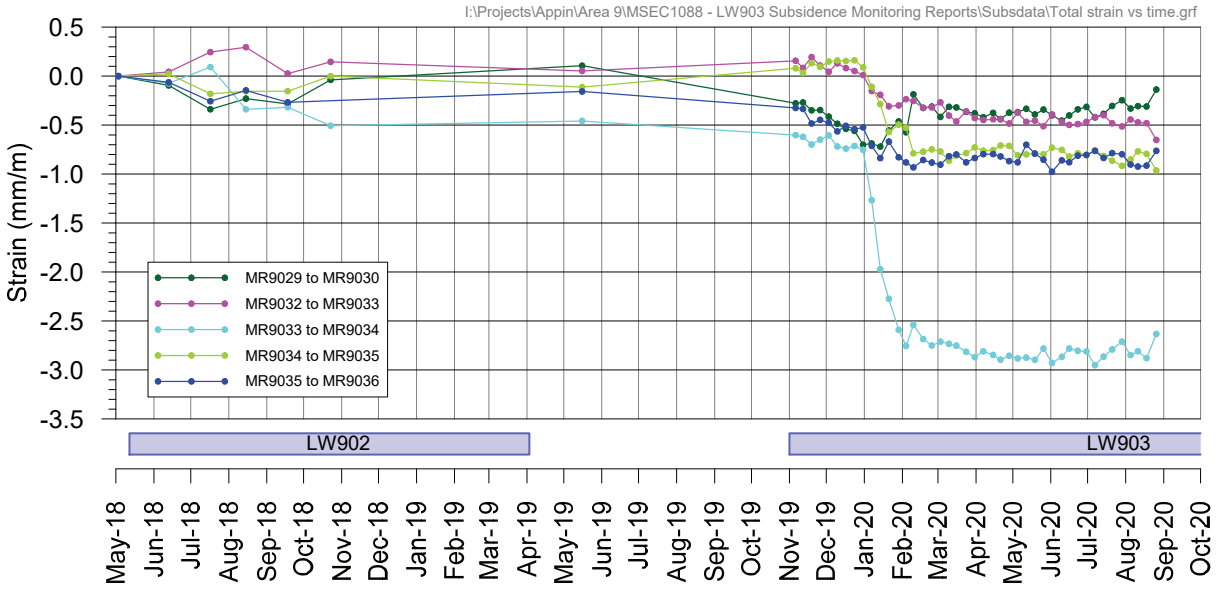

Fig. 2.5 Measured development of total strain over time along the Menangle Road monitoring line during the mining of LW902 and LW903

The 95th percentiles for the measured total strains for the survey bays located directly above the mining area are 0.6 mm/m tensile and 1.0 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 0.9 mm/m tensile and 1.6 mm/m compressive. The measured strains based on the 95th percentiles, therefore, are less than the predicted strains based on the 95 % confidence levels.

The vectors of horizontal movement along the Menangle Road monitoring line are shown in Drawing No. MSEC1176-04. Discussions on these movements have been included in Section 2.9.

2.5. Telstra optical fibre cable line

The Telstra Optical Fibre Cable (OFC) monitoring line is located outside and adjacent to the commencing end of LW903. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Telstra OFC monitoring line during LW903 is provided in Table 2.6.

Table 2.6 Survey dates for the Telstra OFC monitoring line during LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW903; fortnightly 2D surveys for the first 300 m of extraction, then monthly 3D surveys between 300 m and 500 m of extraction; and final survey after completion of LW903	26 September 2017 (end of LW901) 20 May 2019 (end of LW902) 28 October 2019 then approximate fortnightly surveys to 10 December 2019 and then approximate monthly surveys to 22 December 2020 (end of LW903)	As per approved LW904 monitoring program

The measured and predicted total vertical subsidence along the Telstra OFC monitoring line due to the mining of LW901 to LW903 is illustrated in Fig. 2.6. The movements measured during the mining of LW901, LW902 and LW903 are shown by the cyan, olive and green lines, respectively.

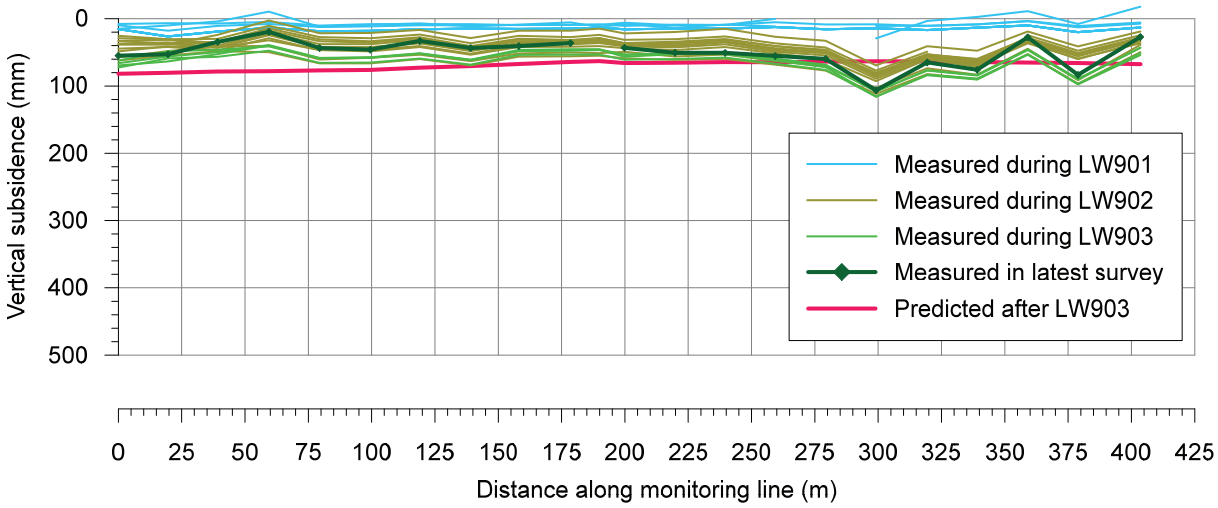

Fig. 2.6 Measured and predicted total vertical subsidence along the Telstra OFC line due to the mining of LW901 to LW903

Low level subsidence (i.e. typically less than 100 mm) was measured and predicted along the Telstra OFC monitoring line due to the mining of LW901 to LW903. The measured vertical subsidence is greater than the predicted values in some locations; however, the exceedances are within the order of accuracy of the prediction method of ±50 mm at low levels of vertical subsidence.

The measured total strain along the Telstra OFC monitoring line due to the mining of LW901 to LW903 is illustrated in Fig. 2.7. The movements measured during the mining of LW901, LW902 and LW903 are shown by the cyan, olive and green lines, respectively.

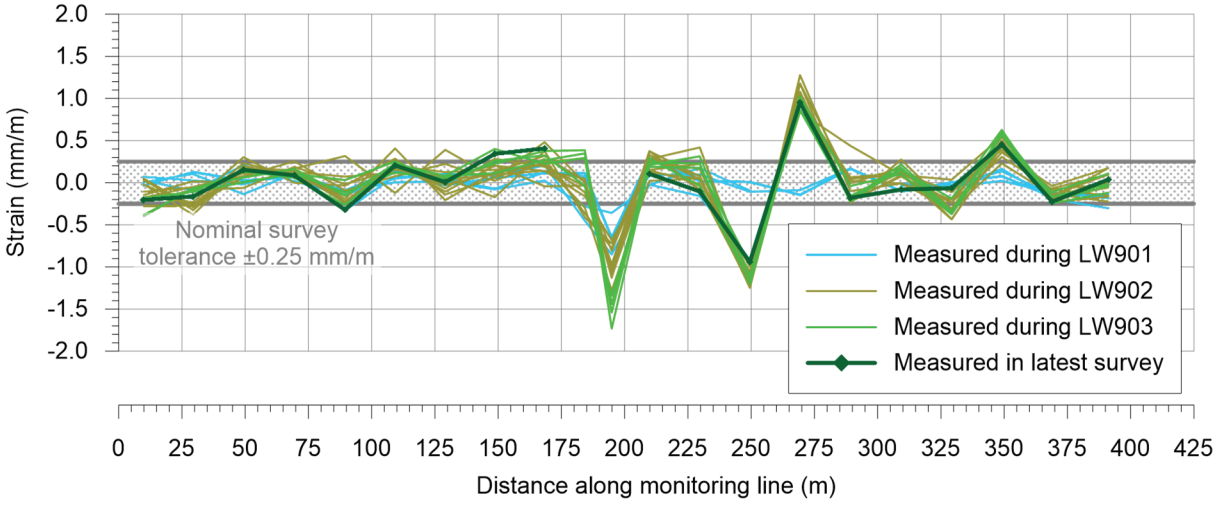

Fig. 2.7 Measured total strain along the Telstra OFC line due to the mining of LW901 to LW903

The maximum measured total strains are 1.3 mm/m tensile and 1.7 mm/m compressive. The maximum predicted total conventional strains, based on applying a factor of 15 to the maximum predicted conventional curvatures, are less than 0.5 mm/m tensile and compressive. The maximum measured strains are therefore greater than the maximum predicted values based on conventional ground movements. However, it was noted in Reports Nos. MSEC448, MSEC829 and MSEC1005 that the measured strains can exceed the predicted values based on conventional movements due to anomalous ground movements or valley related effects.

The 95th percentiles for the measured total strains along the Telstra OFC monitoring line are 0.6 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) outside the mining area are 0.6 mm/m tensile and 0.5 mm/m compressive. The measured tensile strain based on the 95th percentile, therefore, is similar to the predicted strain based on the 95 % confidence level. The measured compressive strain is greater than the predicted value; however, the is partly due to the limited sample size, i.e. 21 survey bays. The monitoring line also crosses a small drainage line and, therefore, could also include valley-related effects.

The vectors of horizontal movement along the Telstra OFC monitoring line are shown in Drawing No. MSEC1176-04. Discussions on these movements have been included in Section 2.9.

2.6. Nepean River closure lines

The Nepean River is located 850 m south-west of LW903 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. A summary of the survey dates for the Nepean River closure lines during LW903 is provided in Table 2.7.

Table 2.7 Survey dates for the Nepean River closure lines during LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW903; monthly surveys during mining; and final survey after completion of LW903	11 September 2017 (end of LW901) 16 April 2019 (end of LW902) 18 December 2019 and then approximate monthly surveys to 7 May 2021 (end of LW903)	As per approved LW904 monitoring program

The predicted closures were originally determined using the method outlined in ACARP Research Projects Nos. C8005 and C9067. However, the predicted values were exceeded at each of the monitoring lines due to the mining of LW901. The predictions for these monitoring lines were therefore revised at the completion of LW901 using the available ground monitoring data from the Southern Coalfield.

The predicted incremental closures for each of the monitoring lines, due to the extraction of LW902 and LW903, have then been derived from the measured values due to the mining of LW901, the relative distances from the longwalls and the shapes of the confidence levels fitted to the measured data.

The measured and predicted total closure movements at each of the Nepean River closure lines along the Nepean River are illustrated in Fig. 2.8. The movements measured during the mining of LW901, LW902 and LW903 are shown by the cyan, olive and green lines, respectively

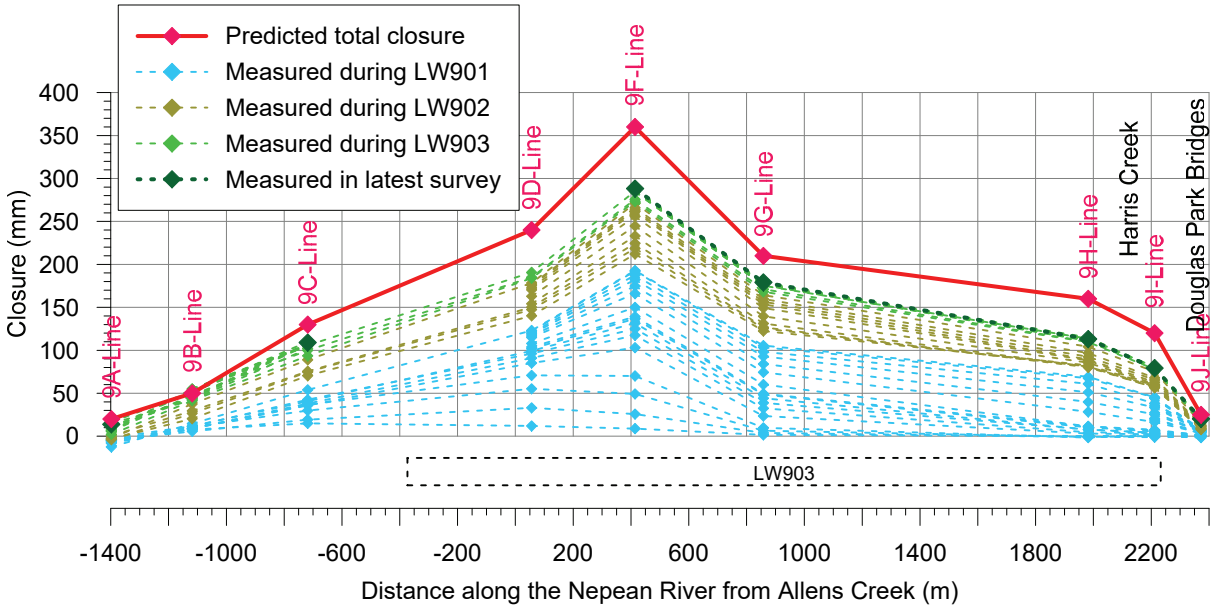

Fig. 2.8 Measured and predicted total closure along the Nepean River due to the mining of LW901 to LW903

A summary of the measured and predicted total closure movements for each of the Nepean River closure lines is provided in Table 2.8. The values are the maximum accumulated movements due to the mining of LW901 to LW903.

Table 2.8 Measured and predicted total closure for the Nepean River lines due to LW901 to LW903

Location	Measured total closure (mm)	Predicted total closure (mm)
Nep X 9A-Line	16	20
Nep X 9B-Line	55	50
Nep X 9C-Line	110	130
Nep X 9D-Line	191	240
Nep X 9E-Line	9	160
Nep X 9F-Line	288	360
Nep X 9G-Line	182	210
Nep X 9H-Line	115	160
Nep X 9I-Line	81	120
Nep X 9J-Line	21	25

The measured total closure at the Nep X 9B-Line of 55 mm is slightly greater than the maximum predicted total value of 50 mm. However, this exceedance of 5 mm is in the order of accuracy of the prediction method. Elsewhere, the measured total closures are less than the predicted total values at each of the other monitoring lines. The maximum measured total closure anywhere along the Nepean River of 288 mm is less than the maximum predicted total value of 360 mm and it represents a ratio of approximately 0.80.

2.7. Harris Creek Cliff Line closure lines

The Harris Creek Cliff Line (HCCL) is located approximately 1.2 km south of the finishing end of LW903 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 LW903 is provided in Table 2.9.

Table 2.9 Survey dates for the HCCL closure lines during LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW903; monthly surveys during mining; and final survey after completion of LW903	10 April 2018 (end of LW901) 7 June 2019 (end of LW902) 13 November 2019 and then approximate monthly surveys to 24 November 2020 and then approximate fortnightly surveys to 11 May 2021 (end of LW903)	As per approved LW904 monitoring program

The development of the measured incremental closure for the HCCL closure lines due to the mining of LW903 is illustrated in Fig. 2.9. Positive values represent net closure and negative values represent net opening.

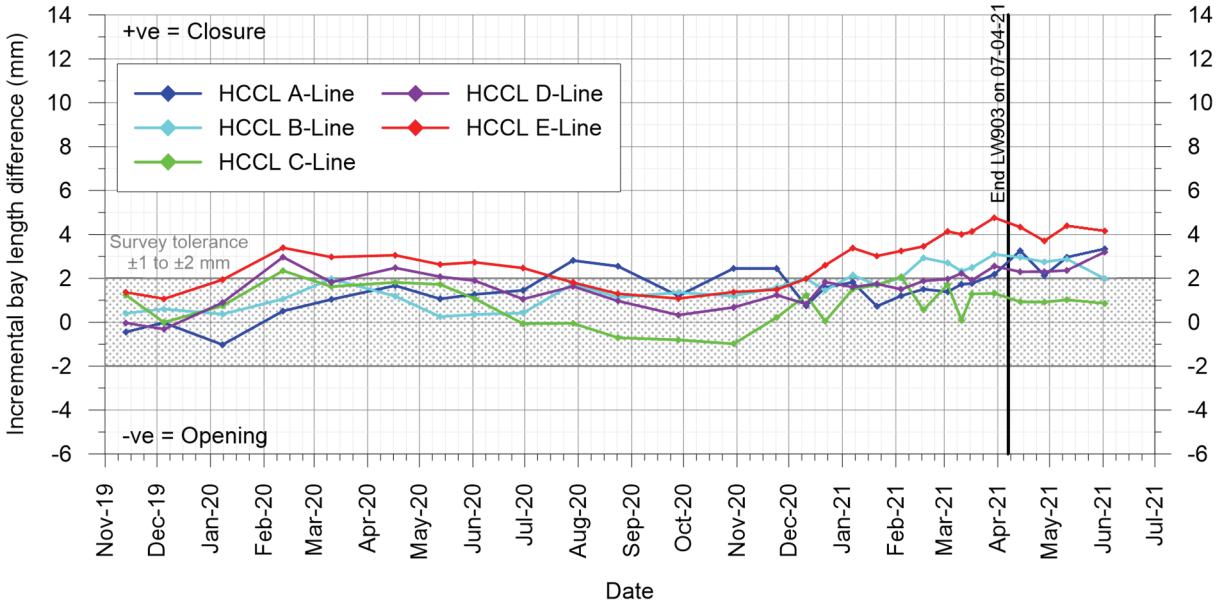

Fig. 2.9 Development of measured incremental closure for the HCCL closure lines due to the mining of LW903

The maximum measured incremental closure due to LW903 is 5 mm at the HCCL E-Line at the southern end of the cliffline. The closure measured at the other monitoring lines varied between 1 mm and 3 mm.

The predicted closures were originally determined using the method outlined in ACARP Research Projects Nos. C8005 and C9067. However, the predicted values were exceeded at each of the monitoring lines due to the mining of LW901. The predictions for these monitoring lines were therefore revised at the completion of LW901 using the available ground monitoring data from the Southern Coalfield.

The predicted incremental closures for each of the monitoring lines, due to the extraction of LW902 and LW903, have then been derived from the measured values due to the mining of LW901, the relative distances from the longwalls and the shapes of the confidence levels fitted to the measured data.

The maximum predicted incremental closure at the HCCL due to the mining of LW903 is 10 mm. The maximum measured incremental closure of 5 mm, therefore, is less than the maximum predicted value.

The development of the measured total closure for the HCCL closure lines due to the mining of LW901 to LW903 is illustrated in Fig. 2.10. Positive values represent net closure and negative values represent net opening.

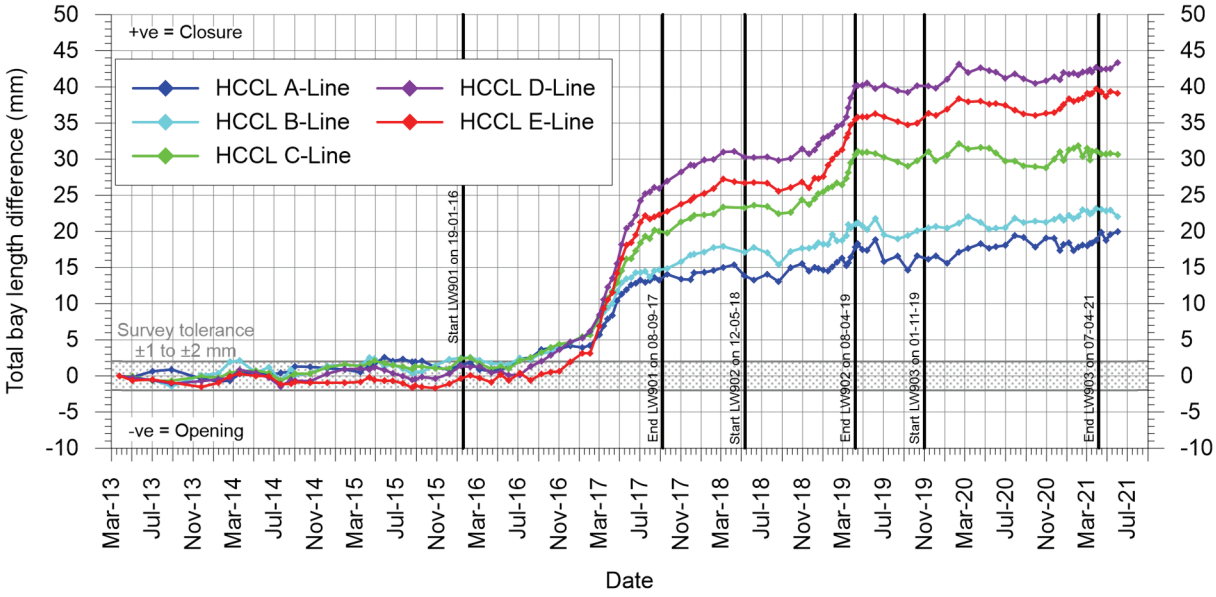

Fig. 2.10 Development of measured total closure for the HCCL due to the mining of LW901 to LW903

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 LW903.

Table 2.10 Measured and predicted total closure for the HCCL closure lines due to LW901 to LW903

Location	Measured total closure (mm)	Predicted total closure (mm)
HCCL A-Line	20	50
HCCL B-Line	22	
HCCL C-Line	31	
HCCL D-Line	43	
HCCL E-Line	39	

The maximum measured total closure due to the mining of LW901 to LW903 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 LW903 are less than the maximum predicted value of 50 mm.

2.8. Blades Bridge monitoring points

Blades Bridge crosses Harris Creek and it is located approximately 1.2 km south of the finishing end of LW903 at its closest point. The horizontal distance across Blades Bridge has been measured using two prisms fixed to the abutments of bridge located on its northern side. A summary of the survey dates for Blades Bridge during LW903 is provided in Table 2.11.

Table 2.11 Survey dates for Blades Bridge during LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW903; monthly surveys during mining; and final survey after completion of LW903	11 May 2018 (end of LW901) 7 June 2019 (end of LW902) 13 November 2019 and then approximate monthly surveys to 24 November 2020 and then approximate fortnightly surveys to 11 May 2021 (end of LW903)	As per approved LW904 monitoring program

The measured incremental closure at Blades Bridge due to the mining of LW903 only is illustrated in Fig. 2.11. The measured closure at the nearby HCCL A-Line is also shown in this figure for comparison.

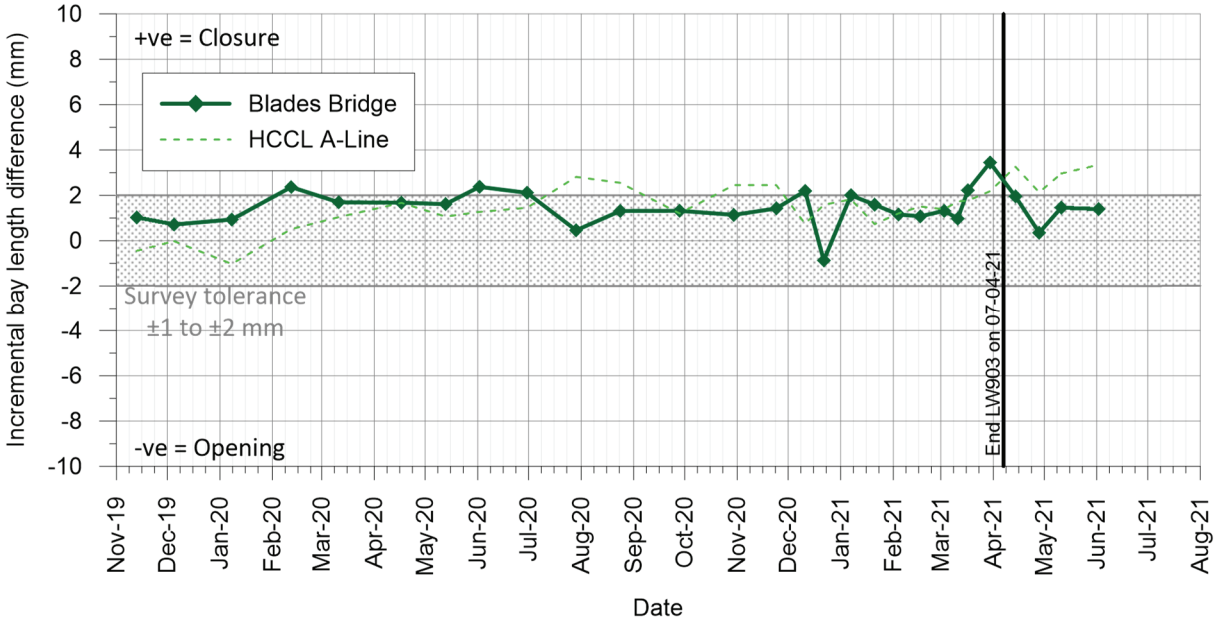

Fig. 2.11 Measured incremental closure at Blades Bridge due to the mining of LW903 only

The measured incremental closure at Blades Bridge due to the mining of LW903 only is 2 mm. Measured movements slightly greater than 2 mm were measured during the mining of LW903; however, it is likely that these were affected by disturbed survey marks. The final incremental closure at the completion of LW903 is in the order of survey tolerance and, therefore, is not measurable.

2.9. 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 and along the ARTC, Camden Road, Menangle Road and Telstra OFC monitoring lines. Infrastructure along the Main Southern Railway were also measured in absolute 3D, including at the culverts, cuttings and embankments.

The survey dates for the AA9 far-field marks during the mining of LW903 are provided in Table 2.12. The survey dates for the ARTC, Camden Road and Telstra OFC monitoring lines are provided in Sections 2.2, 2.3 and 2.5, respectively.

Table 2.12 Survey dates for the AA9 far-field marks for LW903

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW903; monthly surveys during mining; and final survey after completion of LW903	12 September 2017 (end of LW901) 2 May 2019 (end of LW902) 17 December 2019 and then approximate monthly surveys to 7 May 2021 (end of LW903)	As per approved LW904 monitoring program

The measured incremental horizontal movement vectors for the AA9 far-field marks and the ARTC, Camden Road, Menangle Road and Telstra OFC monitoring lines are shown in Drawing No. MSEC1176-04. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±10 mm.

The vectors of horizontal movement are generally orientated towards the south to south-east and are likely to have been influenced by the Nepean River valley and, to a lesser extent, Harris Creek. The regional horizontal movements for the marks located to the north of the Nepean River and to the west of Harris Creek were also orientated towards the south-east.

The comparison between the measured incremental far-field horizontal movements due to the mining of LW903 and those measured elsewhere in the Southern Coalfield is provided in Fig. 2.12. The x-axis represents the distance from the active longwall.

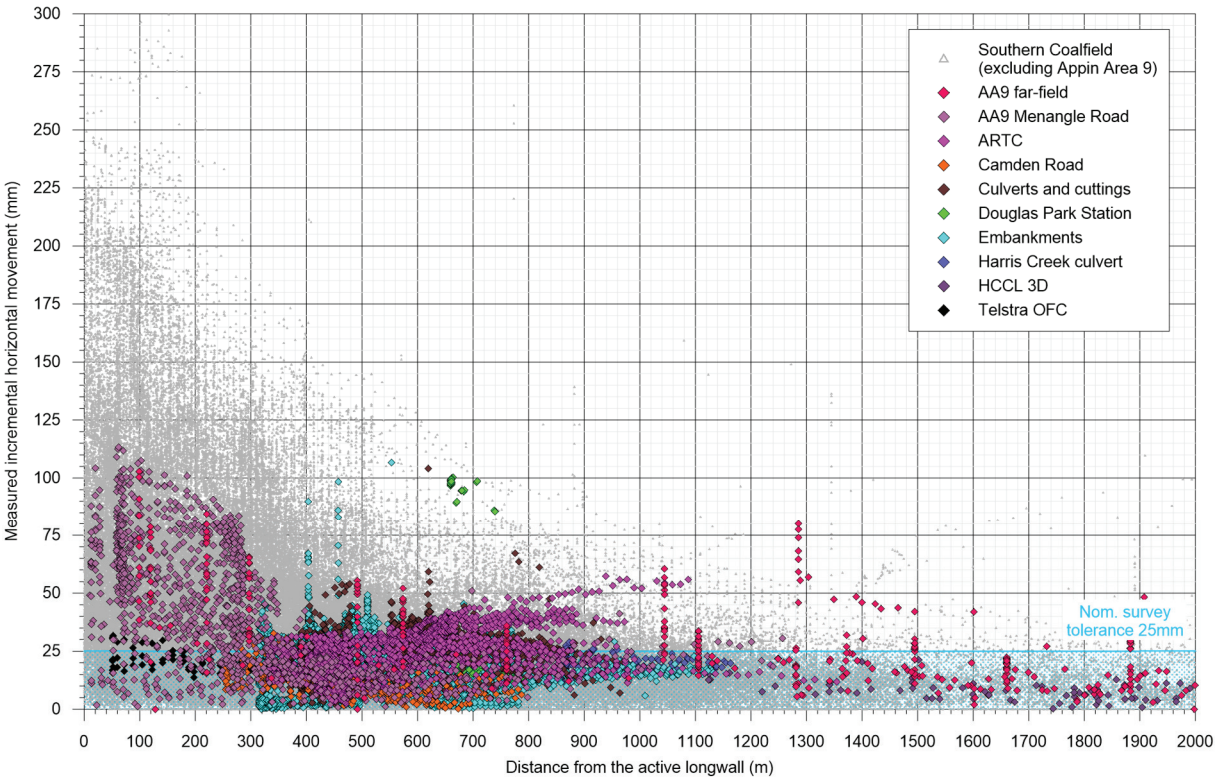

Fig. 2.12 Measured incremental far-field horizontal movements due to the mining of LW903

The measured incremental horizontal movements due to the mining of LW903 are generally within the range of movements that have been measured elsewhere in the Southern Coalfield. The horizontal movements measured at some far-field 3D marks (i.e. red diamonds in Fig. 2.12) are at the upper end of this range where they are located on the sides and at the top of Razorback Range. Higher movements are also measured along the ARTC monitoring line and the Douglas Park Station monitoring points possibly due to their proximity to the Nepean River valley.

The maximum measured incremental horizontal movement due to the mining of LW903 is 113 mm along the Menangle Road monitoring line where it is located closest to the longwall. The horizontal movements at distances greater than approximately 1.5 km from LW903 are generally less than 25 mm and, therefore, are in the order of survey tolerance for absolute position.

2.10. Nepean Twin Bridges monitoring points

The Nepean Twin Bridges are located approximately 1.6 km south of the finishing end of LW903. These bridges experienced far-field movements due to the mining of LW903 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;
- inclinometer monitoring;
- bridge joint monitoring; and
- visual monitoring.

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

2.10.1. 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 2.9.

The absolute horizontal movements at Marks DPBN and DPBS have been measured during mining in Appin Area 7, since the 15 October 2007, and during LW901 to LW903. The development of total horizontal movements for these marks, plotted from the start of April 2014, is shown in Fig. 2.13.

Global Navigation Satellite System (GNSS) units were installed at the ends of 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. 2.13. Greater variation was 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. MSEC1176-04, in Appendix A. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±20 mm. It can be seen that the southern end of the bridge has moved slightly further northwards than the northern end.

The measured incremental horizontal movements at Marks DPBN and DPBS, at the completion of LW903, are 6 mm and 11 mm, respectively. The vectors were orientated towards the west.

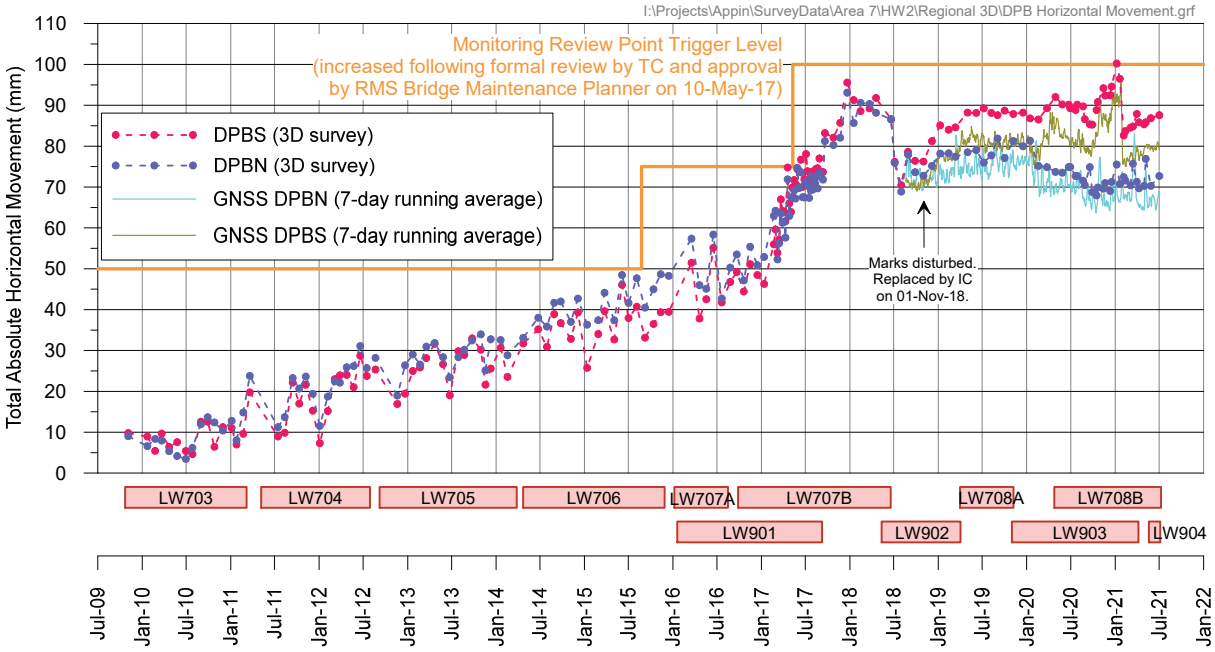

Fig. 2.13 Measured total absolute movements at Marks DPBN and DPBS due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks DPBN and DPBS remained below the Monitoring Review Point Trigger, as shown in Fig. 2.13. A summary of the maximum measured absolute horizontal movements at Marks DPBN and DPBS, measured on 9 April 2021 after the completion of LW903, 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 LW903.

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. 2.14. The nominal survey accuracy is ±3 mm.

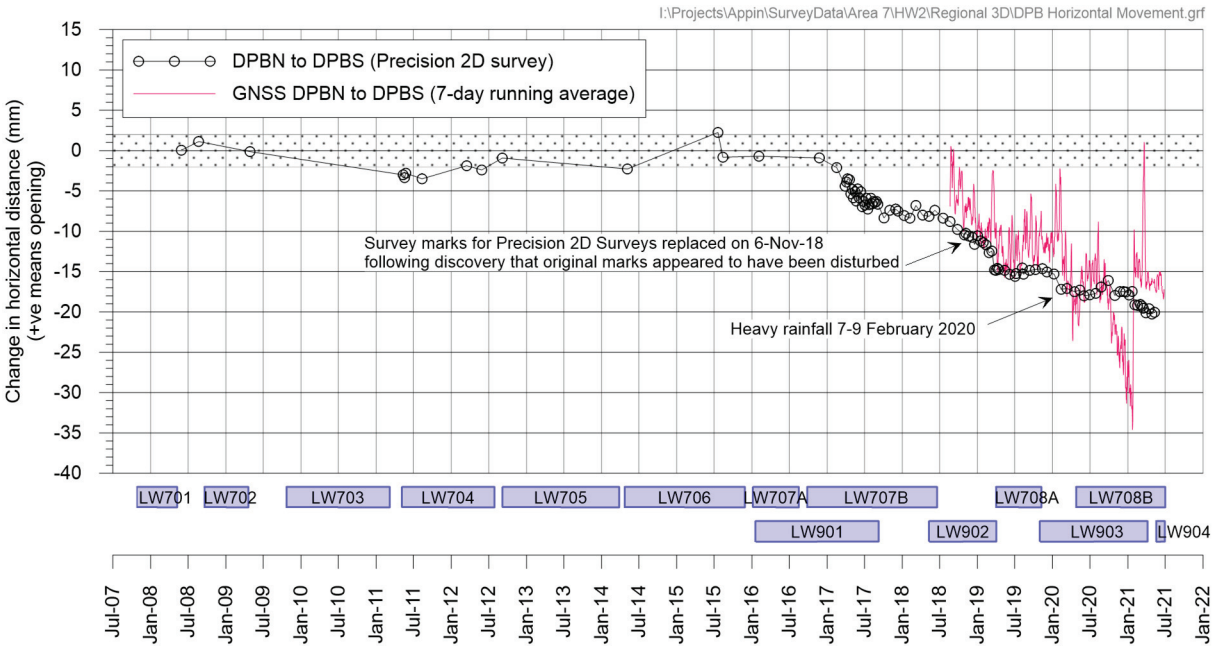

Fig. 2.14 Measured total valley closure at the Nepean Twin Bridges

The measured incremental closure at the completion of LW903 was 5 mm. The results of the GNSS units have been overlaid with the absolute 3D and precision 2D survey results in in Fig. 2.14. 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.

2.10.2. Relative 3D monitoring points

The subsidence effects of 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. 2.15 and Fig. 2.16 (Source: IMC).

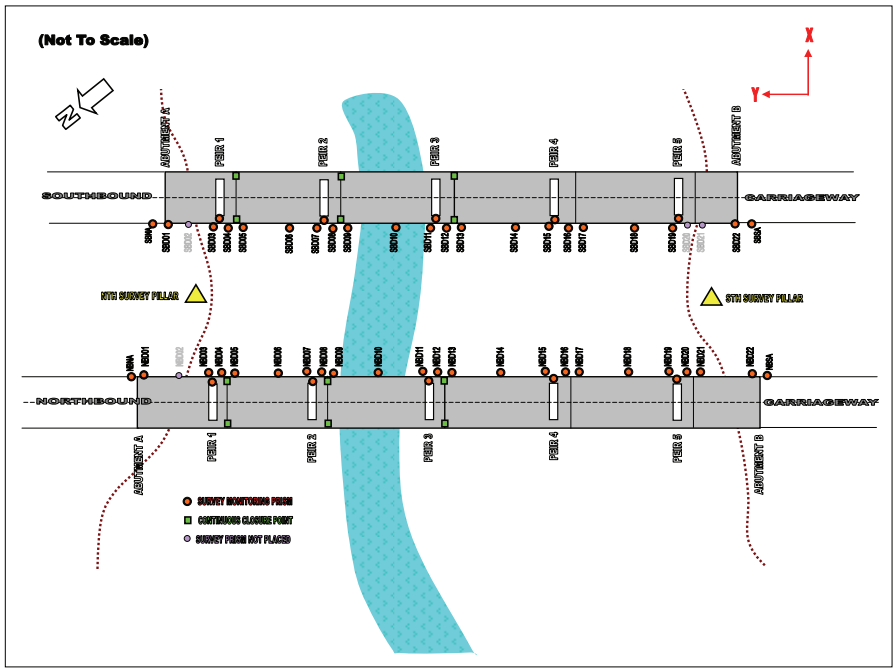

Fig. 2.15 Plan of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IMC)

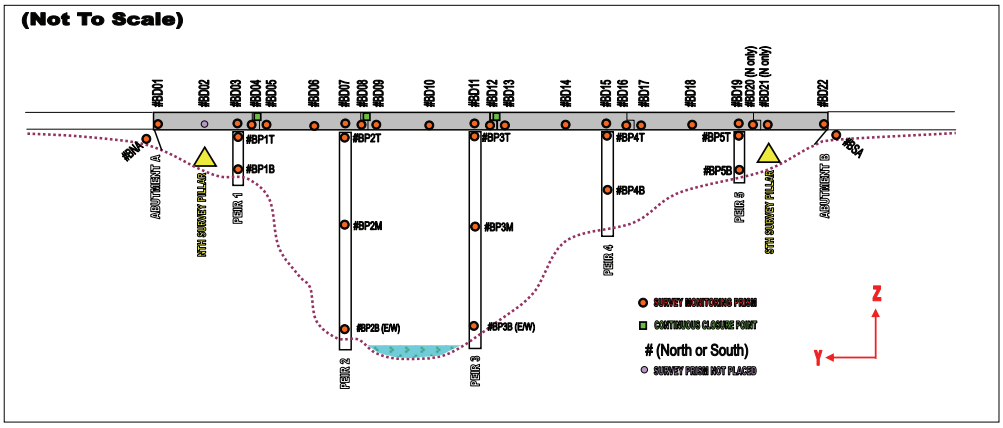

Fig. 2.16 Elevation of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IMC)

The changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges have been measured during mining in Appin Area 7, since the 15 October 2007, and during LW901 to LW903. The development of total changes in horizontal distance between the marks, plotted from the start of April 2014, is shown in Fig. 2.17. The nominal survey accuracy is ±2 mm.

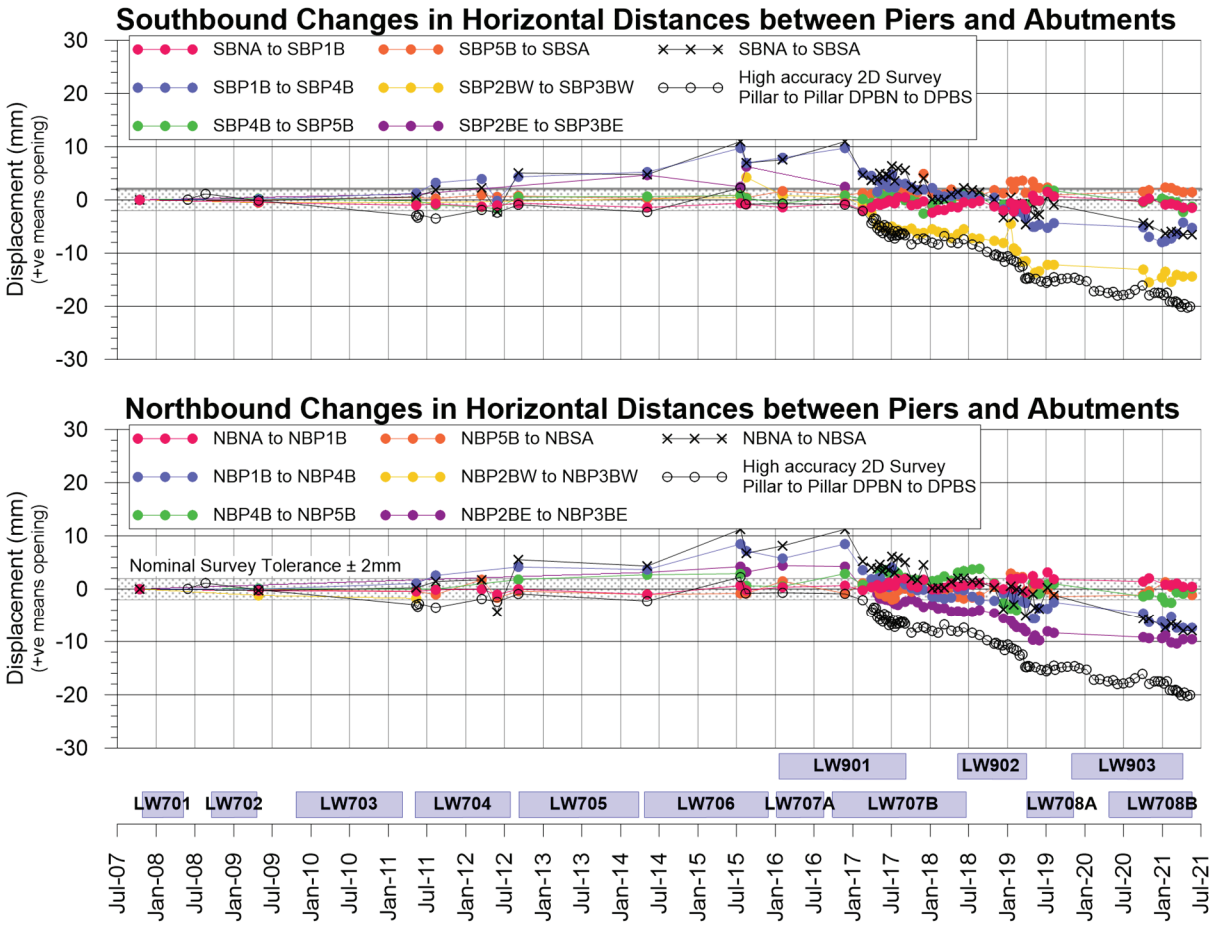

Fig. 2.17 Measured total changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges

It can be seen that observed closure measured across the ends of the bridges has concentrated between Piers 2 and 3 at the bases of the bridges. Very little change in distance was measured between the piers and abutments during the mining of LW903.

Measured changes in the lateral direction of the base of the Southbound and Northbound Bridges are close to survey tolerance, as shown in Fig. 2.18. 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 LW903. Minimal change in lateral alignment has been observed in the bridge deck.

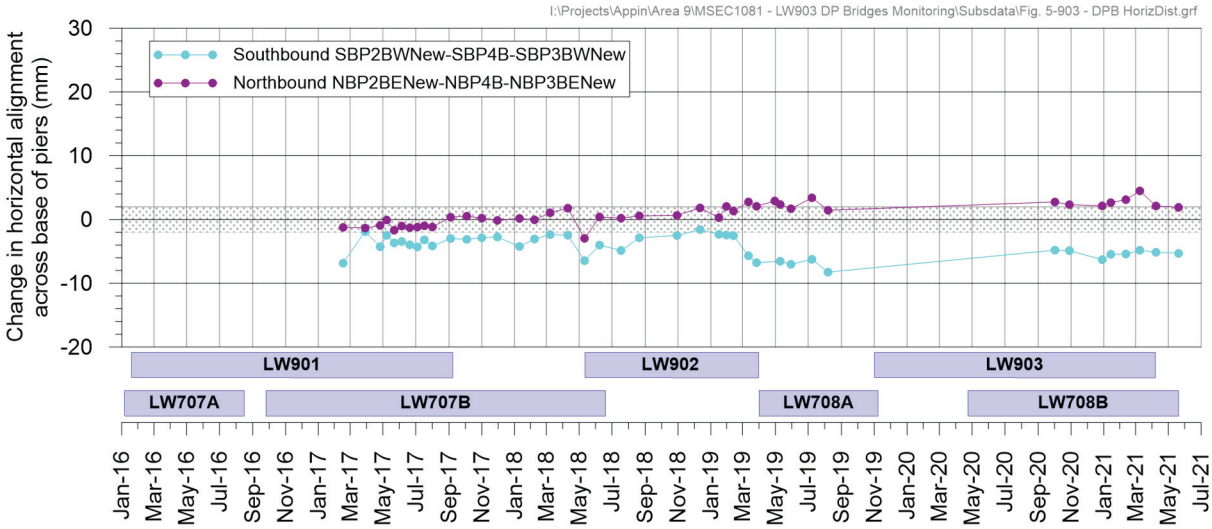

Fig. 2.18 Changes in horizontal alignment across the base of the piers

2.10.3. Inclinometer monitoring

The differential movements at the manual inclinometers (RST) and Shape Accelerometer Array (SAA) inclinometers at Site PSM6, located near the Nepean Twin Bridges, were monitored during the extraction of LW903 and the concurrent mining in the adjacent Appin Area 7. The inclinometers were installed and maintained by Pells Sullivan and Meynink (PSM), measured by IMC and the results interpreted by PSM.

The inclinometers comprise boreholes with plastic casings that allow probes to measure the differential tilt or inclination over the lengths of the boreholes. Further details on the inclinometers and the results were provided in the monitoring reports by PSM numbers PSM883-401L (dated 11 November 2019) through to PSM883-423L (dated 28 April 2021).

Prior to the commencement of LW903, PSM advised in September 2019 that differential movements in inclinometer PSM6 was approaching the 5 mm trigger level. The Technical Committee reviewed the monitoring results on 11 September 2019 and agreed to increase the trigger level from 5 mm to 10 mm on the basis that the observed shear displacements are at a depth of 25.25 m below ground, which has an insignificant effect on the Bridges.

The TARP for the Nepean Twin Bridges, which was developed by the RMS chaired Technical Committee, provided a trigger for differential movements at the inclinometers. A summary of the Level 1 Trigger and the maximum measured total differential movements at the inclinometers, at any time during the extraction of LW903, is provided in Table 2.14.

Table 2.14 Measured differential movements and trigger for the Nepean Twin Bridges inclinometers

Type	Maximum measured differential movement (mm)	Level 1 Trigger (mm)
Differential movement	5.52 (PSM6 – RST) 3.7 (PSM6 – SAA)	10

The measured differential movements at the inclinometers at Site PSM6 did not exceed the revised Level 1 Trigger during the extraction of LW903. The observed movements are at a depth of 25.25 m. Minor changes have been observed since the completion of LW903.

2.10.4. Joint monitoring

Differential movements across the movement joints in the Nepean Twin Bridges were measured by PSM during the extraction of LW903 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 the 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 were provided in monitoring reports by PSM numbers PSM883-401L (dated 11 November 2019) through to PSM883-423L (dated 28 April 2021).

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 LW903, is provided in Table 2.15.

Table 2.15 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 LW903.

2.11. Moreton Park Road Bridge (South) monitoring points

Moreton Park Road Bridge (South) is located approximately 1 km south-east of the finishing end of LW903. 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;
- relative 3D monitoring points; 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 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 2.9.

The vectors of incremental horizontal movement at Marks MPBE and MPBW are shown in Drawing No. MSEC1176-04, 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 LW903, were less than 5 mm. The measured movements, therefore, were similar to the order of survey tolerance.

The absolute horizontal movements at Marks MPBE and MPBW have been measured during mining in Appin Area 7, since the 15 October 2007, and during LW901 to LW903. The development of total horizontal movements for these marks, plotted since the start of April 2014, is shown in Fig. 2.19.

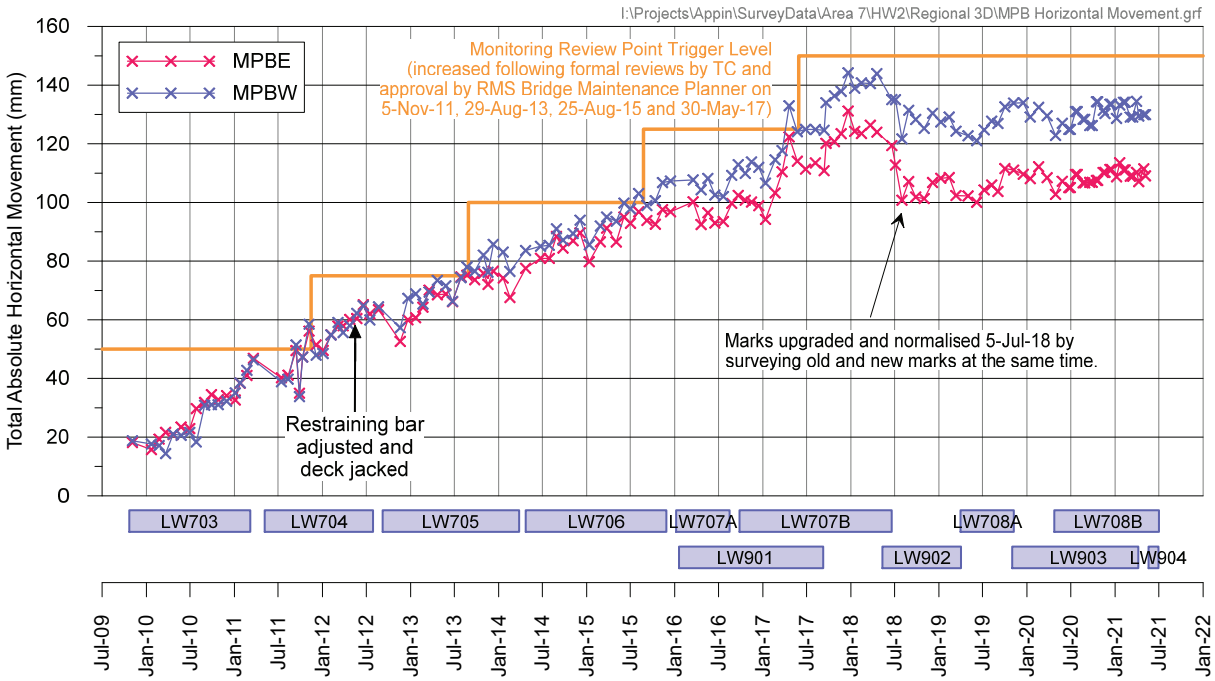

Fig. 2.19 Measured total absolute movements at Marks MPBE and MPBW due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks MPBE and MPBW did not exceed the Monitoring Review Point Trigger during the mining of LW903, as shown in Fig. 2.19.

A summary of the maximum measured absolute horizontal movements at Marks MPBE and MPBW, measured on the 7 May 2021 after the completion of LW903, is provided in Table 2.16.

Table 2.16 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	130	150

The maximum measured absolute horizontal movement at Marks MPBE and MPBW was less than the Level 1 Trigger at the completion of LW903.

2.11.2. 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. 2.20 and Fig. 2.21 (Source: IMC).

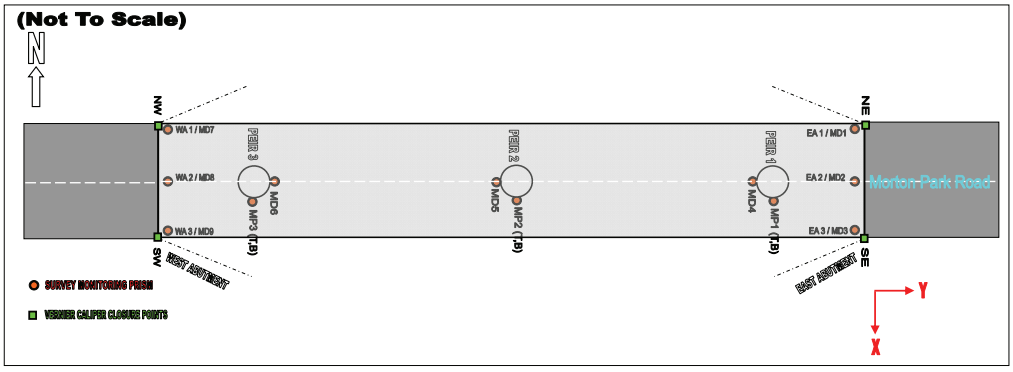

Fig. 2.20 Plan of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

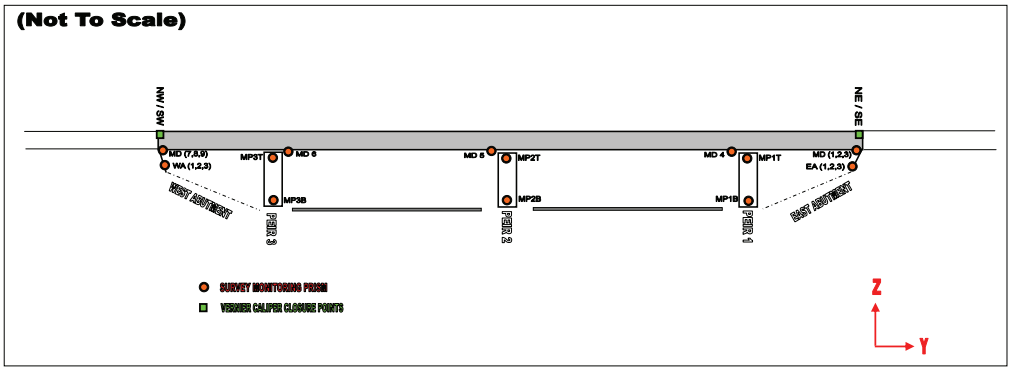

Fig. 2.21 Elevation of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

The changes in horizontal distance between the bridge abutments have been measured during mining in Appin Area 7, since the 15 October 2007, and during LW901 to LW903. 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 the start of April 2014, is shown in Fig. 2.22. The nominal survey accuracy is ±2 mm.

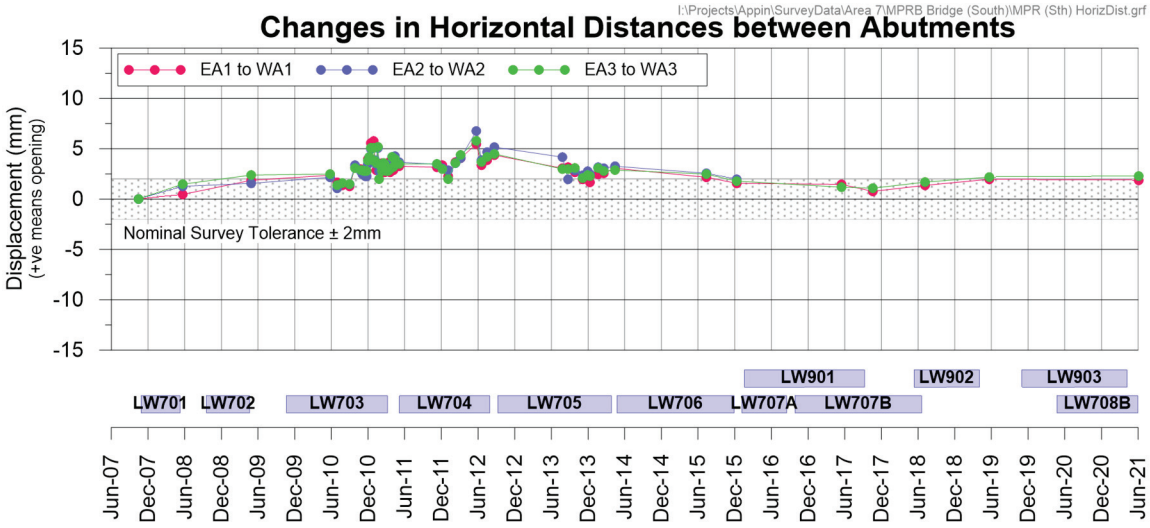

Fig. 2.22 Measured total changes in horizontal distance between the abutments of Moreton Park Road Bridge (South)

The total changes in horizontal distance between the bridge abutments were less than ±3 mm at the completion of LW903. The total measured movements, therefore, were very close to survey tolerance at the completion of the longwall.

2.12. 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), in November 2017 (after the completion of LW901), in late-March 2019 (around the completion of LW902) and in mid-April 2021 (after the completion of LW903).

The measured incremental changes in surface level due to the mining of LW903 only are shown in Fig. 2.23. These contours have been determined by taking the differences between the surface levels measured before and after the extraction 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.

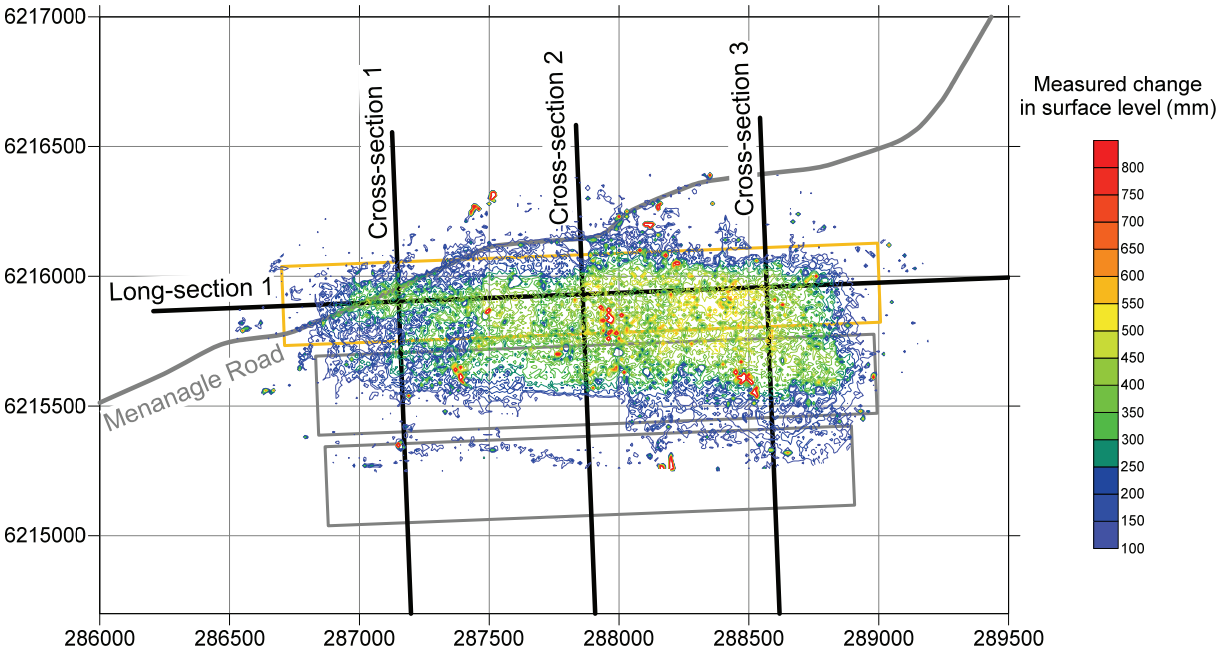

Fig. 2.23 Measured incremental changes in surface level due to the mining LW903 only

The LiDAR surveys after LW902 and LW903 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 two surveys) due to the mining of LW903, therefore, is in the order of ±200 mm.

The measured total changes in surface level due to the mining of LW901 to LW903 are shown in Fig. 2.24. These contours have been determined by taking the differences between the surface levels measured before the commencement of LW901 and after the completion of LW903. 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 LW903 and the accuracy is in the order of ±250 mm or greater.

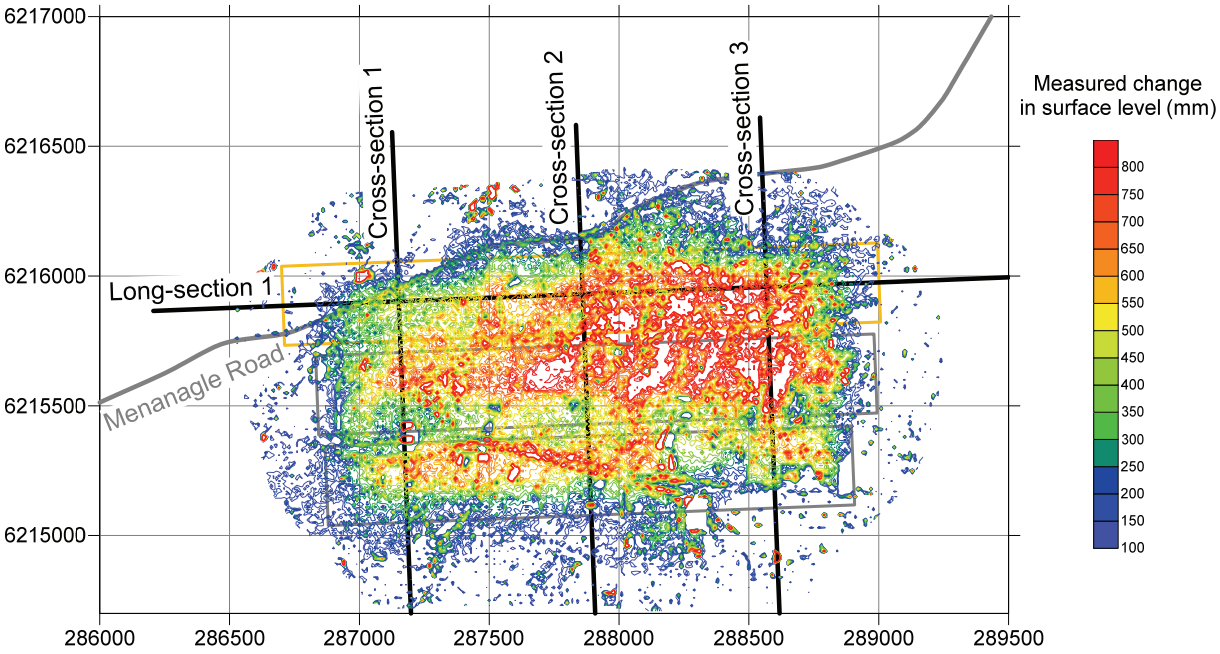

Fig. 2.24 Measured total changes in surface level due to the mining of LW901 to LW903

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. 2.23 and Fig. 2.24 as the localised areas of dark red contours above the longwalls and the lower level subsidence outside the extents of the longwalls.

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 Cross-sections 1 to 3 and Long-section 1 are provided in Fig. 2.25 to Fig. 2.28. The locations of these sections are indicated in Fig. 2.23 and Fig. 2.24. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report No. MSEC1050 which includes the approved modifications to the longwall commencing and finishing ends.

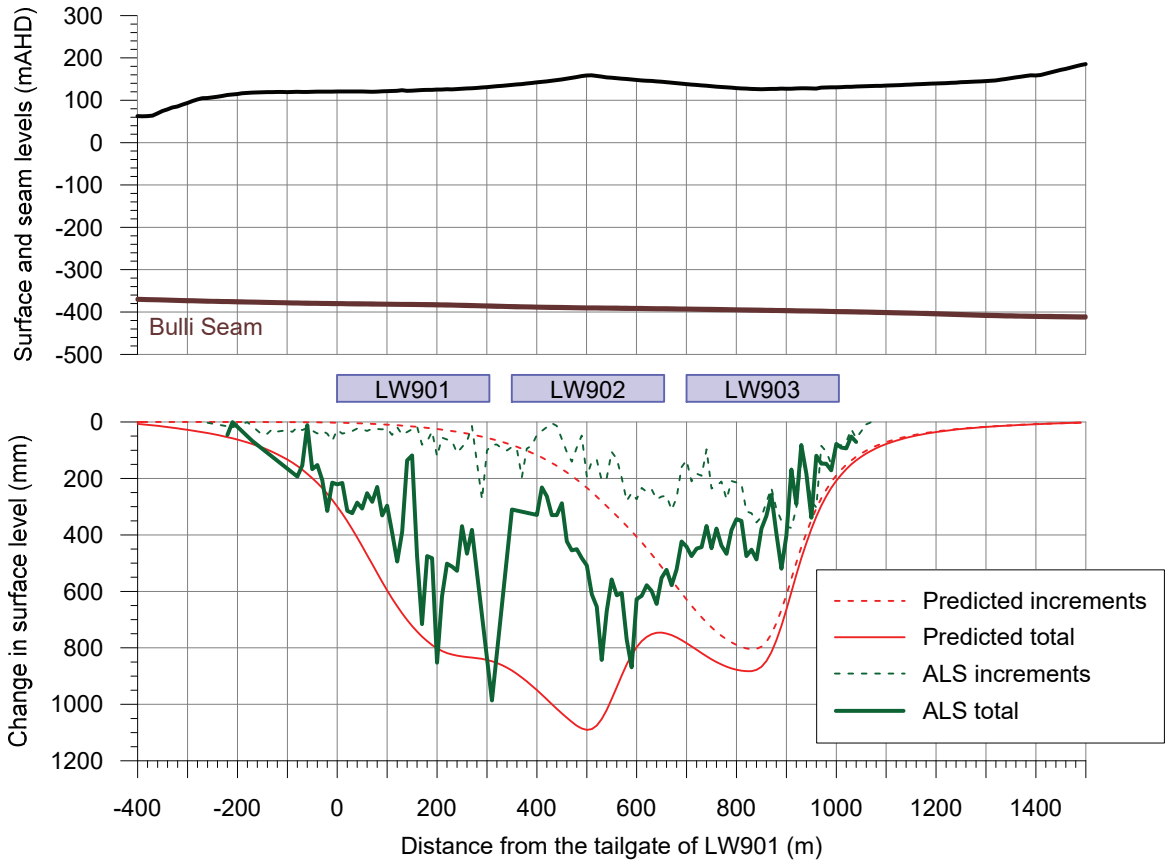

Fig. 2.25 Measured changes in surface level and predicted vertical subsidence along Cross-section 1

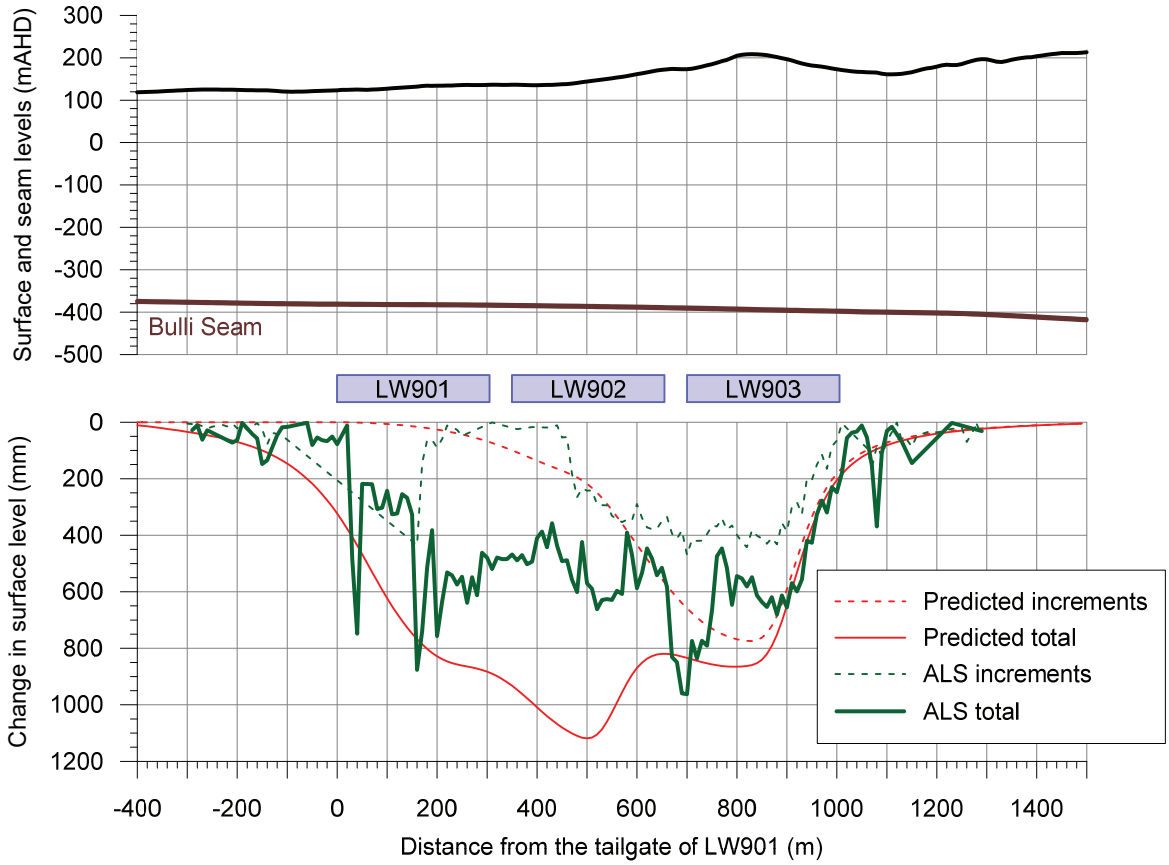

Fig. 2.26 Measured changes in surface level and predicted vertical subsidence along Cross-section 2

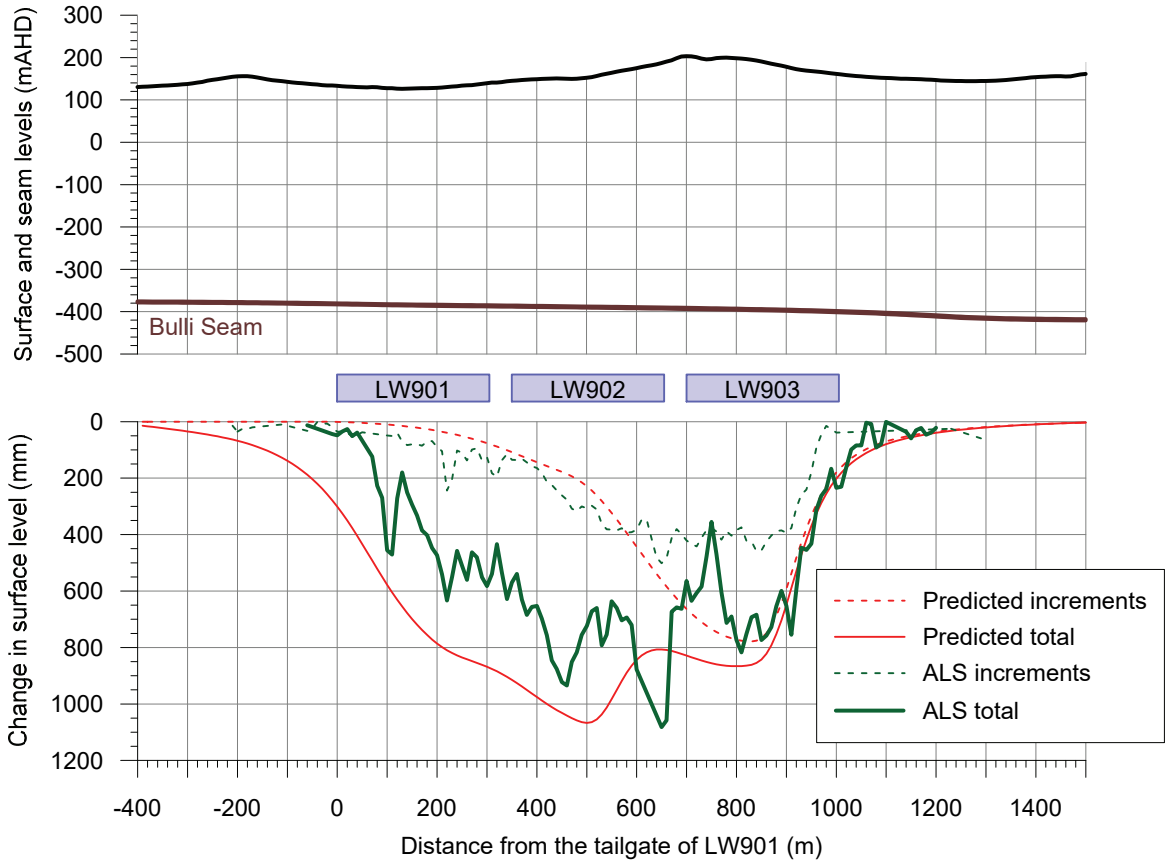

Fig. 2.27 Measured changes in surface level and predicted vertical subsidence along Cross-section 3

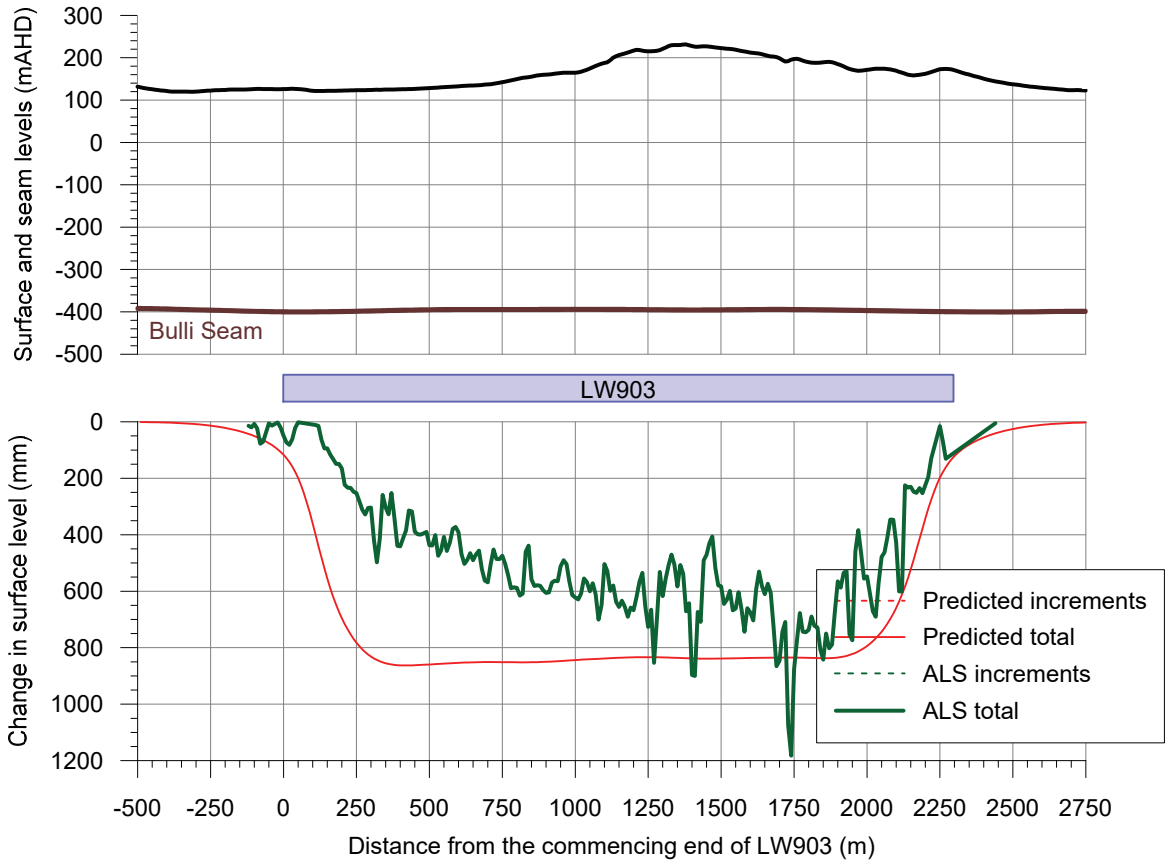

Fig. 2.28 Measured changes in surface level and predicted vertical subsidence along Long-section 1

The profiles of the measured incremental changes in surface level (i.e. dashed lines) reasonably match the predicted profiles of incremental vertical subsidence along each of the cross-sections 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. However, 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 Reports Nos. MSEC448, MSEC829 and MSEC1050.

3.1. Natural features

The natural features near LW903 are shown in Drawing No. MSEC1176-02, in Appendix A, and include the:

- Nepean River;
- Harris Creek and other tributaries to the Nepean River;
- cliffs along the Nepean River and Harris Creek;
- rock outcrops; and
- steep slopes.

The MSEC assessed impacts for the natural features resulting from the extraction of LW903 are provided in Reports Nos. MSEC448, MSEC829 and MSEC1005, which supported the Extraction Plan and Modification Applications. More detailed assessments for the natural features were 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 extraction of LW903, are provided in Table 3.1. The impacts are based on those recorded by IMC Environmental Field Team and are described in the accompanying Landscape report.

Table 3.1 Assessed and reported impacts for the natural features due to LW903

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 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	Gas release (Level 1 impact according to the TARP) was observed at one site along the Nepean River during the mining of LW903 (AA9_LW903_001). Refer to the Landscape Report by IMC for further details
	Water quality – refer to the surface water report by HGEO **Terrestrial ecology** – refer to the Landscape Report by IMC	
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 the Nepean River	Rock falls could occur close to longwall, 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 mining-induced impacts observed. Minor rock falls were observed during mining that were considered to be associated with existing instabilities and after heavy rainfall
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 and 50 mm, with localised cracking in the order of 100 to 150 mm directly above the longwalls	No reported impacts

The recorded impacts on the natural features due to the extraction of LW903 are similar to or less than the MSEC assessments provided in Reports Nos. MSEC448, MSEC829 and MSEC1005. Further assessments of natural features have been provided by other specialist consultants, and are described in the relevant reports attached to the *End of Panel* report.

3.2. Built features

The built features near LW903 are shown in Drawing No. MSEC1176-03, in Appendix A, and include the:

- Main Southern Railway and associated infrastructure;
- Camden and Menangle 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 extraction of LW903 are provided in Reports Nos. MSEC448, MSEC829 and MSEC1005, which supported the Extraction Plan and Modification Applications. Comparisons between the MSEC assessments and the reported impacts for the built features listed above, resulting from the extraction of LW903, are provided in Table 3.2.

Table 3.2 Assessed and reported impacts for the built features due to LW903

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 longwalls	Localised heaving of road surface observed to gradually develop in January 2020 between Pegs MR9032 and MR9033, where increased compressive strains were observed. The bump was repaired on 17 April 2020.
Camden Road	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
Business establishments	Adverse impacts unlikely	No reported impacts
Rural structures	Minor impacts on rural structures located directly above longwalls	No reported impacts
Farm dams	Incidence of impact (cracking and leakage) expected to be extremely low	No reported impacts

Built feature	MSEC assessed impacts	Reported impacts
Groundwater bores	Impacts likely including lowering of piezometric surface, blockage and change in groundwater quality	Refer to the groundwater assessment and the Landscape Report by IMC
Aboriginal heritage sites	Adverse impacts unlikely	No Aboriginal heritage sites located within the Study Area for LW903
Heritage sites	Adverse impacts unlikely	No reported impacts
Houses	Remain safe and serviceable, assessed impacts: 92 % no claim or Category R0, 6 % Category R1 or R2, 2 % Category R3 or R4, and < 0.5 % Category R5	Houses have remained in safe and serviceable conditions. There were four claims submitted to SA NSW relating to the houses, being three Category R0 and one Category R1 impacts (i.e. minor non-structural damage)

The recorded impacts on the built features due to the extraction of LW903 are similar to or less than the MSEC assessments provided in Reports Nos. MSEC448, MSEC829 and MSEC1005. The built features and infrastructure were maintained in safe and serviceable conditions during mining with the implementation of the monitoring and management strategies.

APPENDIX A. DRAWINGS

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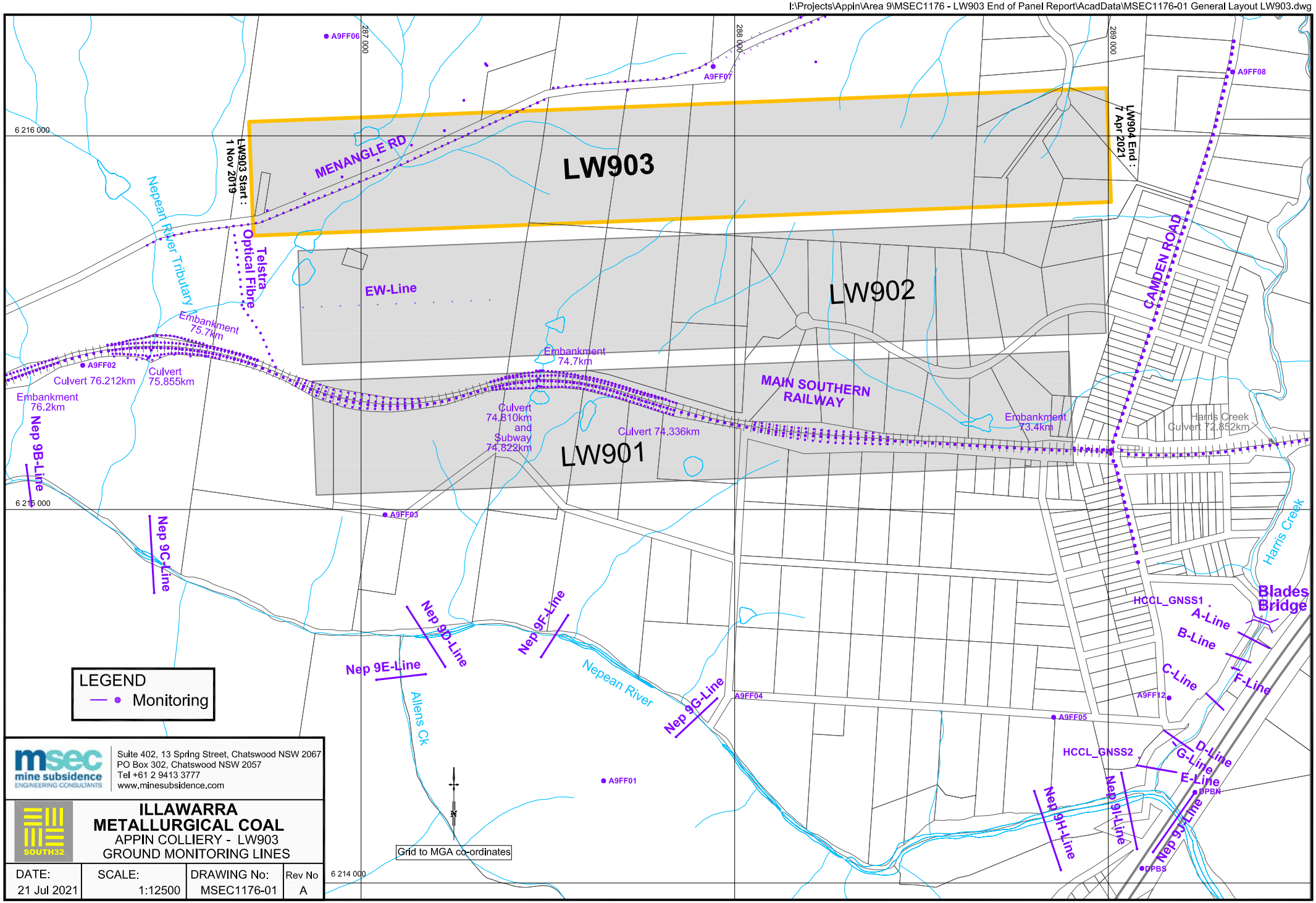

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ILLAWARRA METALLURGICAL COAL

APPIN COLLIERY - LW903
GROUND MONITORING LINES

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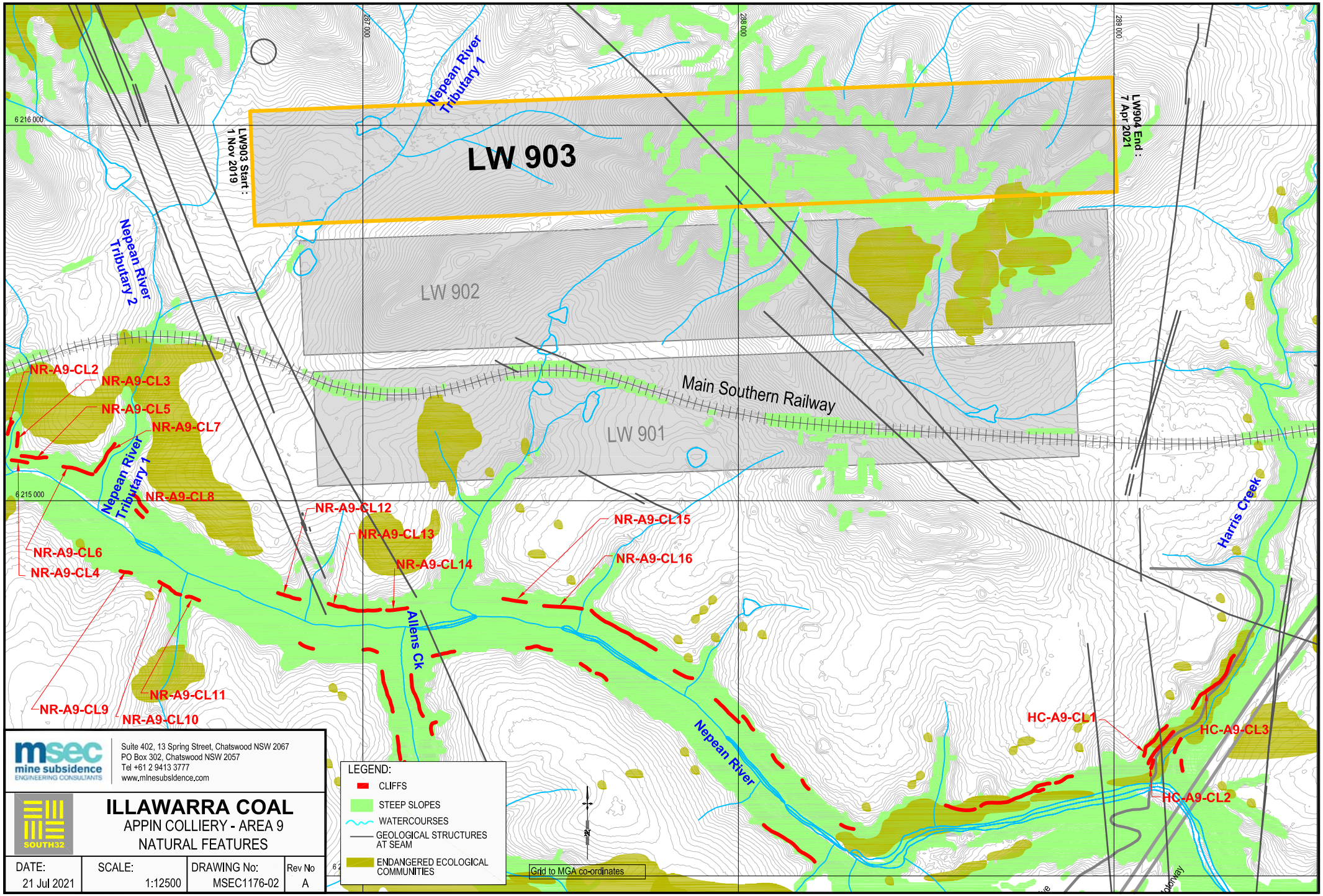

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NATURAL FEATURES

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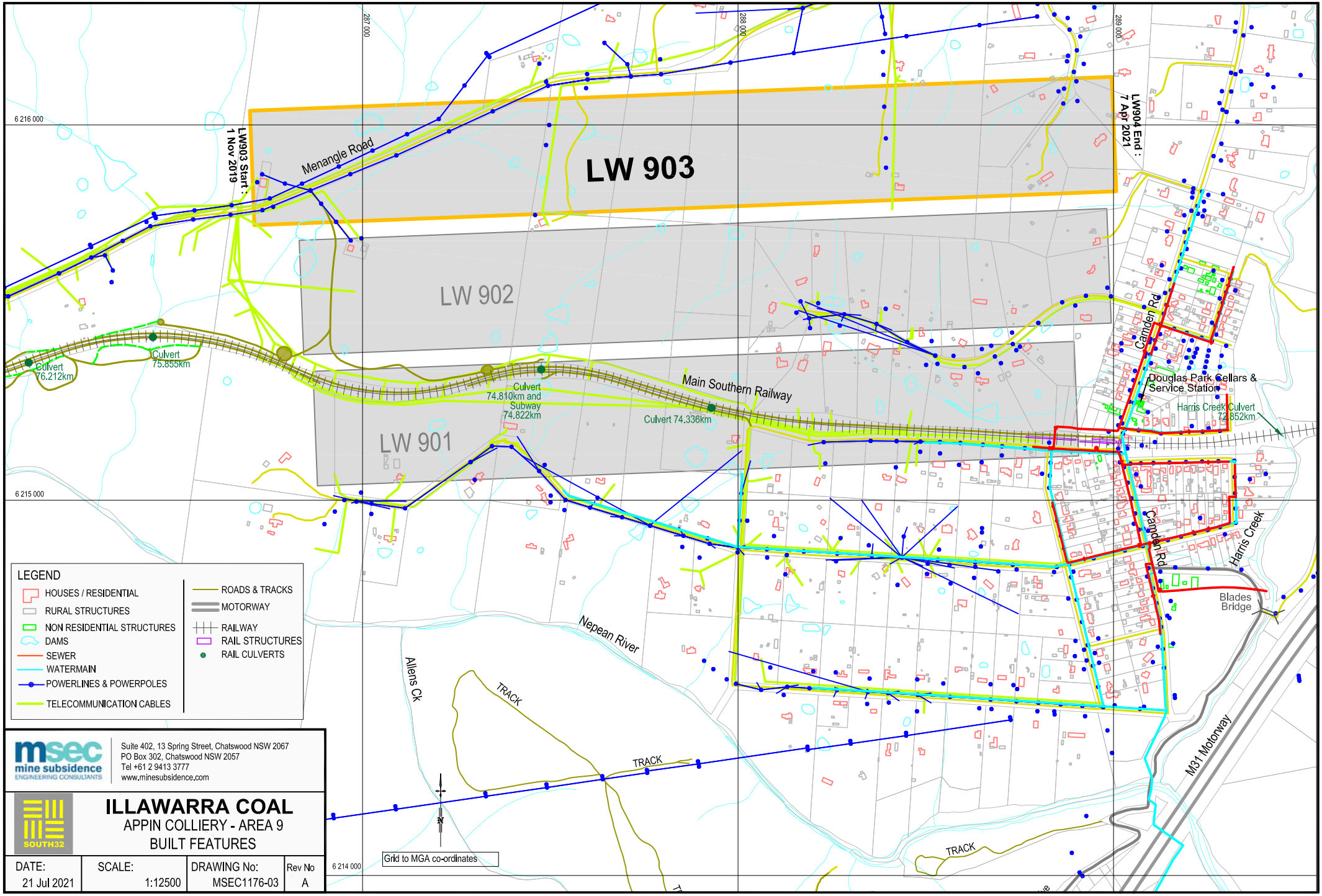

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BUILT FEATURES

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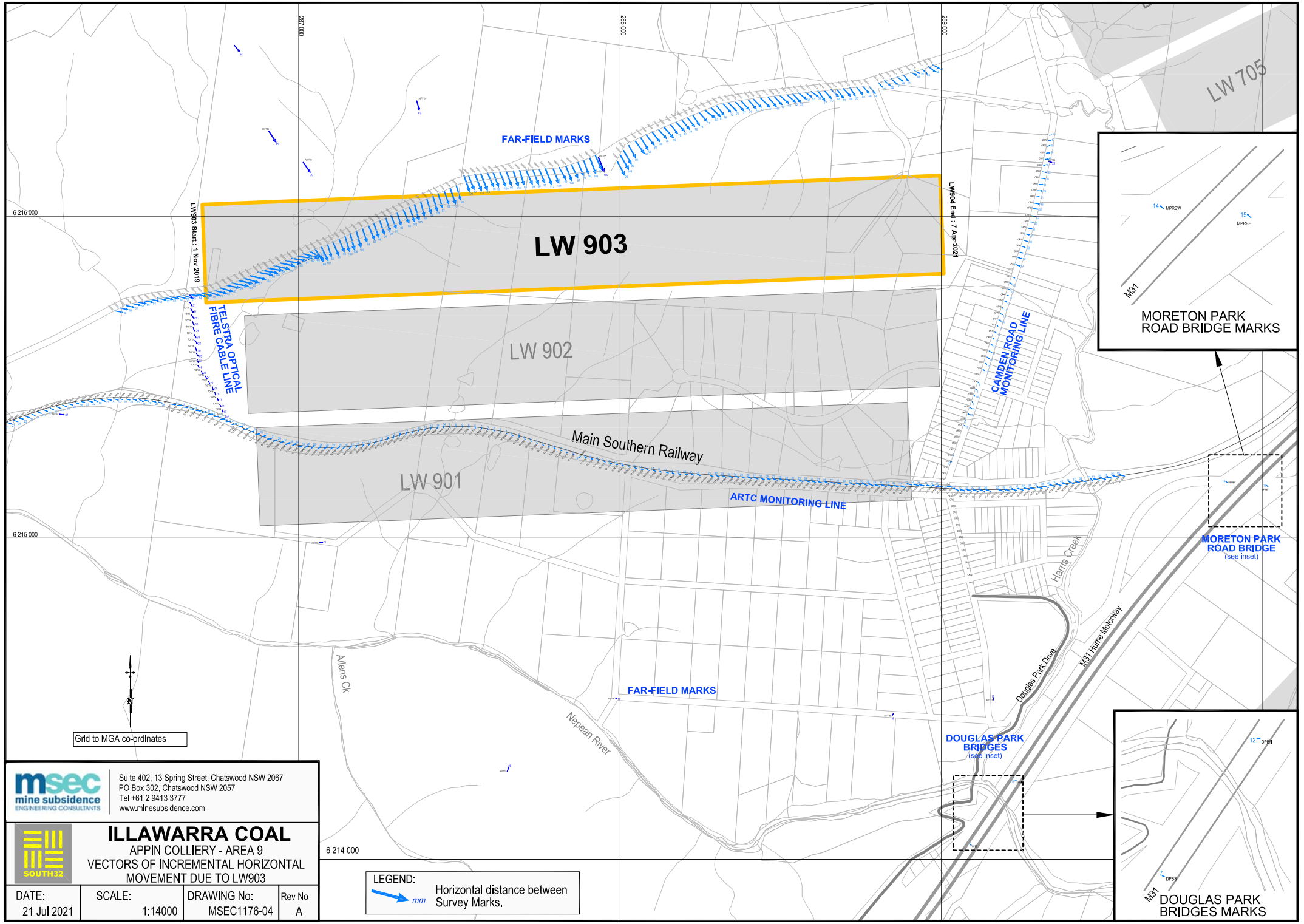

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VECTORS OF INCREMENTAL HORIZONTAL MOVEMENT DUE TO LW903

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LEGEND:

mm Horizontal distance between Survey Marks.