mine subsidence ENGINEERING CONSULTANTS

South32

Illawarra Coal

SOUTH32 ILLAWARRA COAL:

Appin - Area 9 - Longwall 902

End of Panel Subsidence Monitoring Review Report for Appin Longwall 902

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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)

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

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***
MSEC1050-01	General layout and monitoring lines	A
MSEC1050-02	Natural features	A
MSEC1050-03	Built features	A
MSEC1050-04	Vectors of incremental horizontal movement due to LW902	A

1.1. Introduction

South32 Illawarra Coal (IC) has approval for the extraction of Longwalls 901 to 904 (LW901 to LW904) in Area 9 at Appin Colliery. IC has completed the extraction of LW902 which is the second longwall in the series. The location of the longwalls in Area 9 are shown in Drawing No. MSEC1050-01, in Appendix A. A summary of the commencement and finishing dates for LW901 and LW902 is provided in Table 1.1.

Table 1.1 Commencement and finishing dates for LW901 and LW902

Longwall	Commencement date	Finishing date
LW901	19 January 2016	8 September 2017
LW902	12 May 2018	3 April 2019

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IC 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 and Environment (DP&E) granted approval for the Extraction Plan on the 10 September 2014.

IC subsequently shortened the commencing (i.e. western) end of LW902 by 911 m from the extent indicated in the Extraction Plan Application. Report No. MSEC829 (Rev. A) was issued in May 2016 in support of the application for this modification. The modified commencing end of LW902 was approved by the DP&E on the 6 July 2017.

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

- Comparisons between the measured and predicted subsidence movements at the monitoring lines and monitoring points in Appin Area 9 resulting from the extraction of LW902; and
- Comparisons between the observed and assessed impacts on the natural and built features within the mining area resulting from the extraction of LW902.

Further details on the observed and assessed impacts for natural features due to the extraction of LW902 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 LW902. 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 LW902. 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. MSEC1050-01, in Appendix A. A summary of the as-extracted dimensions for LW901 and LW902 is provided in Table 1.2.

Table 1.2 Mining geometry of the as-extracted longwalls

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

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 LW902 are illustrated in Fig. 1.1.

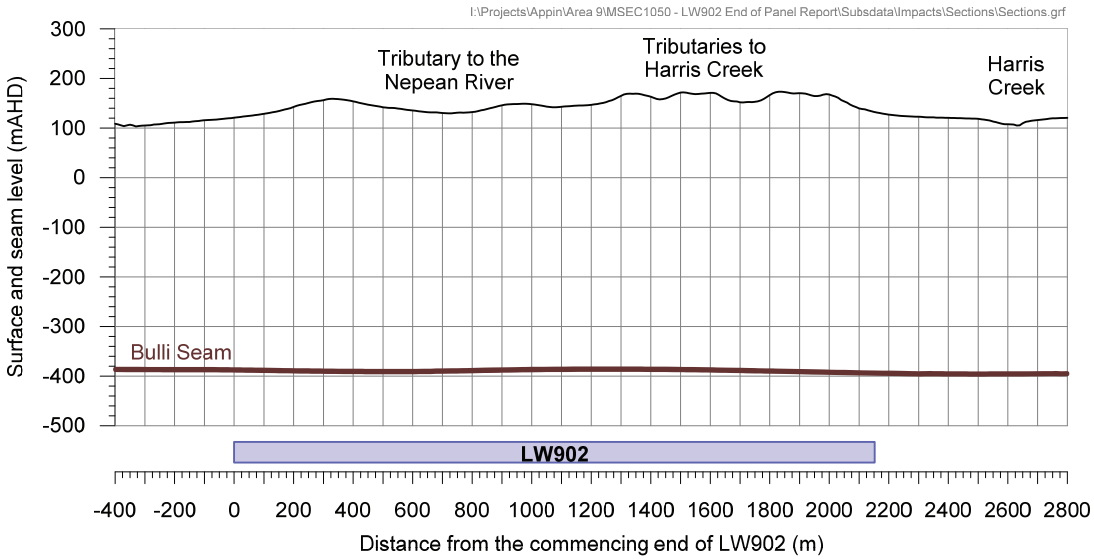

Fig. 1.1 Surface and seam levels along the centreline of LW902

The natural surface generally falls from the north towards the south. The natural drainage lines located directly above LW902 flow into the Nepean River to the south of the longwall. Harris Creek is located approximately 420 m to the east of the finishing end of LW902. Razorback Range is located to the north of the longwall.

The depth of cover to the Bulli Seam directly above LW902 varies between a minimum of 510 m above the commencing end of the longwall, and a maximum of 590 m above the maingate towards 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 and 2.9 m within the extents of LW902. IC extracted the full thickness of the seam.

1.3. Predicted mine subsidence movements

The predicted mine subsidence movements for LW902 were provided in Reports Nos. MSEC448 and MSEC829 which supported the Extraction Plan and Modification Applications, respectively. The predicted conventional ground movements were 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 LW901 and LW902 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 LW901 and LW902

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

A summary of the maximum predicted total vertical subsidence, tilt and curvatures after the mining of LW901 and LW902 is provided in Table 1.4. The values provided in this table are the accumulated movements due to the extraction of both of these longwalls.

Table 1.4 Maximum predicted total vertical subsidence, tilt and curvature after the extraction of LW901 and LW902

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 and LW902	925	6.5	0.06	0.12

The maximum predicted total tilt after the extraction of LW902 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 level, and 1.7 mm/m tensile and 3.4 mm/m compressive based on the 99 % confidence level.

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 LW902 were monitored using monitoring lines, 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;
- Telstra optical fibre cable monitoring line;
- Camden Road monitoring line;
- Menangle Road 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; and
- Moreton Park Road Bridge South monitoring points.

The locations of the monitoring lines and monitoring points are shown in Drawing No. MSEC1050-01, 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. MSEC1050-01 and MSEC1050-03, 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 were provided in weekly subsidence monitoring review reports for the railway (Reports Nos. MSEC961-R01 to MSEC961-R51), which were issued during the extraction of LW902, between May 2018 and June 2019.

A summary of the monitoring results for the Main Southern Railway are 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 LW902 is provided in Table 2.1.

Table 2.1 Survey dates for the ARTC monitoring line during LW902

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Start and end of LW902, with monthly 3D surveys, and weekly 2D focused surveys	26 September 2017 (end of LW901) 21 May 2017; then weekly surveys to the 29 April 2019; and 20 May 2019 (end of LW902)	As per approved LW903 monitoring program

The measured incremental vertical subsidence along the ARTC monitoring line due to the mining of LW902 is illustrated in Fig. 2.1.

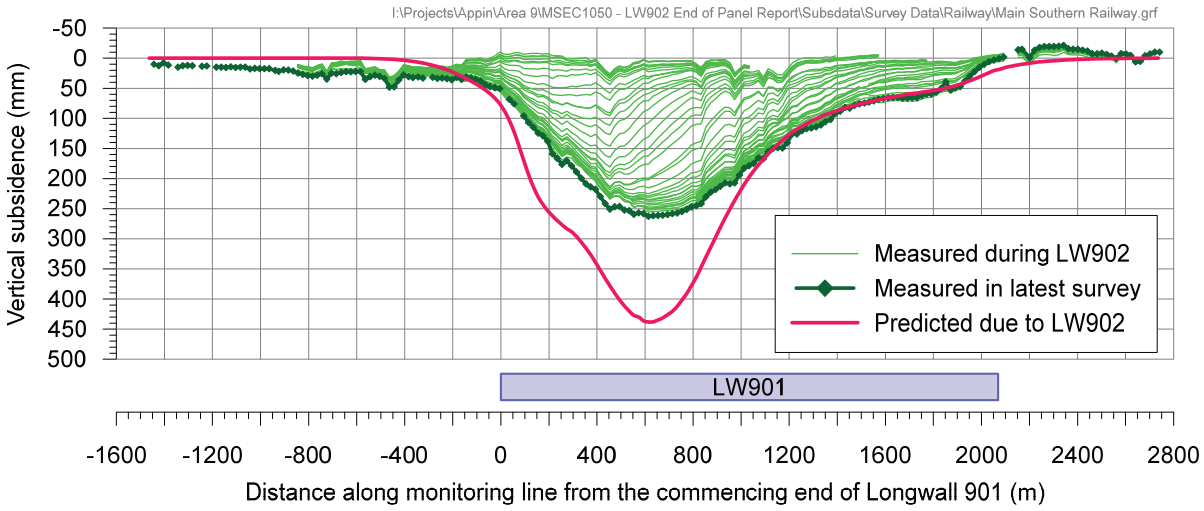

Fig. 2.1 Measured incremental vertical subsidence along the ARTC line due to LW902

The measured incremental vertical subsidence along the ARTC monitoring line was considerably less than the predicted vertical subsidence due to the mining of LW902. The measured vertical subsidence was also less than the predicted vertical subsidence during the previous mining of LW901.

The vertical subsidence to the west of the mining area (i.e. left side of Fig. 2.1) was slightly greater than predicted. This low-level subsidence (i.e. less than 50 mm) was generally not associated with measurable tilts, curvatures or strains, i.e. values were within or close to the order of survey tolerance.

Uplift was observed in front of the longwall extraction face toward the eastern part of the mining area (i.e. right side of Fig. 2.1). The measured uplift was up to 20 mm during the mining of LW902 and uplift was also observed during the mining of LW901.

A summary of the maximum measured and predicted vertical subsidence, tilt and strain for the ARTC monitoring line is provided in Table 2.2. The values are the maximum movements at any time during or after the extraction of LW902.

Table 2.2 Maximum measured and predicted incremental subsidence effects for the ARTC monitoring line due to LW902

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm)	Maximum incremental tensile strain (mm/m)	Maximum incremental compressive strain (mm/m)
Measured	263	1.2	0.7	0.8
Predicted	450	1.4	*- 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 and tilt were less than the maximum predicted values.

The maximum measured strains were 0.7 mm/m tensile and 0.8 mm/m compressive. The maximum predicted conventional strains for LW902, based on applying a factor of 15 to the maximum predicted curvatures due to this longwall, are 1 mm/m tensile and 2 mm/m compressive. The measured strains along the ARTC monitoring are therefore less than the maximum predicted conventional strains for LW902.

The vectors of horizontal movement along the ARTC monitoring line are shown in Drawing No. MSEC1050-04. Discussions on these movements have been included in Section 2.9.

2.2.2. Automated track monitoring

The automated track monitoring includes rail stress transducers and expansion switch displacement sensors.

Rail stress transducers

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 LW902. 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.

Expansion switch displacement sensors

Displacement sensors have been installed at each expansion switch. Measurements were recorded every 5 minutes during the mining of LW902. The results and discussions on switches were provided in the reports by PCE attached to the weekly subsidence monitoring review reports. While some false alarms were triggered during mining due to malfunction or damage to sensors, actual displacement readings did not exceed trigger levels.

2.2.3. Embankment monitoring points

Embankments 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 LW902.

The mine subsidence movements at the embankments were measured by IC 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 LW902.

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 LW902.

The mine subsidence movements at the cuttings were measured by IC using 3D ground monitoring lines along their crests and toes. Closure developed across each of the cuttings that resulted in changes in track geometry. Changes in vertical and horizontal alignment were observed along the survey lines but no impacts were observed on track geometry. There were no adverse impacts 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 0.4 km to the west of LW902.

The mine subsidence movements at the culverts were measured by IC 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. Sewer horizontal bore

A sewer horizontal bore owned by Sydney Water crosses beneath the Main Southern Railway near Durham Street. The 3D movements were measured using survey marks at each end of the bore. A summary of the survey dates for the horizontal bore during LW902 is provided in Table 2.3.

Table 2.3 Survey dates for the horizontal bore during LW902

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to active subsidence; monthly surveys after longwall chainage of 300 m; and final survey after completion of LW902	26 September 2017 (end of LW901) 7 January 2019 4 February 2019 4 March 2019 1 April 2019 20 May 2019 (end of LW902)	As per approved LW903 monitoring program

The measured change in length for the horizontal bore is illustrated in Fig. 2.2. The survey accuracy for change in length is in the order of ±3 mm.

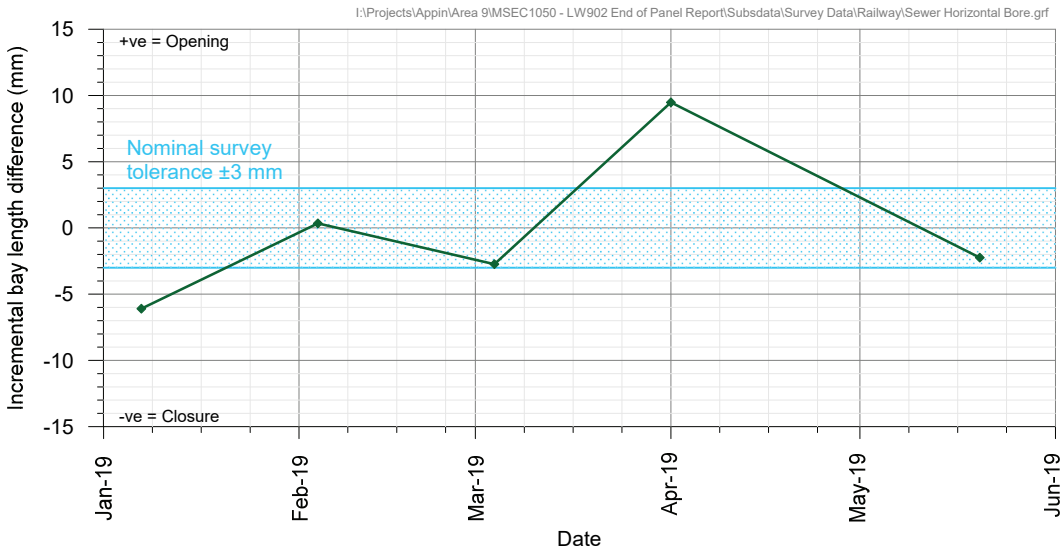

Fig. 2.2 Development of measured incremental change in bay length for the horizontal bore during the mining of LW902

The measured final incremental change in length for the horizontal bore due to LW902 is -2 mm (closure), which is within the order of survey tolerance (i.e. not measurable). Incremental changes greater than survey tolerance were measured during mining; however, these values are likely to include a larger component of survey tolerance and other possible effects. The total change in length due to LW901 and LW902 is -4 mm (closure) which is similar to the order of survey tolerance.

The 3D measurements indicate that the ground moved towards the south-east by approximately 30 mm due to the mining of LW902. The change in absolute level was +45 mm (uplift) due to the mining of this longwall. Uplift was also measured along the ARTC monitoring line to the east of the mining area.

2.2.7. Douglas Park Station monitoring points

Douglas Park Station is located immediately to the east of the finishing end of LW901 and south of the finishing end of LW902. The mine subsidence effects at the station platform were measured by IC 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 LW902, at a minimum distance of 100 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 LW902 is provided in Table 2.4.

Table 2.4 Survey dates for the Camden Road monitoring line during LW902

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 LW902	3 October 2017 (end of LW901) 4 January 2019 5 February 2019; then weekly surveys to the 30 April 2019; and then 6 May 2019 (end of LW902)	As per approved LW903 monitoring program

The measured incremental vertical subsidence along the Camden Road monitoring line is illustrated in Fig. 2.3. Positive values are net downward movements and negative values are net uplift.

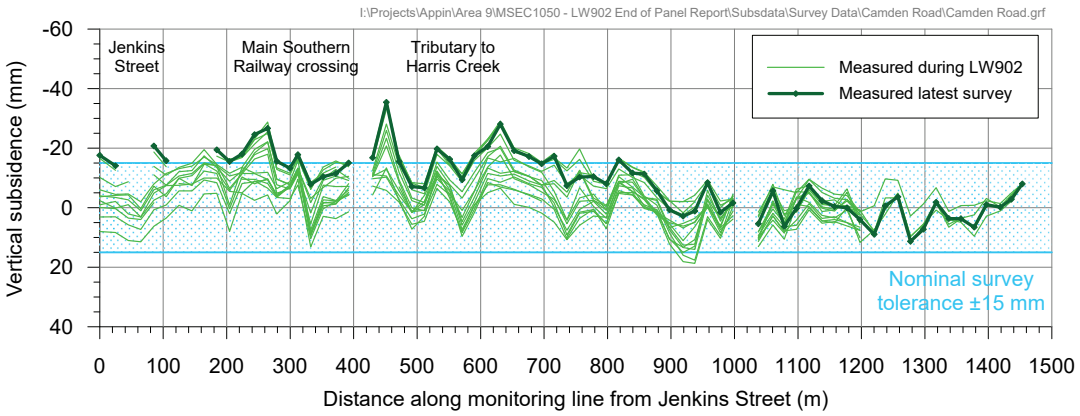

Fig. 2.3 Measured incremental vertical subsidence along the Camden Road line due to LW902

Uplift was measured along the southern part of the Camden Road monitoring line, i.e. between Jenkins Street and the tributary to Harris Creek. The maximum measured incremental uplift due to LW902 was 35 mm. Uplift was also measured along the ARTC monitoring line to the east of the mining area.

The measured incremental vertical subsidence (i.e. downward movement) along the Camden Road monitoring line due to LW902 was less than 20 mm, i.e. was similar to the order of survey tolerance for absolute level. The measured strains were typically up to 0.5 mm/m tensile and compressive.

The vectors of horizontal movement along the Camden Road monitoring line are shown in Drawing No. MSEC1050-04. Discussions on these movements have been included in Section 2.9.

2.4. Menangle Road monitoring line

The Menangle Road monitoring line is located to the north of LW902, at a minimum distance of 100 m from the longwall commencing end. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Menangle Road monitoring line during LW902 is provided in Table 2.5.

Table 2.5 Survey dates for the Menangle Road monitoring line during LW902

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 LW902	3 May 2018 (base survey) 13 June 2018 17 July 2018 15 August 2018 18 September 2018 23 October 2018; and 16 May 2019 (end of LW902)	As per approved LW903 monitoring program

The measured incremental vertical subsidence along the Menangle Road monitoring line due to LW902 is illustrated in Fig. 2.4. Positive values are net downward movements and negative values are net uplift.

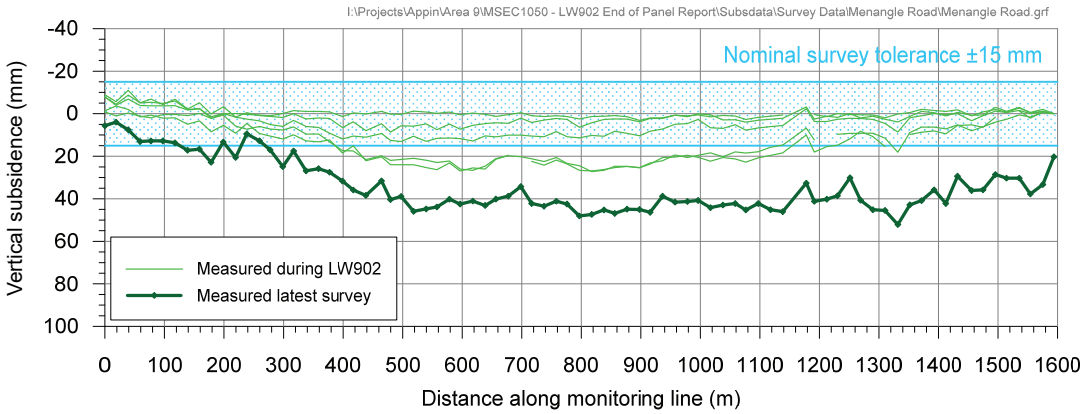

Fig. 2.4 Measured incremental vertical subsidence along the Menangle Road line due to LW902

The maximum measured incremental vertical subsidence along the Menangle Road monitoring line was approximately 50 mm at the completion of LW902. The predicted vertical subsidence outside and adjacent to the longwall was 50 mm or less.

The measured incremental strains were up to 0.6 mm/m tensile and 0.8 mm/m compressive. The maximum predicted conventional strains for LW902, based on applying a factor of 15 to the maximum predicted curvatures due to this longwall, are 1 mm/m tensile and 2 mm/m compressive. The measured strains along the Menangle Road monitoring are therefore less than the maximum predicted conventional strains for LW902.

The vectors of horizontal movement along the Menangle Road monitoring line are shown in Drawing No. MSEC1050-04. 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 north-west of LW902, at a minimum distance of approximately 70 m from the longwall commencing end. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Telstra OFC monitoring line during LW902 is provided in Table 2.6.

Table 2.6 Survey dates for the Telstra OFC monitoring line during LW902

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW902; 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 LW902	26 September 2017 (end of LW901) 13 June 2018; then fortnightly surveys to the 18 September 2018; 23 October 2018; and then 20 May 2019 (end of LW902)	As per approved LW903 monitoring program

The measured incremental vertical subsidence along the Telstra OFC monitoring line due to the mining of LW902 is illustrated in Fig. 2.5.

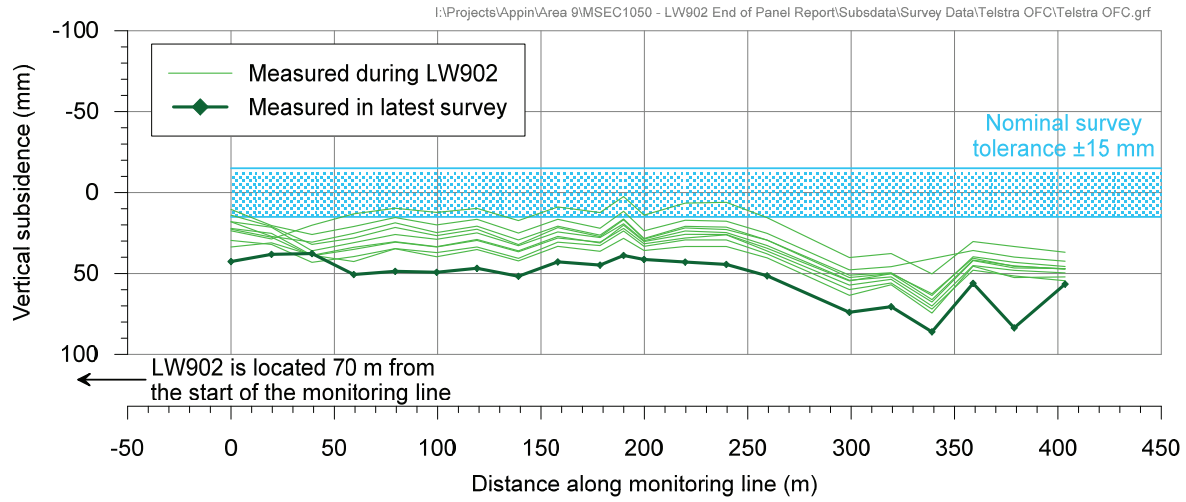

Fig. 2.5 Measured incremental vertical subsidence along the Telstra OFC line due to LW902

The measured incremental vertical subsidence at the southern end of the Telstra OFC monitoring line (i.e. closest to the mining area) was 50 mm at the completion of LW902. The predicted vertical subsidence outside and adjacent to the longwall was 50 mm or less.

The maximum measured incremental vertical subsidence at the northern end of the monitoring line (i.e. further away from the mining area) was 86 mm. Whilst the maximum measured vertical subsidence was greater than the maximum predicted value, it was associated with only low levels of strains.

The Telstra OFC occurred crossing a small drainage line and therefore is likely to have experienced some valley related effects. Elsewhere, the maximum measured incremental strains were 0.3 mm/m, or less, tensile and compressive. The incremental strains along the Telstra OFC monitoring line were therefore similar to the order of survey tolerance.

The vectors of horizontal movement along the Telstra OFC monitoring line are shown in Drawing No. MSEC1050-04. Discussions on these movements have been included in Section 2.9.

2.6. Nepean River closure lines

The Nepean River is located 650 m south of LW902 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 LW902 is provided in Table 2.7.

Table 2.7 Survey dates for the Nepean River closure lines during LW902

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW902; monthly surveys during mining; and final survey after completion of LW902	11 September 2017 (end of LW901) 6 July 2018; then monthly surveys to the 13 March 2019; and then 16 April 2019 (end of LW902)	As per approved LW903 monitoring program

The measured and predicted incremental closure movements at each of the Nepean River closure lines along the river is illustrated in Fig. 2.6. 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 extraction of LW901. The predictions for these monitoring lines were therefore revised 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, were derived from the measured values due to LW901, the relative distances from the longwalls and the shapes of the confidence levels fitted to the measured data. The revised predicted incremental values for each of the monitoring lines, due to LW902, were approximately half the measured values due to LW901.

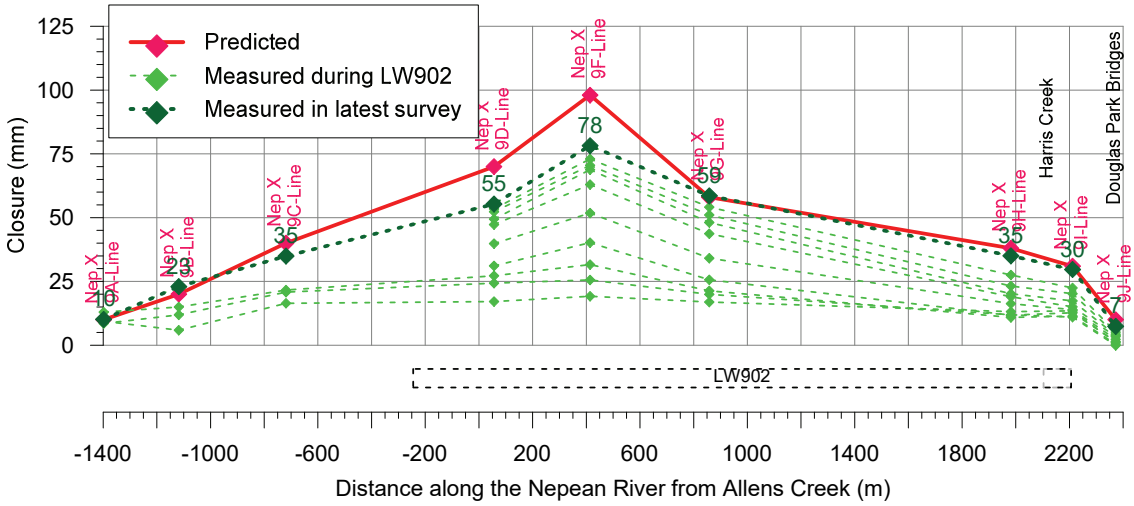

Fig. 2.6 Measured incremental valley closure along the Nepean River due to LW902

A summary of the measured and predicted closure movements for each of the Nepean River closure lines is provided in Table 2.8. The values are the maximum movements measured at any time during or after the extraction of LW902.

Table 2.8 Measured and predicted incremental closure for the Nepean River lines due to LW902

Location	Measured closure (mm)	Predicted closure (mm)
Nep X 9A-Line	10	< 20
Nep X 9B-Line	23	20
Nep X 9C-Line	35	40
Nep X 9D-Line	55	70
Nep X 9E-Line	2	70
Nep X 9F-Line	78	98
Nep X 9G-Line	59	58
Nep X 9H-Line	35	38
Nep X 9I-Line	30	31
Nep X 9J-Line	7	< 20

The maximum measured incremental closure of 78 mm at the Nep X 9F-Line was less than the maximum predicted incremental value of 98 mm for this monitoring line. The measured incremental closures for the other monitoring lines were typically similar to or less than their predicted values.

The measured incremental closure at the Nep X 9B-Line of 23 mm was slightly greater than the predicted value of 20 mm. The measured incremental closure at the Nep X 9G-Line of 59 mm was also slightly greater than the predicted value of 58 mm. However, these exceedance of up to 3 mm are within the order of accuracy of the prediction method.

2.7. Harris Creek Cliff Line closure lines

The Harris Creek Cliff Line (HCCL) is located 860 m south of the finishing end of LW902 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 LW902 is provided in Table 2.9.

Table 2.9 Survey dates for the HCCL closure lines during LW902

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW902; monthly surveys during mining; and final survey after completion of LW902	10 April 2018 (end of LW901) 8 June 2018; then monthly surveys to the 20 November 2018; then fortnightly surveys to the 12 March 2019; then weekly surveys to the 29 April 2019, then fortnightly surveys to the 27 May 2019; and 7 June 20219 (end of LW902)	As per approved LW903 monitoring program

The measured incremental valley closure for the HCCL closure lines due to LW902 is illustrated in Fig. 2.7.

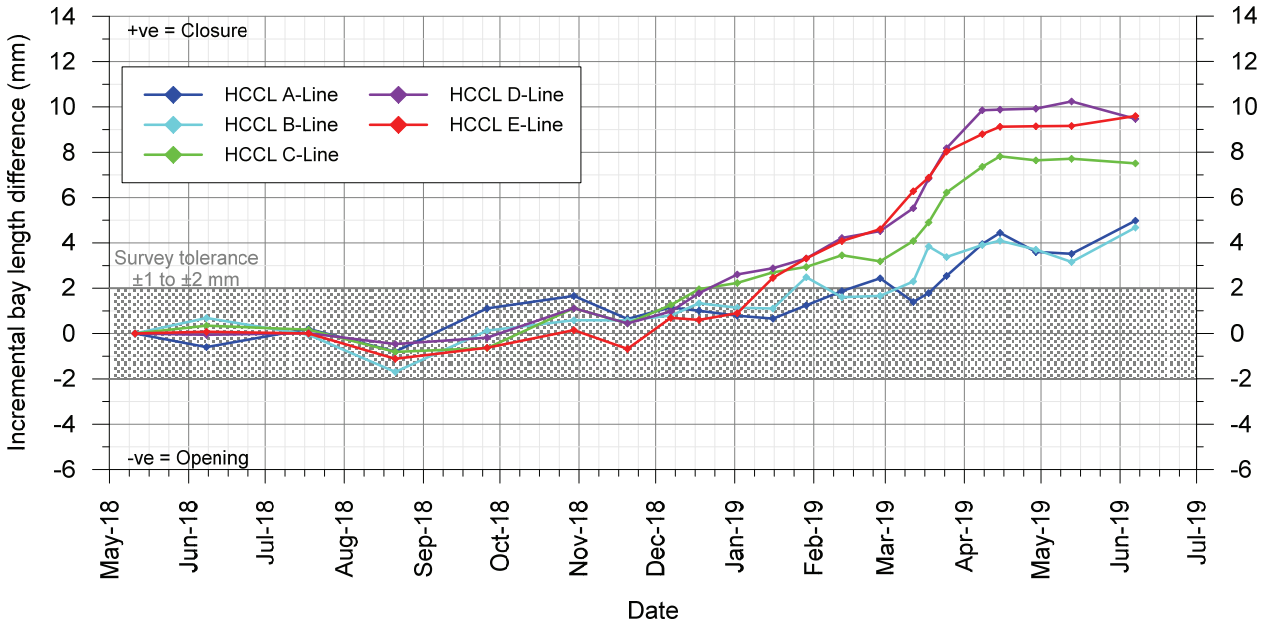

Fig. 2.7 Development of measured incremental closure for the HCCL due to LW902

The maximum measured incremental closure due to LW902 was 10 mm at the HCCL D-Line (i.e. towards the southern end of the cliffline). The incremental closure measured at the northern end of the cliff line was 5 mm at the HCCL A-Line and B-Line.

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

The predicted incremental closures for the HCCL monitoring lines, due to the extraction of LW902, were derived from the measured values due to 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 LW902 was 20 mm. The measured incremental closures due to LW902 were therefore less than the revised predicted value.

The measured total valley closure for the HCCL closure lines due to LW901 and LW902 is illustrated in Fig. 2.8.

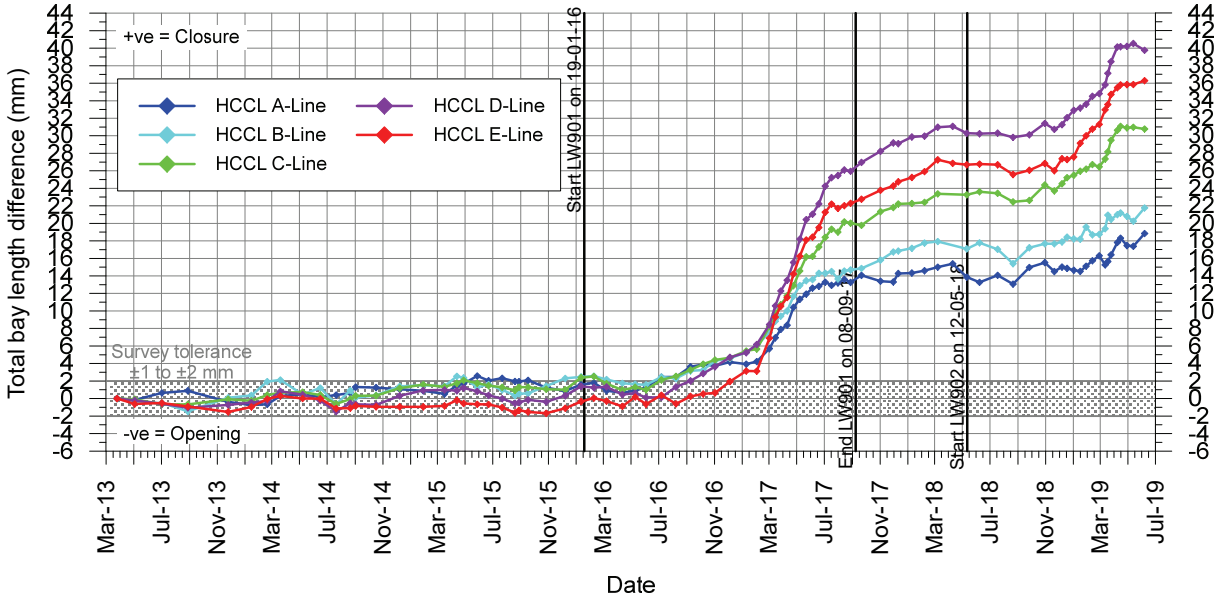

Fig. 2.8 Development of measured total closure for the HCCL due to LW901 and LW902

The maximum measured total closure due to LW901 and LW902 was 41 mm at the HCCL D-Line. The total closure measured after LW902 was less than the revised maximum predicted value of 50 mm.

2.8. Blades Bridge monitoring points

Blades Bridge crosses Harris Creek and it is located 860 m south of the finishing end of LW902 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 LW902 is provided in Table 2.10.

Table 2.10 Survey dates for Blades Bridge during LW902

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW902; monthly surveys during mining; and final survey after completion of LW902	11 May 2018 (end of LW901) 8 June 2018; then monthly surveys to the 7 December 2018; then fortnightly surveys to 13 May 2019; and 7 June 2019 (end of LW902)	As per approved LW903 monitoring program

The measured total valley closure at Blades Bridge due to LW901 and LW902 is illustrated in Fig. 2.9. The measured closure at the nearby HCCL A-Line is also shown in this figure for comparison.

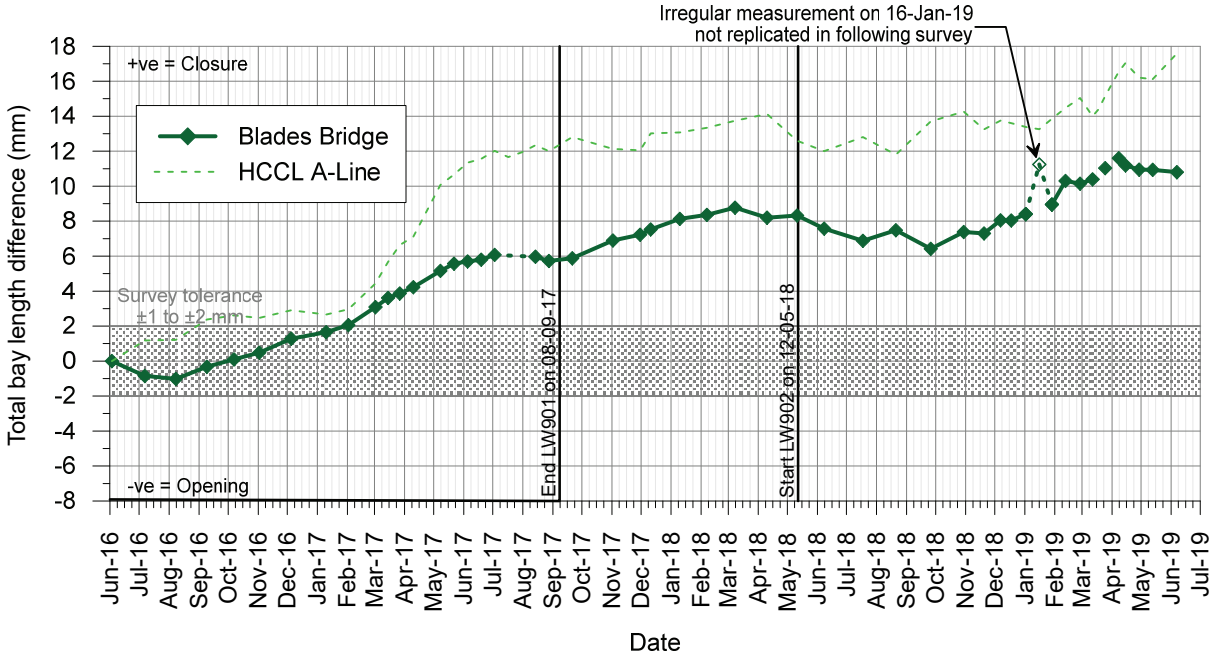

Fig. 2.9 Measured total valley closure at Blades Bridge due to LW901 and LW902

The maximum measured total valley closure at Blades Bridge due to LW901 and LW902 was 11 mm. The predicted total valley closure at the completion of LW902 was less than 20 mm. The measured total closure at the bridge was therefore less than the predicted value.

2.9. Far-field monitoring points

The far-field horizontal movements near LW902 have been measured by IC 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 for LW902 are provided in Table 2.11. 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 2.11 Survey dates for the AA9 far-field marks for LW902

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW902; monthly surveys during mining; and final survey after completion of LW902	12 September 2017 (end of LW901) 5 July 2018; then monthly surveys to 2 May 2019 (end of LW902)	As per approved LW903 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. MSEC1050-04. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±10 mm.

The vectors of horizontal movement were 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 LW902 with those measured elsewhere in the Southern Coalfield is provided in Fig. 2.10. The x-axis represents the distance from the active longwall.

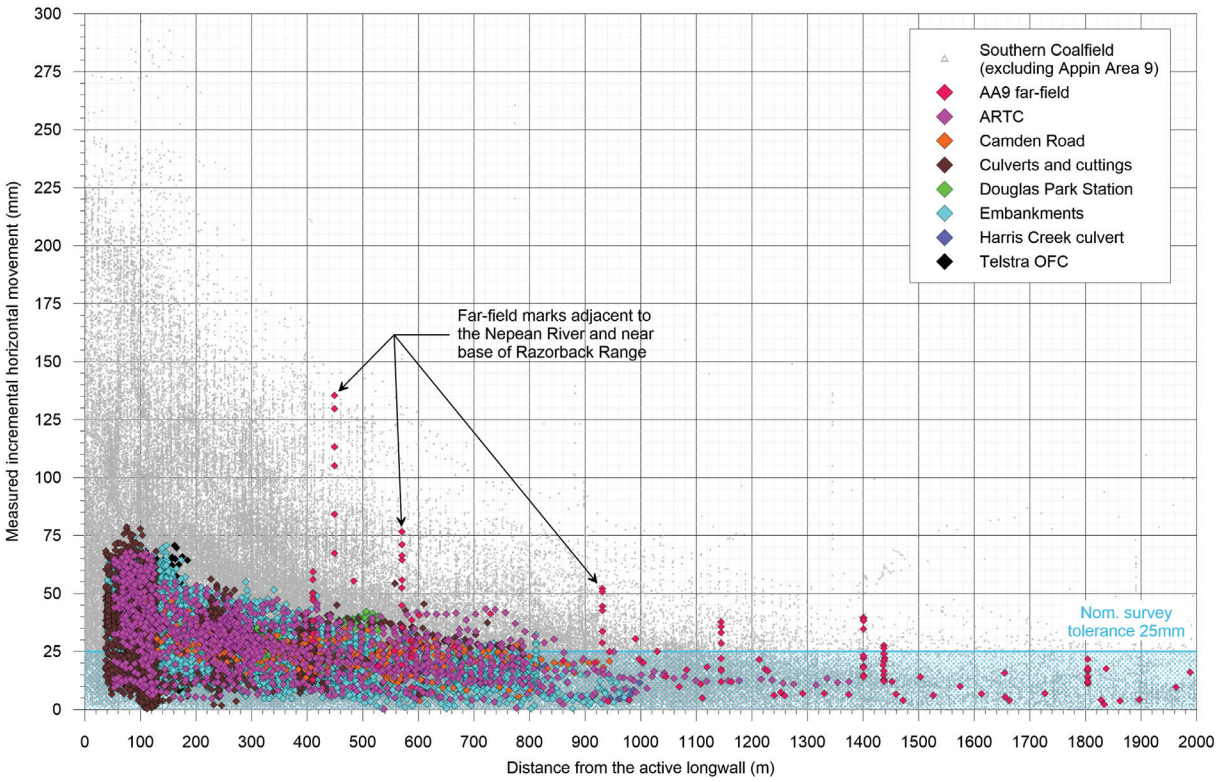

Fig. 2.10 Measured incremental far-field horizontal movements due to LW902

The greatest far-field horizontal movements due to LW902 occurred at the survey marks located along Razorback Range (i.e. the red diamonds in Fig. 2.10). The values of these movements are similar to the movements measured at similar distances elsewhere in the Southern Coalfield.

The far-field horizontal movements at the other survey marks were less than the range measured at similar distances elsewhere in the Southern Coalfield. The measured values at distances greater than 1000 m from LW902 were typically less than 25 mm (i.e. in the order of survey tolerance), apart from some of the survey marks located along Razorback Range.

2.10. Nepean Twin Bridges monitoring points

The Nepean Twin Bridges are located approximately 1.3 km south-east of the finishing end of LW902. These bridges experienced far-field movements due to the extraction of LW902 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 vectors of incremental horizontal movement at Marks DPBN and DPBS are shown in Drawing No. MSEC1050-04, 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 movements at Marks DPBN and DPBS, at the completion of LW902, were 7 mm and 19 mm, respectively. The vectors were orientated towards the west and north-west.

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 and LW902. The development of total horizontal movements for these marks, plotted from the start of April 2014, is shown in Fig. 2.11.

Global Navigation Satellite System (GNSS) units were installed at the ends of Bridges in late 2018. The results have been overlaid with absolute 3D ground surveys in Fig. 2.11. A similar trend was observed, in that the southern end of the bridge has moved slightly further northwards than the northern end.

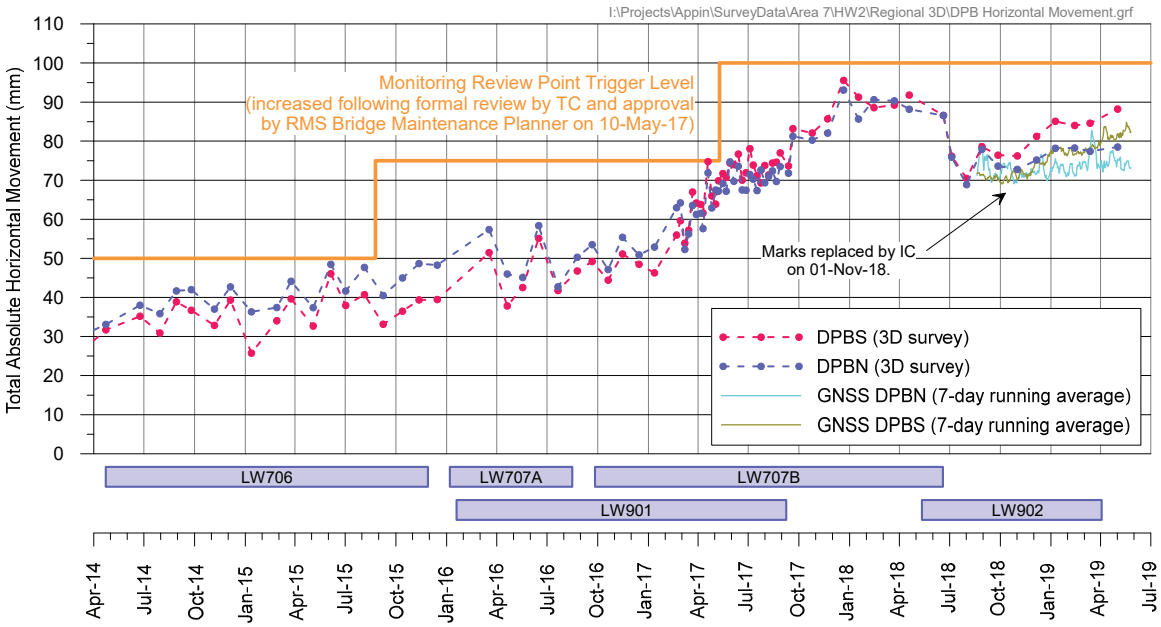

Fig. 2.11 Measured total absolute movements at Marks DPBN and DPBS due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks DPBN and DPBS remained below the Monitoring Review Point Trigger, as shown in Fig. 2.11. The trigger was reviewed by the M31 Hume Motorway Technical Committee and increased on two occasions.

A summary of the maximum measured absolute horizontal movements at Marks DPBN and DPBS, measured on the 2nd May 2019 after the completion of LW902, is provided in Table 2.12.

Table 2.12 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	88	100

The maximum measured absolute horizontal movement at Marks DPBN and DPBS was less than the Level 1 Trigger at the completion of LW902.

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

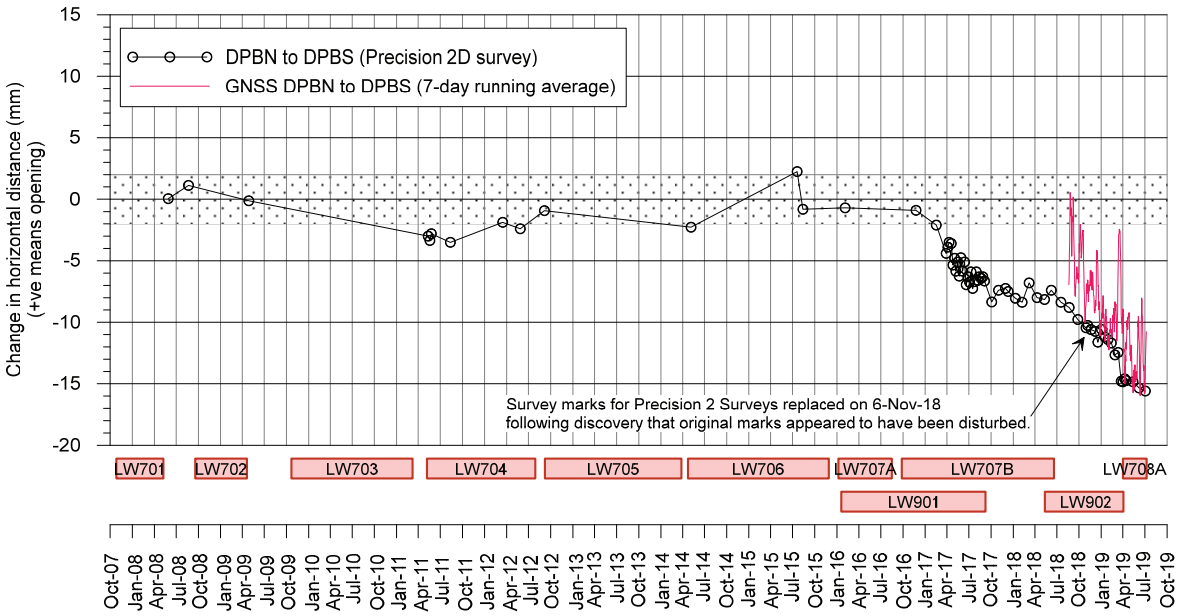

Fig. 2.12 Measured total valley closure at the Nepean Twin Bridges

The measured incremental closure at the completion of LW902 was 8 mm. The results of the GNSS units have been overlaid with the absolute 3D and precision 2D survey results in in Fig. 2.12. 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 mine subsidence movements of the Nepean Twin Bridges were measured by IC 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. 2.13 and Fig. 2.14 (Source: IC).

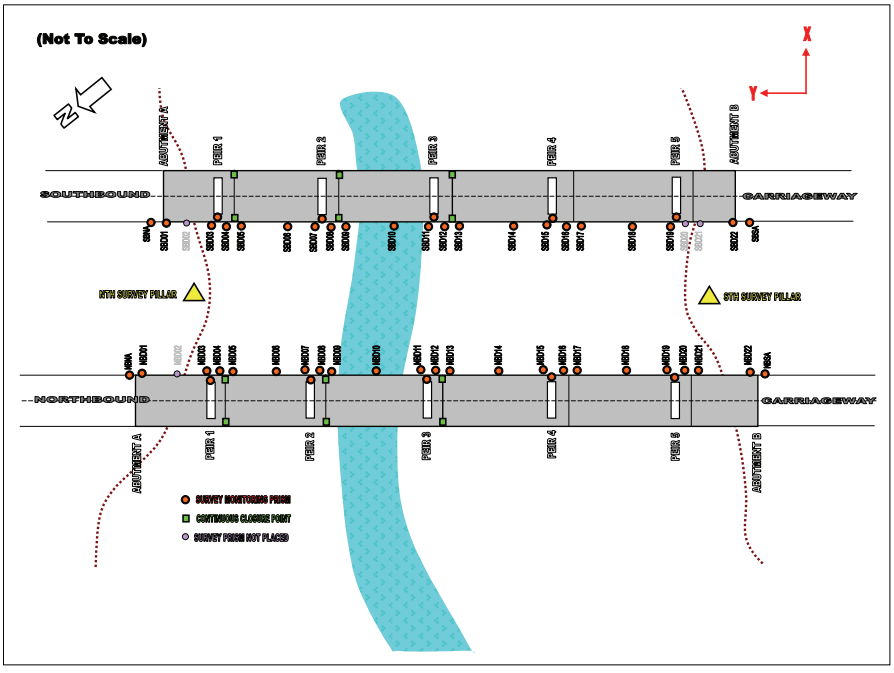

Fig. 2.13 Plan of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IC)

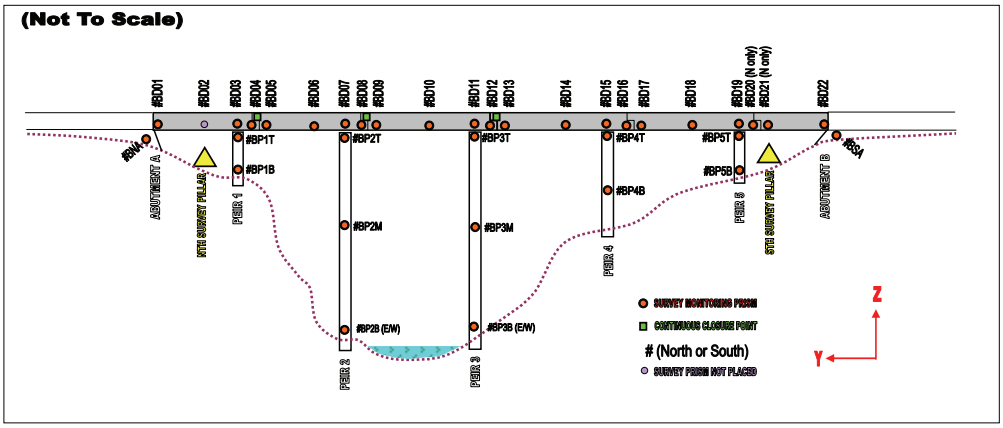

Fig. 2.14 Elevation of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IC)

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 and LW902. The development of total changes in horizontal distance between the marks, plotted from the start of April 2014, is shown in Fig. 2.20. The nominal survey accuracy is ±2 mm.

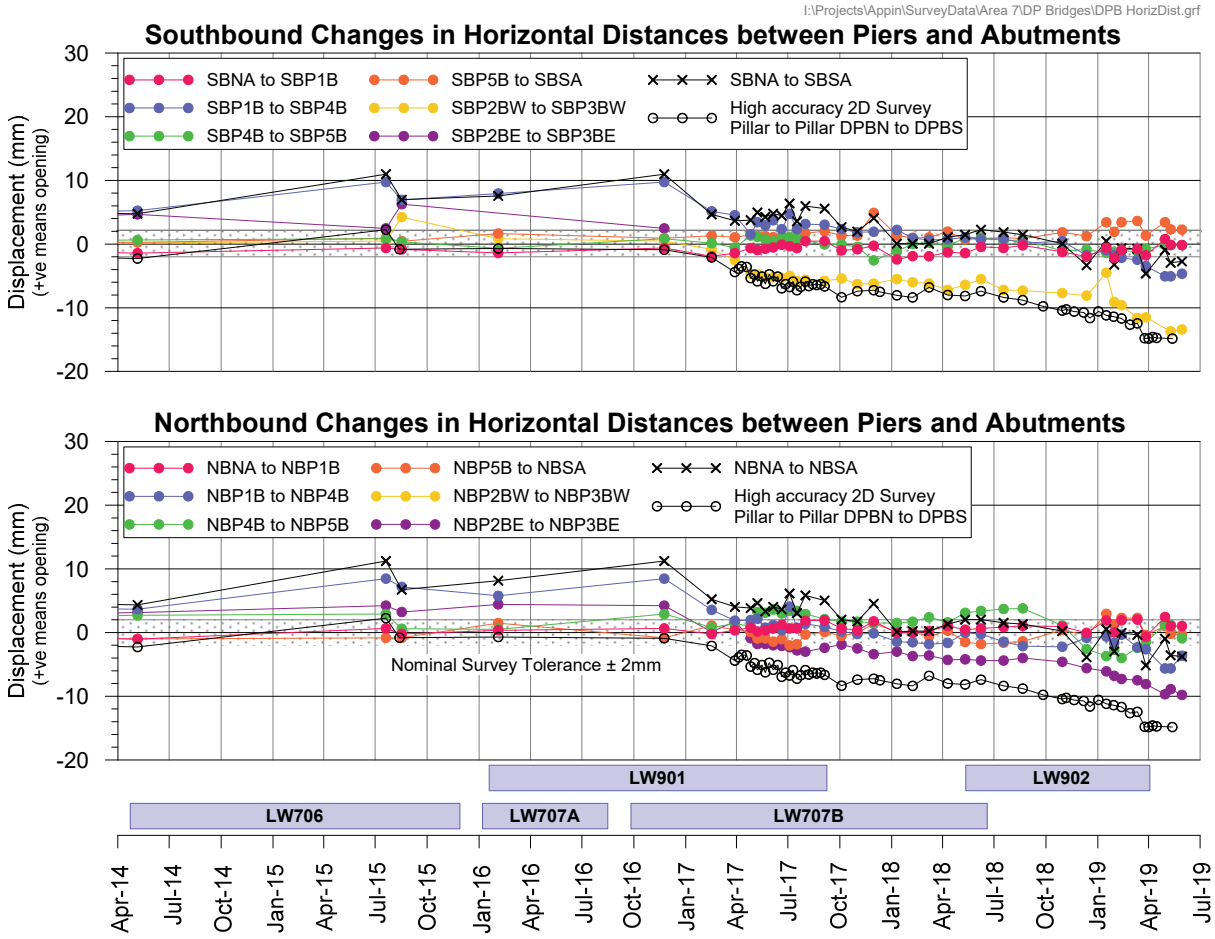

Fig. 2.15 Measured total changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges

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.

Measured changes in the lateral direction of the base of the Southbound and Northbound Bridges are close to survey tolerance, as shown in Fig. 2.16. It is noted that a lateral shift was observed in the positions of the base of Piers 2 and 3 relative the upper levels of the bridges at the end of mining of LW902. Minimal change in lateral alignment has been observed in the bridge deck.

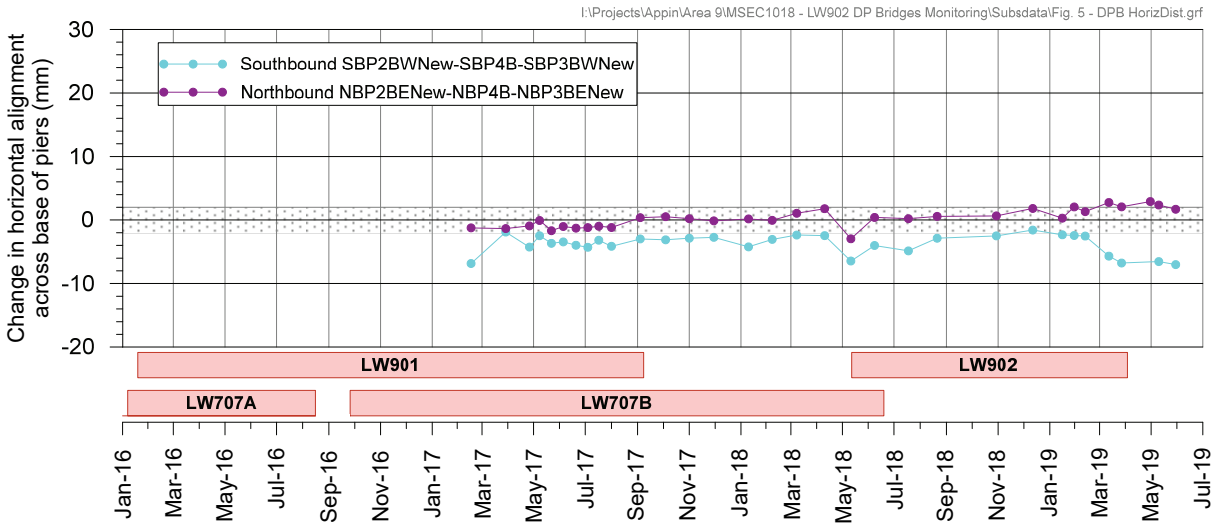

Fig. 2.16 Changes in horizontal alignment across the base of the piers

2.10.3. Inclinometer monitoring

The differential movements at the RST and SAA inclinometers at Site PSM6, located near the Nepean Twin Bridges, were monitored during the extraction of LW902 and the concurrent mining in the adjacent Appin Area 7. The inclinometers were installed and maintained by Pells Sullivan and Meynink (PSM), measured by IC 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 PSM883-372L (dated 4 January 2019) through to PSM883-393L (dated 31 May 2019).

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 LW902, is provided in Table 2.13.

Table 2.13 Measured differential movements and trigger for the Nepean Twin Bridges inclinometers

Type	Maximum measured differential movement (mm)	Level 1 Trigger (mm)
Differential movement	4.2 (PSM6 – RST) 2.8 (PSM6 – SAA)	5

The measured differential movements at the inclinometers at Site PSM6 approached very close to but did not exceed the Level 1 Trigger during the extraction of LW902. The observed movements are at a depth of 25.25 m and gradually increased as LW902 approached the finishing end. Minor changes have been observed since the completion of LW902.

2.10.4. Joint monitoring

Differential movements across the movement joints in the Nepean Twin Bridges were measured by PSM during the extraction of LW902 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 PSM883-372L (dated 4 January 2019) through to PSM883-393L (dated 31 May 2019).

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 LW902, 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)	+0.22 (northbound carriageway) +0.55 (southbound carriageway)	2
Joint 2 (middle joint)	-0.78 (northbound carriageway) -0.34 (southbound carriageway)	2
Joint 3 (main expansion joint)	-3.55 (northbound carriageway) -1.76 (southbound carriageway)	10

The measured differential movements at the bridge joints did not exceed the Level 1 Triggers during the mining of LW902.

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 LW902. The bridge experienced far-field movements due to the extraction of LW901 and LW902 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. MSEC1050-04, 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 LW902, were 17 mm and 12 mm, respectively. 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 and LW902. The development of total horizontal movements for these marks, plotted since the start of April 2014, is shown in Fig. 2.17.

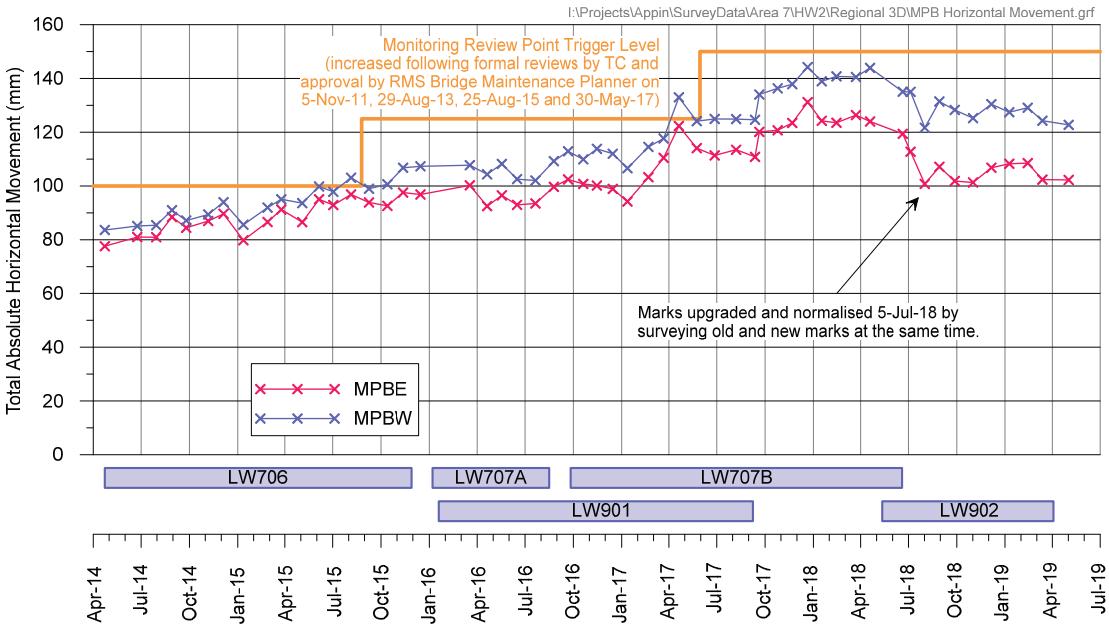

Fig. 2.17 Measured total absolute movements at Marks MPBE and MPBW due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks MPBE and MPBW exceeded the Monitoring Review Point Trigger, as shown in Fig. 2.11, on two occasions. The trigger was reviewed by the M31 Hume Motorway Technical Committee on these two occasions and was subsequently increased.

A summary of the maximum measured absolute horizontal movements at Marks MPBE and MPBW, measured on the 2nd May 2019 after the completion of LW902, 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	123	150

The maximum measured absolute horizontal movement at Marks MPBE and MPBW was less than the Level 1 Trigger at the completion of LW902.

2.11.2. Relative 3D monitoring points

The mine subsidence movements of the Moreton Park Road Bridge (South) were measured by IC using relative 3D marks fixed directly to the bridge structure. The locations of the monitoring points on the bridges are shown in Fig. 2.18 and Fig. 2.19 (Source: IC).

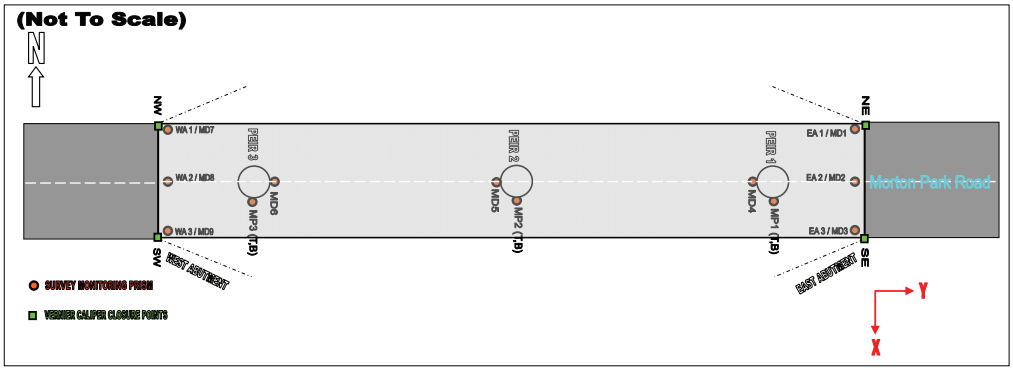

Fig. 2.18 Plan of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IC)

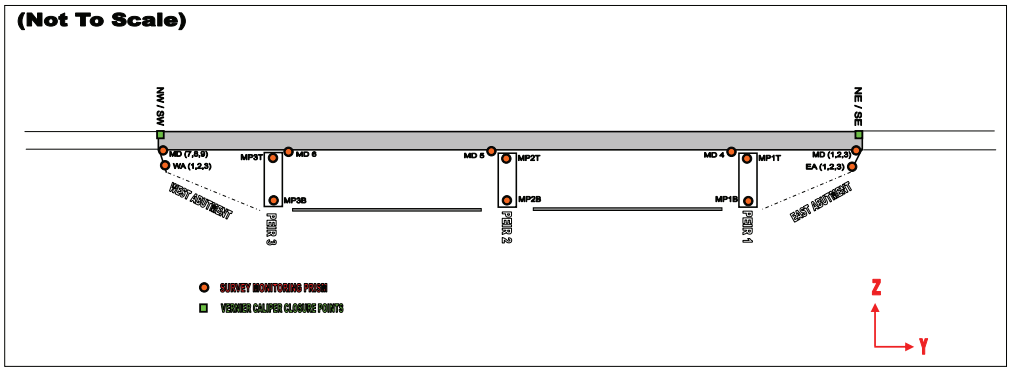

Fig. 2.19 Elevation of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IC)

The changes in horizontal distance between the bridge abutments have been measured during mining in Appin Area 7, since the 15th October 2007, and during LW901 and LW902. 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. 2.20. The nominal survey accuracy is ±2 mm.

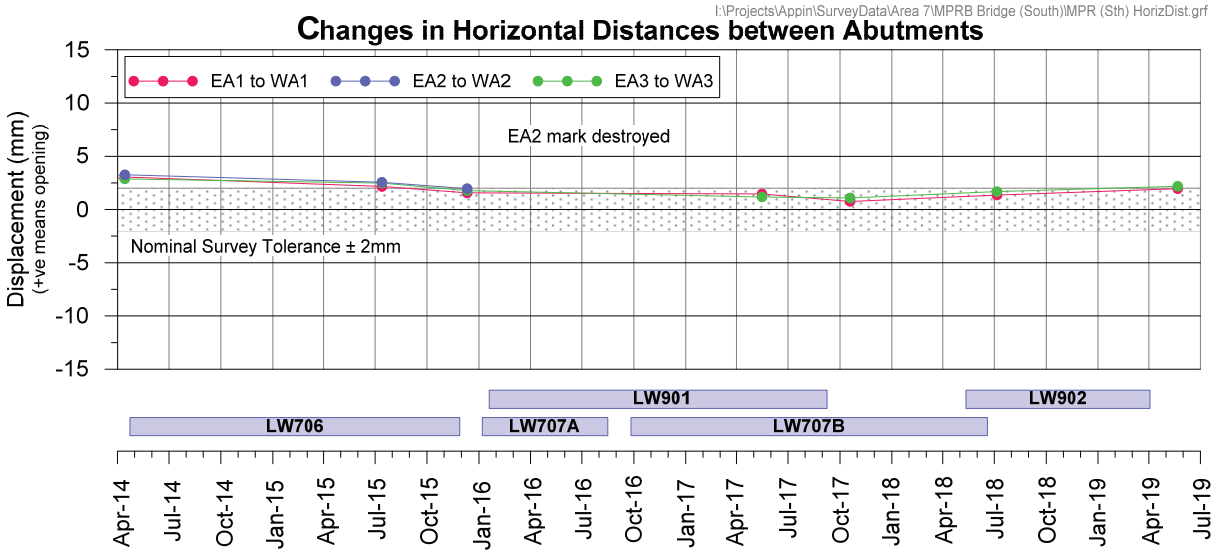

Fig. 2.20 Measured total changes in horizontal distance between the abutments of Moreton Park Road Bridge (South)

The total changes in horizontal distance between the bridge abutments were less than ±2 mm at the completion of LW902. The total measured movements, therefore, were within the order of survey tolerance at the completion of the longwall.

3.1. Natural features

The natural features near LW902 are shown in Drawing No. MSEC1050-02, 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 LW902 are provided in Reports Nos. MSEC448 and MSEC829, which supported the Extraction Plan and Modification Applications, respectively. 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 LW902, are provided in Table 3.1. The impacts are based on those recorded by IC Environmental Field Team and are described in the accompanying Landscape report.

Table 3.1 Assessed and reported impacts for the natural features due to LW902

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 releases (Level 1 impacts according to the TARP) were observed at six sites along the Nepean River during the extraction of LW902. Refer to the Landscape Report by IC for further details
	Water quality – refer to the surface water report by HGEO **Terrestrial ecology** – refer to the Landscape Report by IC	
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 LW902 were similar to or less than the MSEC assessments provided in Reports Nos. MSEC488 and MSEC829. 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 LW902 are shown in Drawing No. MSEC1050-03, in Appendix A, and include the:

- Main Southern Railway and associated infrastructure;
- Menangle Road;
- 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;
- Archaeological site (rock shelter located 350 m south of LW901);
- Heritage sites (railway cottage); and
- Houses and associated structures.

The MSEC assessed impacts for the built features resulting from the extraction of LW902 are provided in Reports Nos. MSEC448 and MSEC829, 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 LW902, are provided in Table 3.2.

Table 3.2 Assessed and reported impacts for the built features due to LW902

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	No reported impacts (not directly mined beneath by LW902)
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 due to mining. Tilt of a private pole was observed; however, investigations found that it was not mining related
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	One claim submitted to SA NSW for potential impact on a farm dam. An investigation found that the changes were due to low rainfall and was not related to the longwall mining

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 IC
Archaeological sites	Adverse impacts unlikely	No reported impacts. Refer to the Landscape Report by IC
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, 4 % Category R3 or R4, and < 0.5 % Category R5	Houses have remained in safe and serviceable conditions. There were three claims submitted to SA NSW relating to the houses: 1. differential movement between a veranda slab and a residential structure (not occupied); 2. minor (non-structural) cracking inside another house; and 3. sticky internal doors and leaking bathroom waterproofing (house with an existing claim from LW901). Other claims are related to a pool and pool gates, groundwater bores, a broken stormwater pipe and cracking of an external pavement.

The recorded impacts on the built features due to the extraction of LW902 were similar to or less than the MSEC assessments provided in Reports Nos. MSEC488 and MSEC829. 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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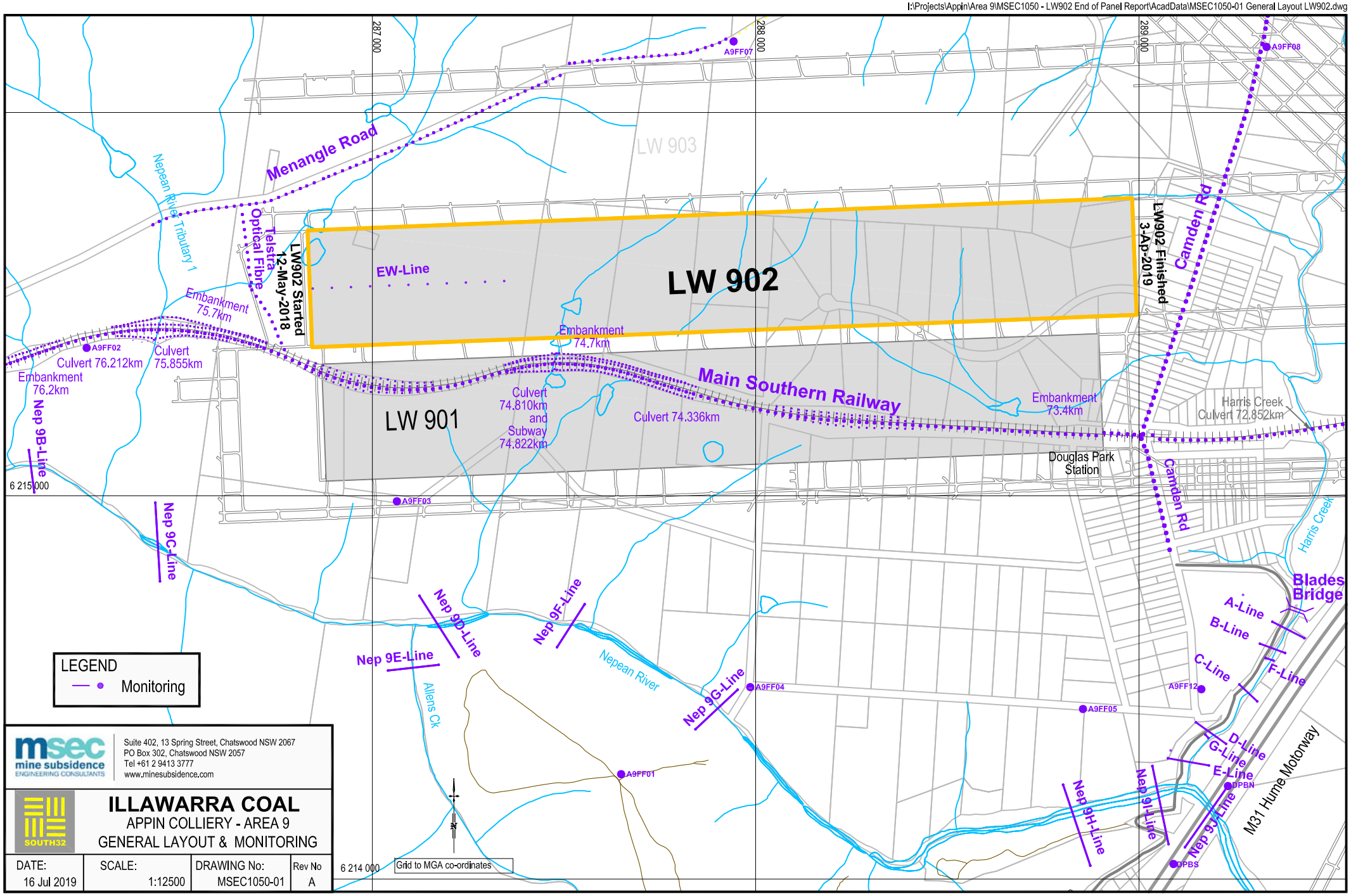

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GENERAL LAYOUT & MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
16 Jul 2019	1:12500	MSEC1050-01	A

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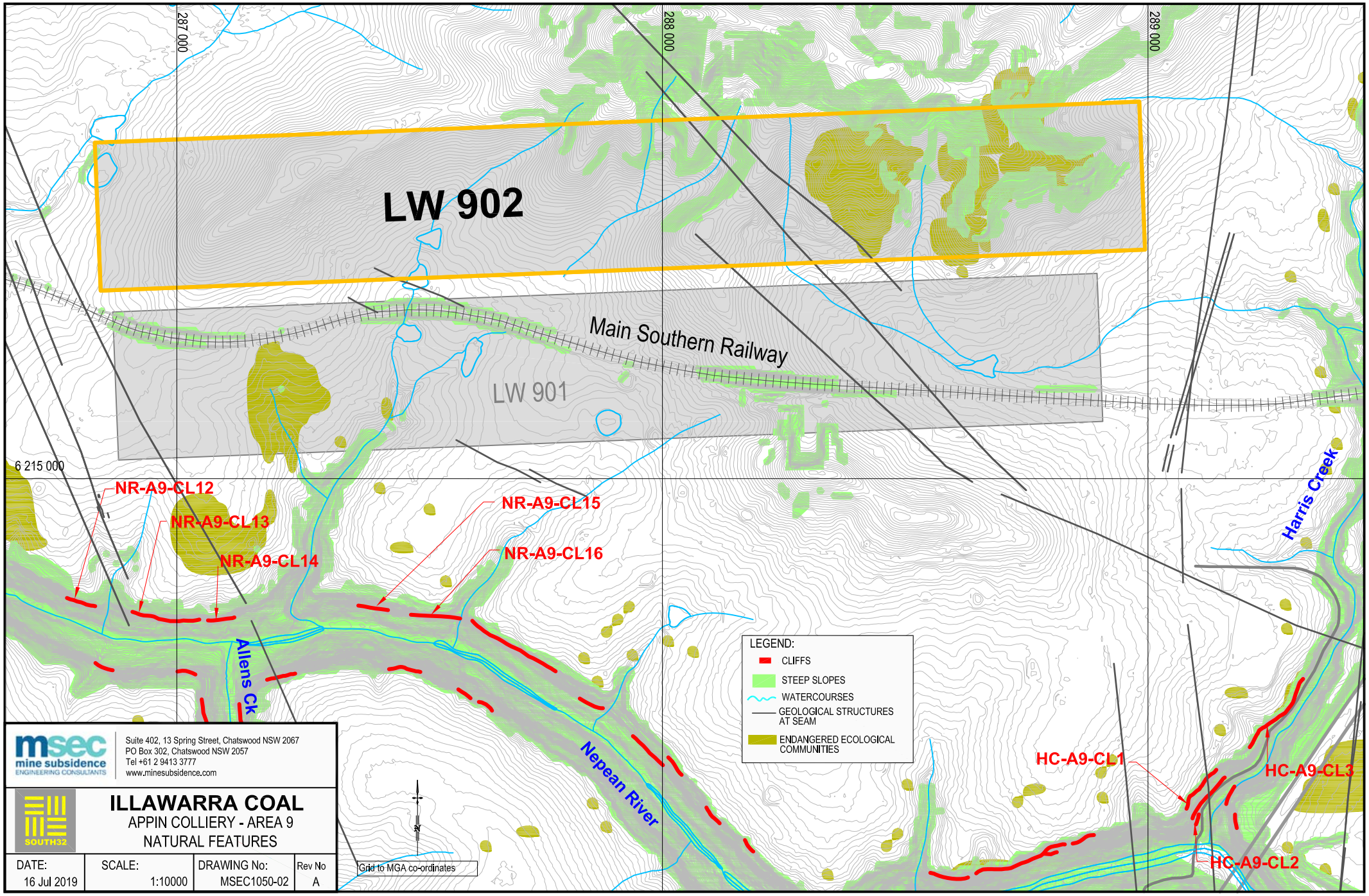

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APPIN COLLIERY - AREA 9

NATURAL FEATURES

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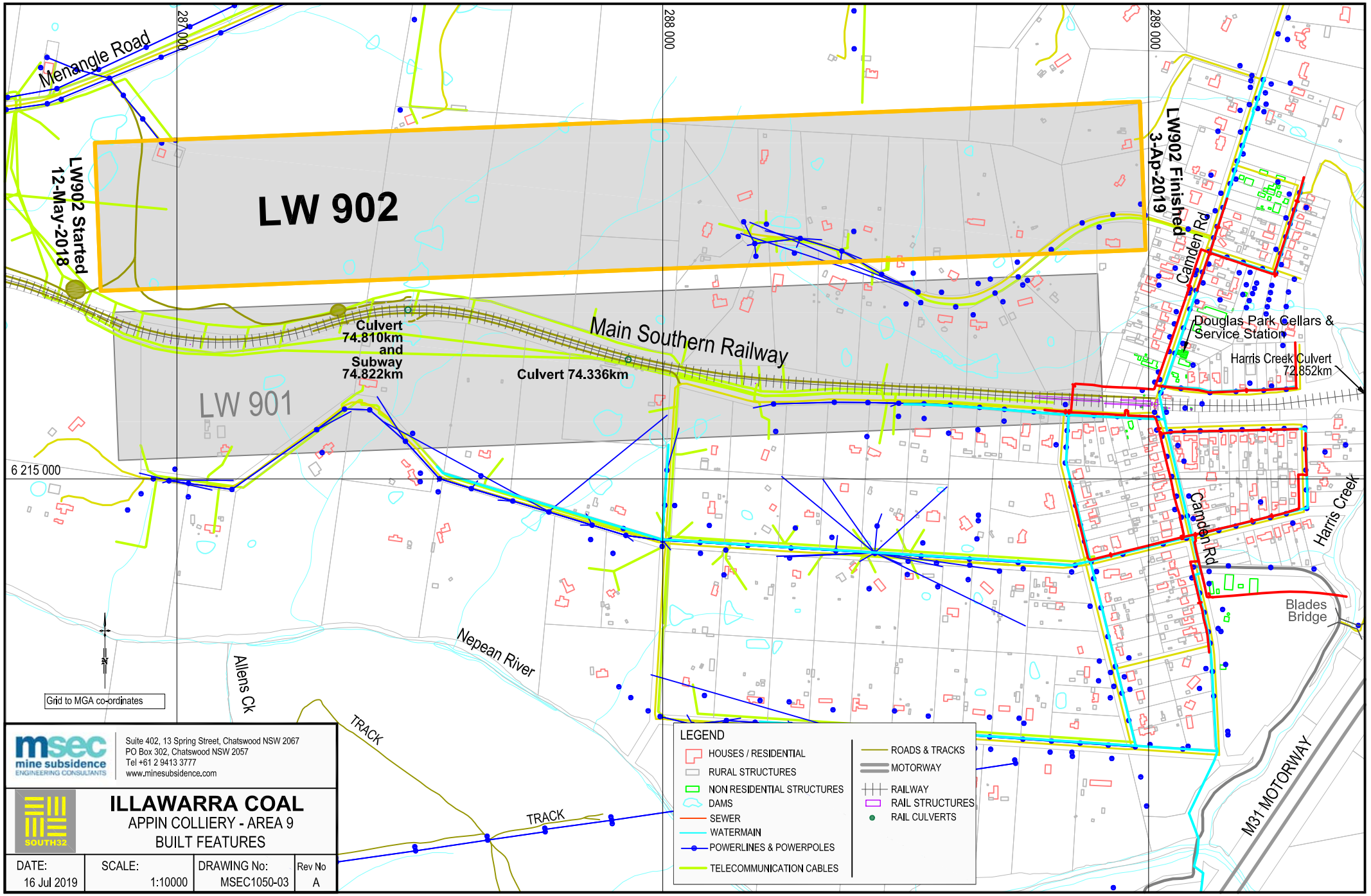

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BUILT FEATURES

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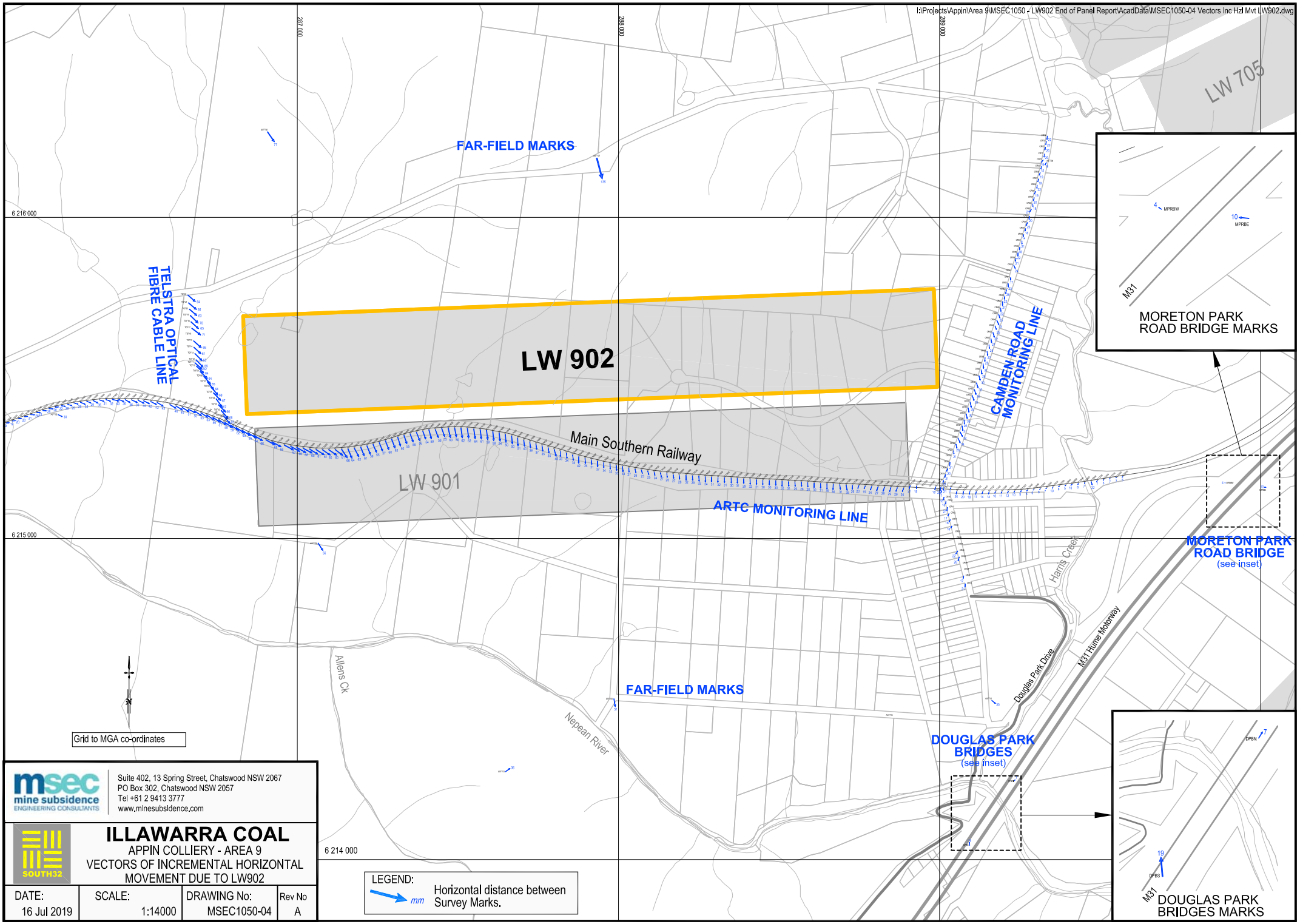

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VECTORS OF INCREMENTAL HORIZONTAL MOVEMENT DUE TO LW902

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