mine subsidence ENGINEERING CONSULTANTS

South32

Illawarra Coal

SOUTH32 ILLAWARRA COAL:

Appin - Area 9 - Longwall 901

End of Panel Subsidence Monitoring Review Report for Appin Longwall 901

 | REPORT NUMBER: MSEC927 | REVISION B

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	JB	BM	30th Nov 17
A	Final Issue	JB	BM	11th Jan 18
B	Minor updates	JB	BM	26th Mar 18

Report produced for: End of panel report for Longwall 901

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)

MSEC743 (Rev. A) – Appin Colliery – Longwall 901 – The Effects of the Proposed Modified Commencing End of Longwall 901 on Previous Subsidence Predictions and Impact Assessments (February 2015)

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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Tables

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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***
MSEC927-01	General layout and monitoring lines	A
MSEC927-02	Natural features	A
MSEC927-03	Built features	A
MSEC927-04	Vectors of incremental horizontal movement due to Longwall 901	A

1.1. Introduction

South32 Illawarra Coal (IC) has approval for the extraction of Longwalls 901 to 904 in Area 9 at Appin Colliery. IC has completed the extraction of Longwall 901, which is the first longwall in the series. The location of the longwalls in Area 9 are shown in Drawing No. MSEC927-01, in Appendix A. A summary of the commencement and finishing dates for Longwall 901 is provided in Table 1.1.

Table 1.1 Commencement and finishing dates for Longwall 901

Longwall	Commencement date	Finishing date
901	19th January 2016	8th September 2017

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IC to prepare subsidence predictions and impact assessments for Longwalls 901 to 904. 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 10th September 2014.

IC subsequently shortened the commencing (i.e. western) end of Longwall 901 by 418 m from the extent indicated in the Extraction Plan Application. Report No. MSEC743 (Rev. A) was issued in February 2015 in support of the application for this modification. The modified commencing end of Longwall 901 was approved by the DP&E on the 29th April 2015.

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 Longwall 901; and
- Comparisons between the observed and assessed impacts on the natural and built features within the mining area resulting from the extraction of Longwall 901.

Further details on the observed and assessed impacts for natural features due to the extraction of Longwall 901 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 which were surveyed during the extraction of Longwall 901. 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 Longwall 901. 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. MSEC927-01, in Appendix A. A summary of the as-extracted dimensions for Longwall 901 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	901	2028	305	-

The mined length of the longwall excluding the installation heading is approximately 9 m shorter than the overall void length 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 Longwall 901 are illustrated in Fig. 1.1.

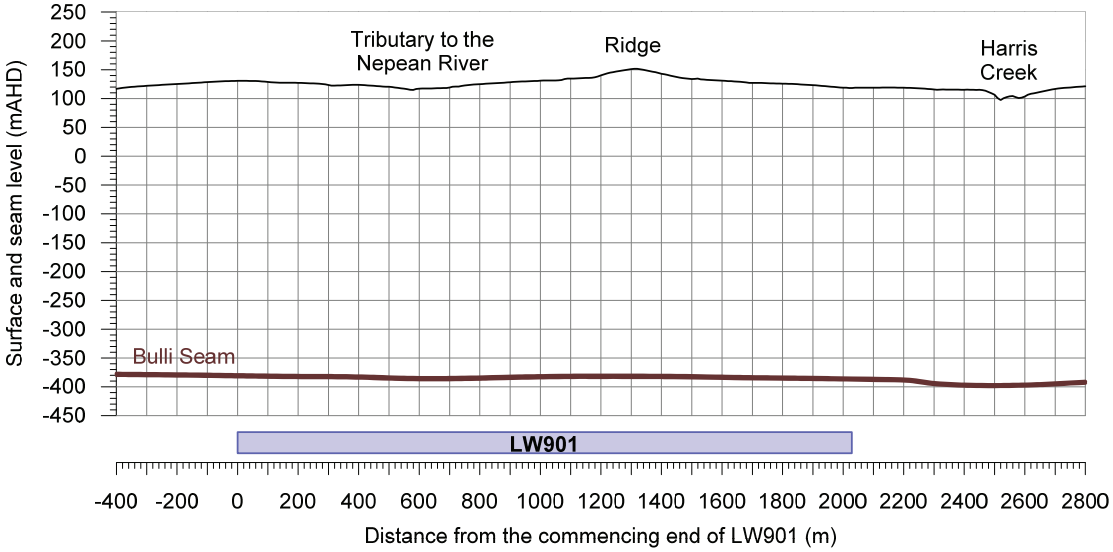

Fig. 1.1 Surface and seam levels along the centreline of Longwall 901

The natural surface generally falls from the north towards the south. The natural drainage lines located directly above Longwall 901 flow into the Nepean River to the south of the longwall. Harris Creek is located approximately 640 m to the east of the finishing end of Longwall 901. Razorback Range is located to the north of the longwall.

The depth of cover to the Bulli Seam directly above Longwall 901 varies between a minimum of 485 m above the tailgate towards the western end of the longwall, and a maximum of 540 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 2.7 and 2.9 m within the extents of Longwall 901. IC extracted the full thickness of the seam.

1.3. Predicted mine subsidence movements

The predicted mine subsidence movements for Longwall 901 were provided in Reports Nos. MSEC448 and MSEC743 which supported the Extraction Plan and Modification Applications. 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 for Longwall 901 is provided in Table 1.3. Longwall 901 is the first longwall in the series and, therefore, the predicted incremental subsidence parameters are less than those predicted for the subsequent longwalls.

Table 1.3 Maximum predicted incremental vertical subsidence, tilt and curvature due to the extraction of Longwall 901

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})
901	600	3.0	0.03	0.04

The predicted valley related movements 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 movements resulting from the extraction of Appin Longwall 901 were monitored using monitoring lines, monitoring points and other systems including the following:

- Main Southern Railway, including monitoring associated with the track, embankments, culverts, sewer horizontal bore and Douglas Park Station;
- Telstra optical fibre cable monitoring line;
- Camden 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;
- Moreton Park Road Bridge South monitoring points; and
- Airbourne Laser Scan (ALS) surveys.

The locations of the monitoring lines and monitoring points are shown in Drawing No. MSEC927-01, in Appendix A. Comparisons between the measured and predicted subsidence movements at these monitoring lines and points are provided in the following sections. The predicted subsidence parameters 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 Longwall 901, as shown in Drawings Nos. MSEC927-01 and MSEC927-03, in Appendix A. The monitoring associated with this section of railway includes the:

- Australian Rail and Track Corporation (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 the weekly subsidence monitoring review reports for the railway (Reports Nos. MSEC811-R01 to MSEC811-R80), which were issued during the extraction of Longwall 901, between February 2016 and August 2017.

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

2.2.1. ARTC monitoring line

The Australian Rail and Track Corporation (ARTC) monitoring line follows the Main Southern Railway directly above Longwall 901. This monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the ARTC monitoring line during Longwall 901 is provided in Table 2.1.

Table 2.1 Survey dates for the ARTC monitoring line during Longwall 901

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of Longwall 901; weekly surveys during mining; and final survey after completion of Longwall 901	11th January 2016 (base survey) 27th January 2016; then weekly surveys to the 19th December 2016; 16th January 2017; and then weekly surveys to the 22nd August 2017 (end of Longwall 901)	Weekly surveys during Longwall 902 and at the completion of that longwall

The measured incremental vertical subsidence along the ARTC monitoring line is illustrated in Fig. 2.1.

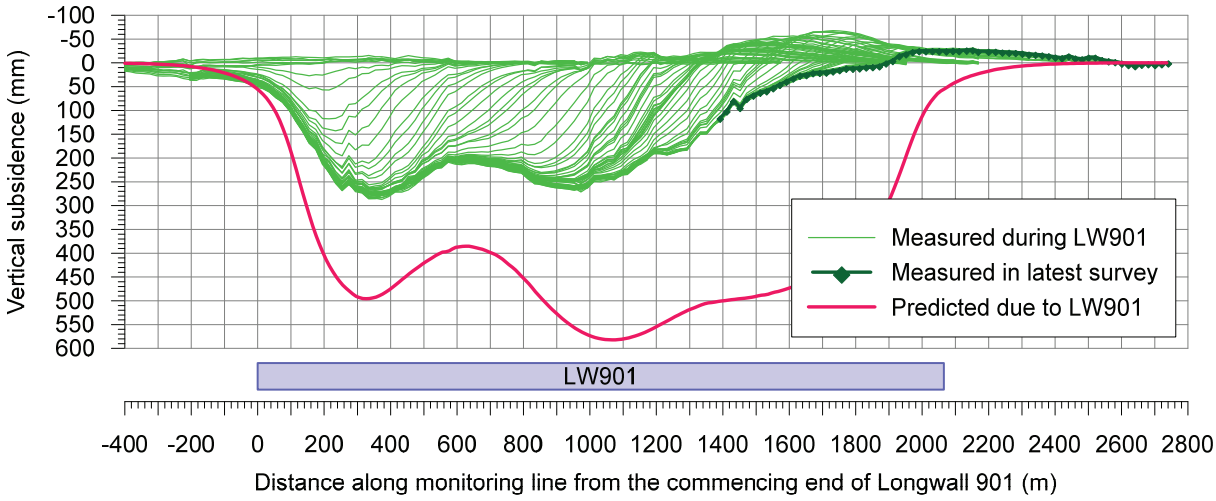

Fig. 2.1 Measured incremental vertical subsidence along the ARTC monitoring line

The measured vertical subsidence was considerably less than the predicted vertical subsidence directly above Longwall 901. The main reason for this is that the IPM generally provides conservative predictions for the first longwall in a series. The monitoring line is also located close to the longwall maingate at the western end and close to the tailgate at the eastern end of the longwall, which could result in lower subsidence being measured if the profile is broader or flatter than predicted.

The vertical subsidence to the west of Longwall 901 (i.e. left side of Fig. 2.1) was slightly greater than predicted. This low-level subsidence (i.e. less than 50 mm) was not associated with measurable tilts, curvatures or strains, i.e. values were in the order of survey tolerance.

Uplift was observed in front of the longwall extraction face above the eastern part of Longwall 901 (i.e. right side of Fig. 2.1). The uplift was up to 70 mm during the mining of Longwall 901, reducing to approximately 30 mm at the completion of the longwall.

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 Longwall 901.

Table 2.2 Maximum measured and predicted subsidence parameters for the ARTC monitoring line

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm)	Maximum incremental tensile strain (mm/m)	Maximum incremental compressive strain (mm/m)
Measured	287	1.7	0.5	1.1
Predicted	575	2.5	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the ARTC monitoring line are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels are in the order of ±15 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 0.5 mm/m tensile and 1.1 mm/m compressive. The maximum predicted conventional strains for Longwall 901, based on applying a factor of 15 to the maximum predicted curvatures, are 0.5 mm/m tensile and 1.0 mm/m compressive. The measured strains, therefore, were similar to those predicted based on conventional ground movements.

The vectors of horizontal movement along the ARTC monitoring line are shown in Fig. 2.11. Discussions on these movements have been included in Section 2.8.

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 to 60 m. The transducers measured changes in rail stress every 5 minutes during the mining of Longwall 901. The results and discussions on rail stress 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 transducers, actual 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 Longwall 901. The results and discussions on switches were provided in the reports by PCE attached to the weekly subsidence monitoring review reports. While some low-level (Blue) alarms were triggered during mining, responses had already been planned in anticipation of the alarms.

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 Longwall 901 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 Longwall 901.

The mine subsidence movements at the embankments were measured by IC using 3D ground monitoring lines along their tops 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 David Christie attached to the weekly subsidence monitoring review reports. Only minor changes were recorded during the mining of Longwall 901.

2.2.4. Cutting monitoring points

Cuttings in Appin Area 9 are located at railway chainages 74.0 km and 75.3 km. The cutting at 74.0 km is located directly above Longwall 901 and the cutting at 75.3 km is located at a minimum distance of approximately 0.1 km to the west of Longwall 901.

The mine subsidence movements at the cuttings were measured by IC using 3D ground monitoring lines along their tops and toes. Closure developed across each of the cuttings that resulted in changes in track geometry. The changes in track geometry were managed in accordance with the Management Plan and there were no adverse impacts on the safety or serviceability of the railway. 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 Longwall 901 and the culvert at 75.7 km is located at a distance of approximately 0.4 km to the west of Longwall 901.

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 Longwall 901 is provided in Table 2.3.

Table 2.3 Survey dates for the horizontal bore during Longwall 901

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 Longwall 901	10th April 2017 (base survey) 18th April 2017 16th May 2017 14th June 2017 11th July 2017 8th August 2017 26th September 2017 (end of Longwall 901)	Monthly surveys during Longwall 902 and at the completion of that longwall

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 ±3 mm.

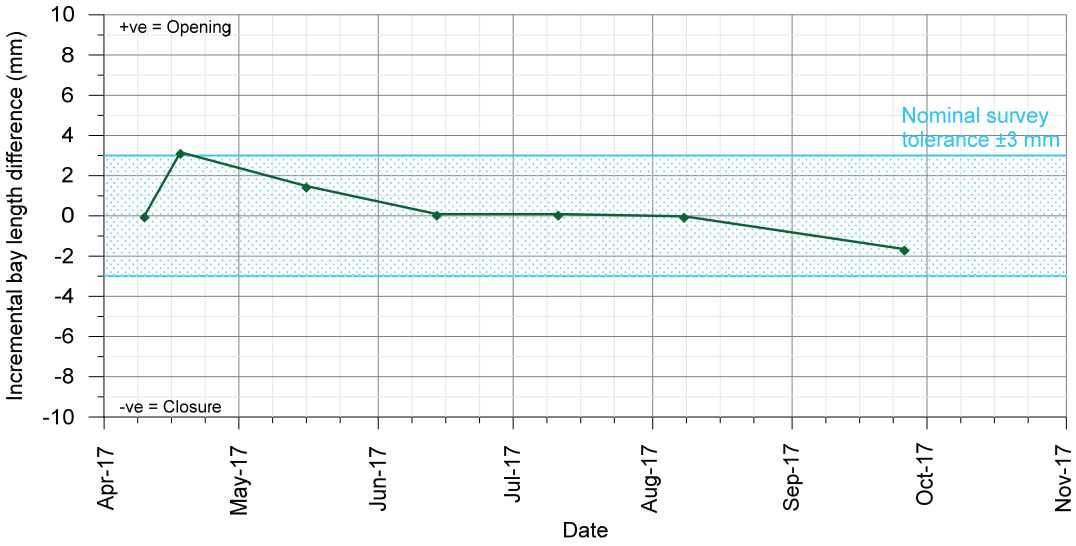

Fig. 2.2 Development of measured incremental change in bay length for the horizontal bore

The measured changes in length for the horizontal bore were within the order of survey tolerance. The 3D measurements indicate that the ground had moved towards the south-east by approximately 50 mm. The change in absolute level was less than 20 mm and, therefore, was in the order of survey tolerance.

2.2.7. Douglas Park Station monitoring points

Douglas Park Station is located immediately to the east of the finishing end of Longwall 901. The mine subsidence movements 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 Longwall 901, at a minimum distance of 0.1 km from the longwall finishing end. This monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Camden Road monitoring line during Longwall 901 is provided in Table 2.4.

Table 2.4 Survey dates for the Camden Road monitoring line during Longwall 901

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 Longwall 901	11th January 2017 (base survey) 15th March 2017; then weekly surveys to the 17th August 2017; and 3rd October 2017 (end of Longwall 901)	Weekly surveys during Longwall 902 and at the completion of that longwall

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.

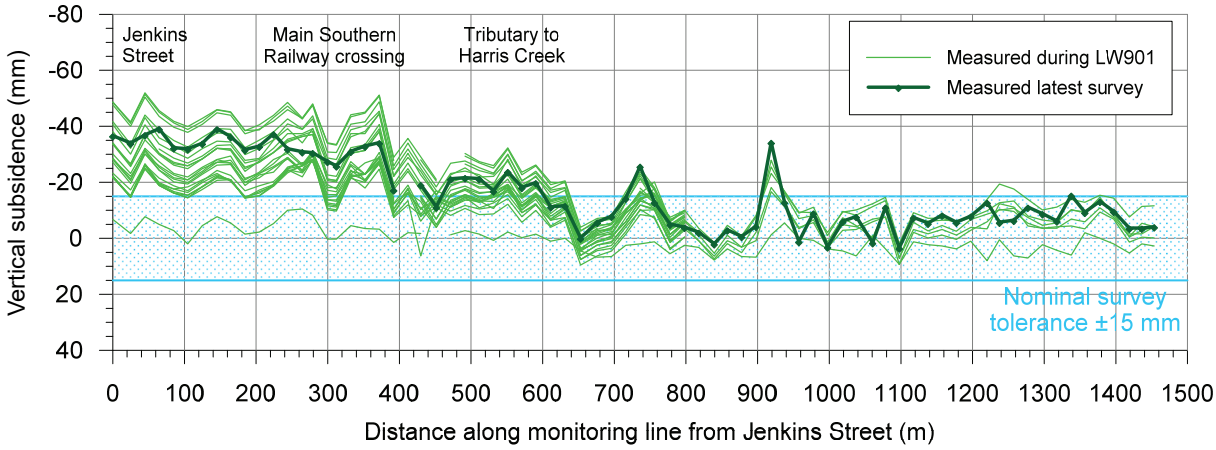

Fig. 2.3 Measured incremental vertical subsidence along the Camden Road monitoring line

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 uplift was up to 50 mm during the mining of Longwall 901, reducing to approximately 40 mm at the completion of the longwall. Similar behaviour was observed along the ARTC monitoring line in front of the longwall extraction face.

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

The vectors of horizontal movement along the Camden Road monitoring line are shown in Fig. 2.11. Discussions on these movements have been included in Section 2.8.

2.4. Telstra optical fibre cable line

The Telstra Optical Fibre Cable (OFC) monitoring line is located north-west of Longwall 901, at a minimum distance of approximately 0.1 km from the longwall commencing end. This monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Telstra OFC monitoring line during Longwall 901 is provided in Table 2.5.

Table 2.5 Survey dates for the Telstra OFC monitoring line during Longwall 901

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of Longwall 901; monthly surveys for first 500 m of extraction; and final survey after completion of Longwall 901	16th December 2015 (base survey) 19th February 2016; then monthly surveys to the 14th November 2016; and 26th September 2017 (end of Longwall 901)	Monthly surveys during Longwall 902 and at the completion of that longwall

The measured incremental vertical subsidence along the Telstra OFC monitoring line is illustrated in Fig. 2.4.

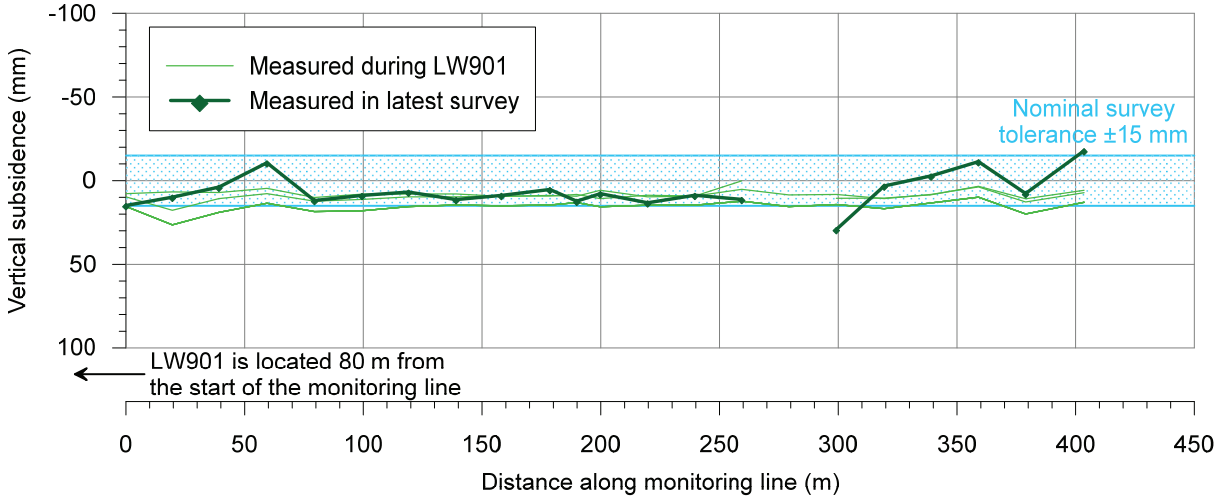

Fig. 2.4 Measured incremental vertical subsidence along the Telstra OFC monitoring line

Only low-level vertical subsidence was measured along the Telstra OFC monitoring line. In the final survey, the magnitudes were typically less than ±15 mm, i.e. in the order of survey tolerance for absolute level. Vertical subsidence greater than survey tolerance was measured in one location in the final survey, being 30 mm at Mark TOF17; however, it is likely that this survey mark was disturbed by a non-mining related event, as the longwall extraction face was more than 1 km away at that time.

The maximum measured strains for the Telstra OFC were 0.2 mm/m tensile and 0.9 mm/m compressive. The conventional strains outside the extents of Longwall 901 were predicted to be less than the order of survey tolerance of 0.25 mm/m tensile and compressive.

The maximum compressive strain along the Telstra OFC occurred at a crossing with a small drainage line and, therefore, was likely due to valley closure effects. Elsewhere, the measured strains were in the order of survey tolerance.

2.5. Nepean River closure lines

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 and 225 m. A summary of the survey dates for the Nepean River closure lines during Longwall 901 is provided in Table 2.6.

Table 2.6 Survey dates for the Nepean River closure lines during Longwall 901

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of Longwall 901; monthly surveys during mining; and final survey after completion of Longwall 901	20th October 2015 (base survey) 31st May 2016; then monthly surveys to the 22nd March 2017; then weekly to fortnightly surveys to 29th June 2017; then 11th August 2017; and 11th September 2017 (end of Longwall 901)	Monthly surveys during Longwall 902 and at the completion of that longwall

The measured incremental valley closure along the Nepean River is illustrated in Fig. 2.5.

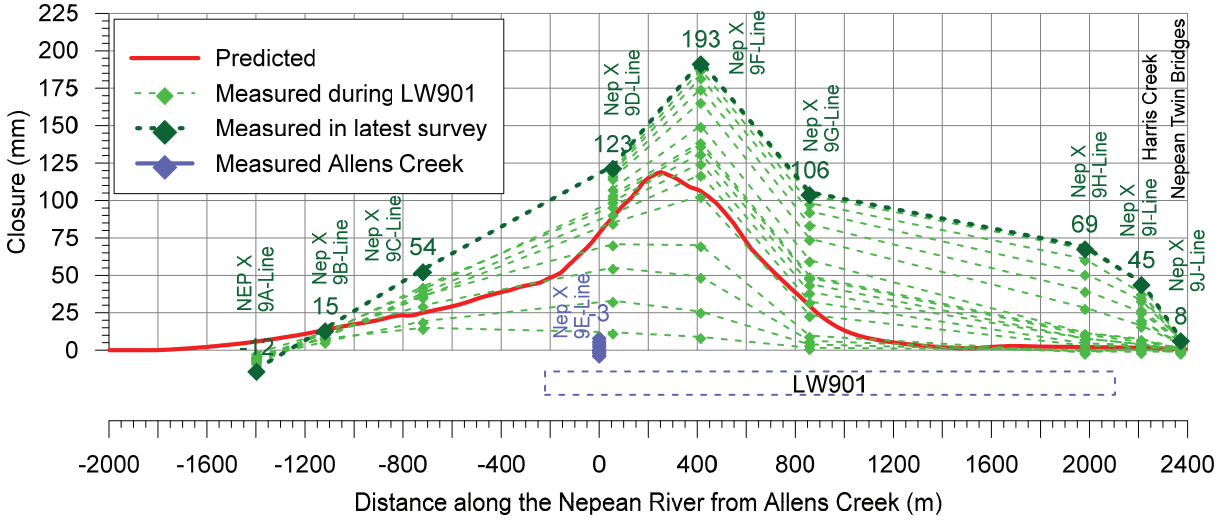

Fig. 2.5 Measured incremental valley closure along the Nepean River

A summary of the measured and predicted closure movements for each of the Nepean River closure lines is provided in Table 2.7. The values are the maximum movements measured at any time during or after the extraction of Longwall 901.

Table 2.7 Measured and predicted closure for the Nepean River closure lines

Location	Measured closure (mm)	Predicted closure (mm)
Nep X 9A-Line	-12 (opening)	< 20
Nep X 9B-Line	15	< 20
Nep X 9C-Line	54	30
Nep X 9D-Line	123	100
Nep X 9E-Line	-3 (opening)	70
Nep X 9F-Line	193	110
Nep X 9G-Line	106	40
Nep X 9H-Line	69	< 20
Nep X 9I-Line	45	< 20
Nep X 9J-Line	8	< 20

The measured closure movements at the Nep X 9C-Line, 9D-Line, 9F-Line, 9G-Line, 9H-Line and 9I-Line were greater than the predicted values at each of their locations. The maximum measured closure of 193 mm at the Nep X 9F-Line was greater than the maximum predicted final closure anywhere along the Nepean River of 120 mm.

The maximum measured closure exceeds the maximum predicted closure by a factor of 1.6 times. The vectors of horizontal movement at the far-field marks (refer to Drawing No. MSEC924-04) indicate that the ground on the northern side of the Nepean River has moved towards the south to south-east and that the ground on the southern side of the river has moved towards the north. These vectors indicate 'plate' type regional movements that may have contributed to the higher than predicted closure.

The comparison of the measured incremental valley closure movements across the Nepean River in Appin Areas 7 and 9 is provided in Fig. 2.6. The x-axis in this figure represents the distance from the valley centreline to the active longwall.

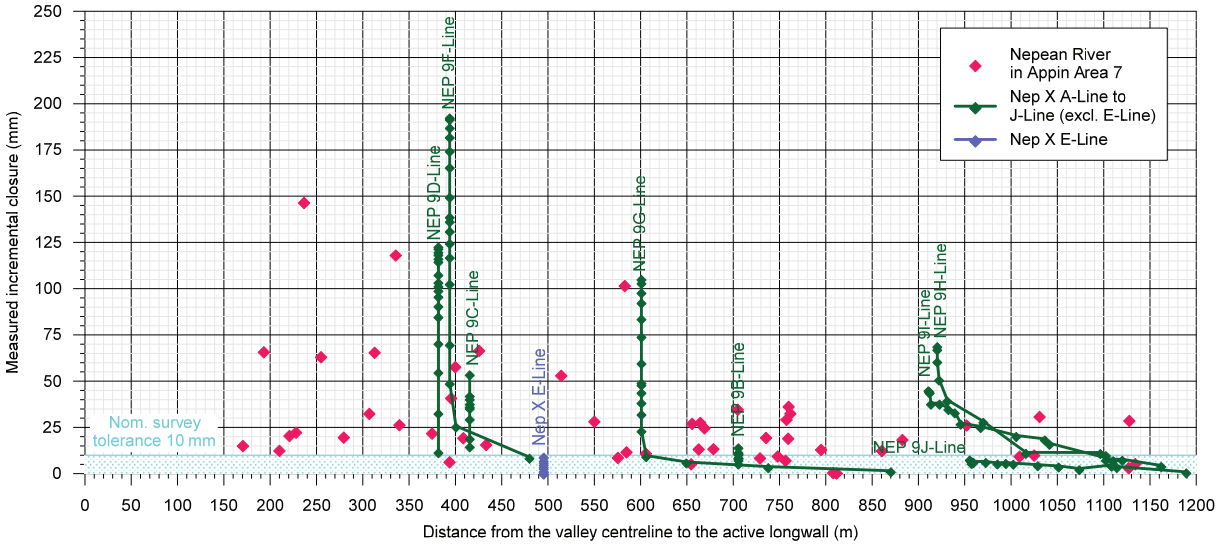

Fig. 2.6 Measured incremental valley closure versus distance from the active longwall

The valley closure measured at the Nep X 9F-Line, 9G-Line, 9H-Line and 9I-Line are greater than the movements measured at similar distances from mining in Appin Area 7. It is noted, that the monitoring lines in Area 7 are located off both the sides and the ends of the active longwalls.

2.6. Harris Creek Cliff Line closure lines

The Harris Creek Cliff Line (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 and 110 m. A summary of the survey dates for the HCCL closure lines during Longwall 901 is provided in Table 2.8.

Table 2.8 Survey dates for the HCCL closure lines during Longwall 901

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of Longwall 901; monthly surveys during mining; and final survey after completion of Longwall 901	25th March 2013 (base survey) 3rd May 2013; then one to two monthly surveys to the 12th January 2016 (pre-mining surveys); then monthly surveys to 2nd March 2017; then fortnightly surveys to the 28th August 2017; 21st September 2017; and 2nd November 2017 (end of Longwall 901)	Monthly surveys during Longwall 902 and at the completion of that longwall

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

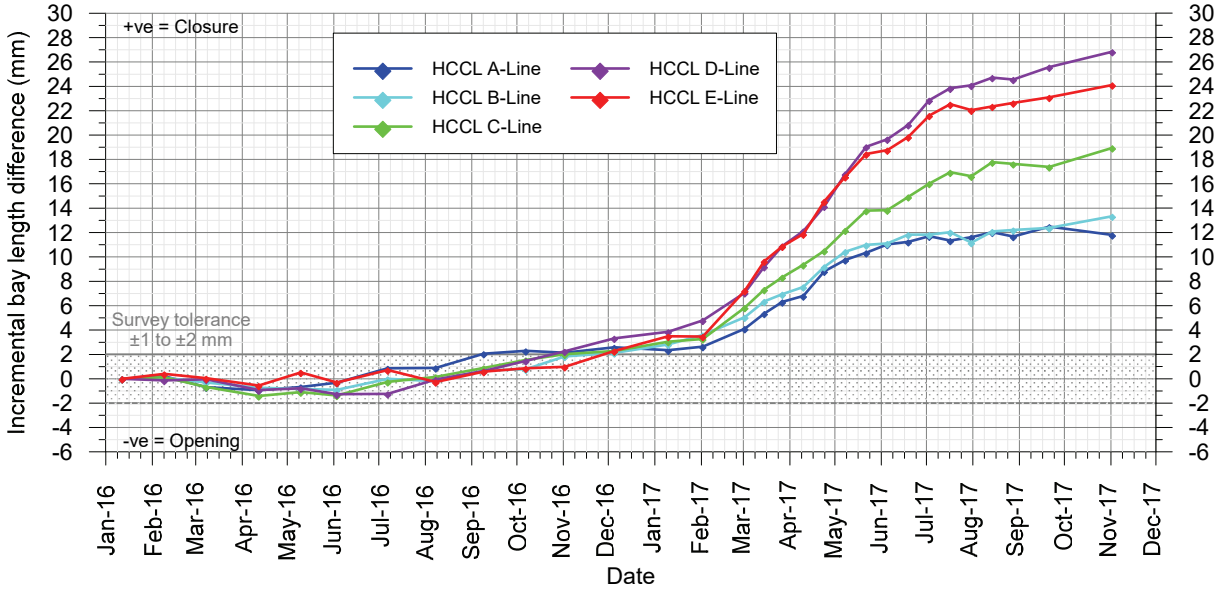

Fig. 2.7 Development of measured incremental valley closure for Harris Creek

The measured incremental closures varied between 12 mm at the HCCL A-Line to 27 mm at the HCCL D-Line. Higher valley closure has developed towards the confluence with the Nepean River (i.e. southern end) and the closure generally reduces towards Blades Bridge (i.e. northern end).

The predicted incremental closure for Harris Creek due to the extraction of Longwall 901 was less than 20 mm. The measured closure movements towards the southern end of Harris Creek, therefore, were greater than the predicted closure. The horizontal movement vectors (refer to Drawing No. MSEC927-04) indicate that the ground to the west of Harris Creek has moved towards the south to south-east. Only low-level horizontal movements were measured on the eastern side of the creek. The higher than predicted closure across Harris Creek, therefore, could be due to the 'plate' type regional movements defined by the Nepean River and Harris Creek.

The maximum measured incremental closure for the HCCL monitoring lines has been compared with that measured elsewhere in the Southern Coalfield in Fig. 2.8. This figure shows the incremental closure versus the distance from the active longwall. The grey diamonds represent all the available data, the blue diamonds represent the data off the corners of longwalls, and the black diamonds represent the data off the corners of longwalls and with valley heights of 30 m (i.e. similar to that for the HCCL relative to Longwall 901).

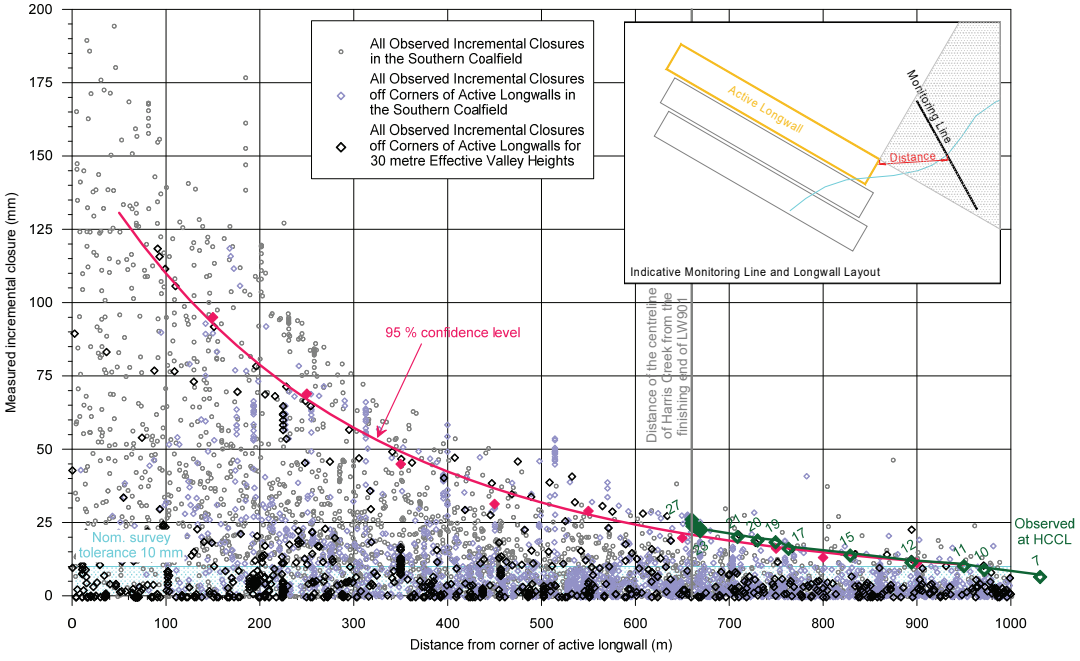

Fig. 2.8 Comparison of maximum incremental closure for the HCCL monitoring lines with that measured elsewhere in the Southern Coalfield

The 95 % confidence level based on the monitoring data from the Southern Coalfield off the corners of longwalls and with valley heights of 30 m (i.e. similar to that for the HCCL relative to Longwall 901) is shown as the red line in Fig. 2.8. The maximum measured incremental closure for the HCCL monitoring lines is shown as the green line at the bottom right corner of the figure.

The maximum measured closure at the HCCL due to the mining of Longwall 901 was similar to, but, slightly greater than the 95 % confidence level. The measured closure at the HCCL, therefore, is towards the upper end of the range of data measured elsewhere in the Southern Coalfield at similar distances from mining.

Additional survey marks were installed near the base of Harris Creek to provide further information on the closure movements developing within the valley. The HCCL F-Line is in a similar location to the HCCL B-Line and the HCCL G-Line is in a similar location to the HCCL D-Line. The base surveys for the HCCL F and G-Lines were carried out on the 27th March 2017.

The development of closure for the HCCL F and G-Lines are shown in Fig. 2.9. The development of closure for the HCCL B and D-Lines over the same period (i.e. since the 27th March 2017) are also shown in this figure for comparison.

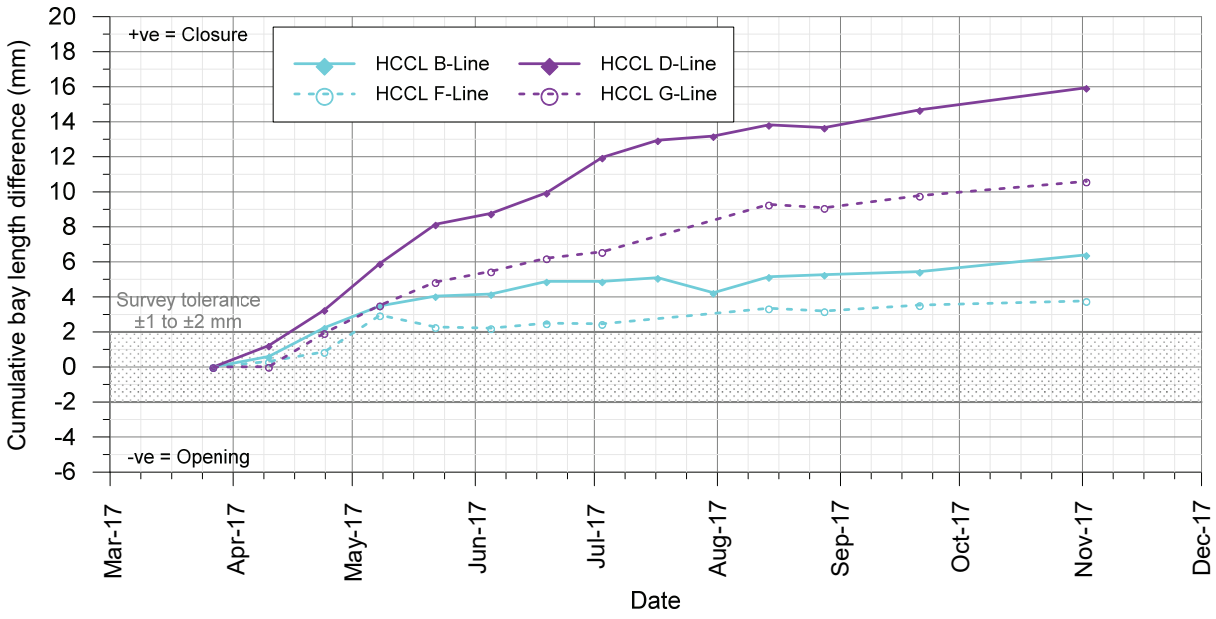

Fig. 2.9 Comparison of the closure for the HCCL B, D, F and G-Lines since the 27th March 2017

The closure measured at the HCCL D-Line (i.e. top of cliff) of 15 mm was greater than that measured at the HCCL G-Line (i.e. below base of cliff) of 10 mm. The difference in the measured closures of 5 mm suggests that not all the compressive strain due to closure was confined to the base of the creek, near the southern end of the cliff line. However, the HCCL D-Line is approximately 8 times longer than the HCCL G Line, so it is not possible to say whether the difference is due to elastic compression or a localised movement. There was no measurable difference between the measured closures at the HCCL B-Line (i.e. top of cliff) and HCCL F-Line (i.e. below base of cliff), which are located near the northern end of the cliff line.

2.7. Blades Bridge monitoring points

The horizontal distance across the Harris Creek valley has been measured using two prisms fixed to the abutments of Blades Bridge located on the northern side of this bridge. A summary of the survey dates for Blades Bridge during Longwall 901 is provided in Table 2.9.

Table 2.9 Survey dates for Blades Bridge during Longwall 901

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to active subsidence; monthly surveys during mining; and final survey after completion of Longwall 901	3rd June 2016 (base survey) 7th July 2016; then monthly surveys to the 2nd March 2017; then fortnightly surveys to 28th August 2017; then 21st September 2017; and 2nd November 2017 (end of Longwall 901)	Monthly surveys during Longwall 902 and at the completion of that longwall

The measured incremental valley closure at Blades Bridge is illustrated in Fig. 2.10. The measured additional closure at the nearby HCCL A-Line, since the base survey for Blades Bridge on the 3rd June 2016, is also shown in this figure for comparison.

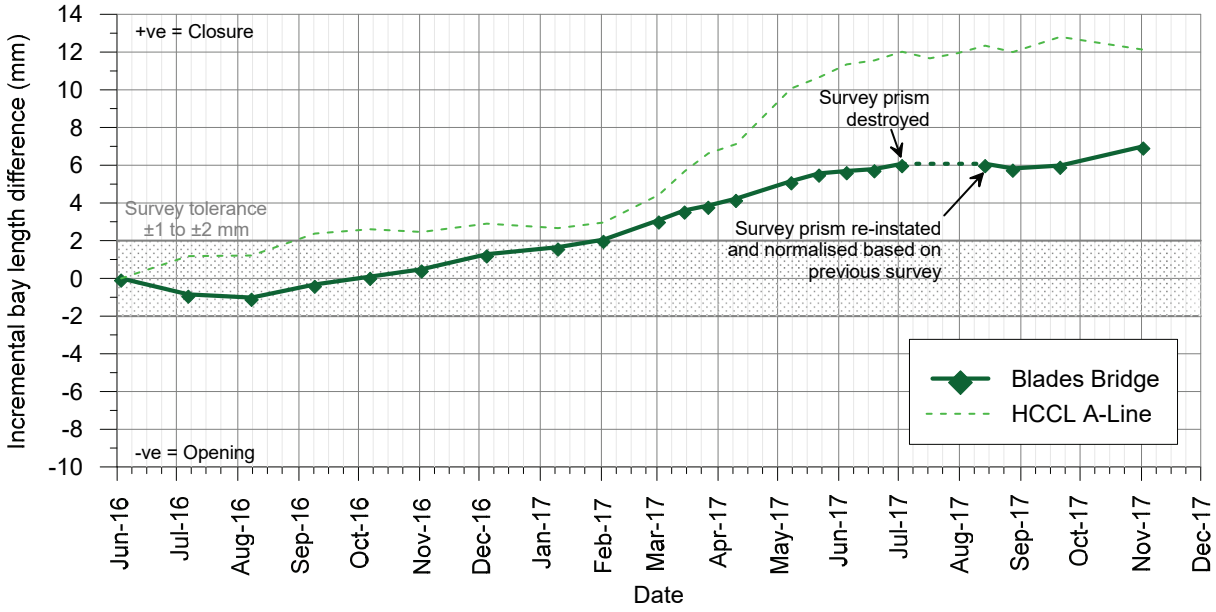

Fig. 2.10 Measured incremental valley closure at Blades Bridge

The maximum measured valley closure at Blades Bridge was 7 mm. The predicted valley closure due to the extraction of Longwall 901 was less than 20 mm. The measured closure at the bridge, therefore, was less than the predicted value.

The closure measured at Blades Bridge was less than that measured at the nearby HCCL A-Line over a similar period. The difference in measured closure of 5 mm could be partly due to the difference in the lengths of the monitoring lines, with the HCCL A-Line being approximately five times longer than the line for Blades Bridge.

2.8. Far-field monitoring points

The far-field horizontal movements near Longwall 901 have been measured by IC using the Appin Area 9 (AA9) far-field marks and along the ARTC, Camden Road and the 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 Longwall 901 are provided in Table 2.10. The survey dates for the ARTC, Camden Road and Telstra OFC monitoring lines are provided in Sections 2.2, 2.3 and 2.4, respectively.

Table 2.10 Survey dates for the AA9 far-field marks for Longwall 901

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of Longwall 901; monthly surveys during mining; and final survey after completion of Longwall 901	14th January 2014 (base survey) 31st March 2016; then monthly surveys to 12th September 2017 (end of Longwall 901)	Monthly surveys and at completion of each of the future longwalls in Area 9

The measured incremental horizontal movement vectors for the AA9 far-field marks and the ARTC, Camden Road and the Telstra OFC monitoring lines are shown in Drawing No. MSEC927-04. The accuracies of the measured absolute positions (i.e. Eastings and Northings) are in the order of ±20 mm.

The horizontal movements were greatest along the ARTC monitoring line directly above Longwall 901. These vectors were 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.

There is one 3D mark located on the southern side of the Nepean River and the horizontal movement was oriented towards the north to north-east. Only low-level horizontal movements were measured on the eastern side of Harris Creek. The AA9 far-field horizontal movements indicate 'plate' type regional movements defined by the Nepean River and Harris Creek.

The comparison between the measured incremental horizontal movements at Appin Area 9 with those measured elsewhere in the Southern Coalfield is provided in Fig. 2.11. The x-axis represents the distance from the active longwall.

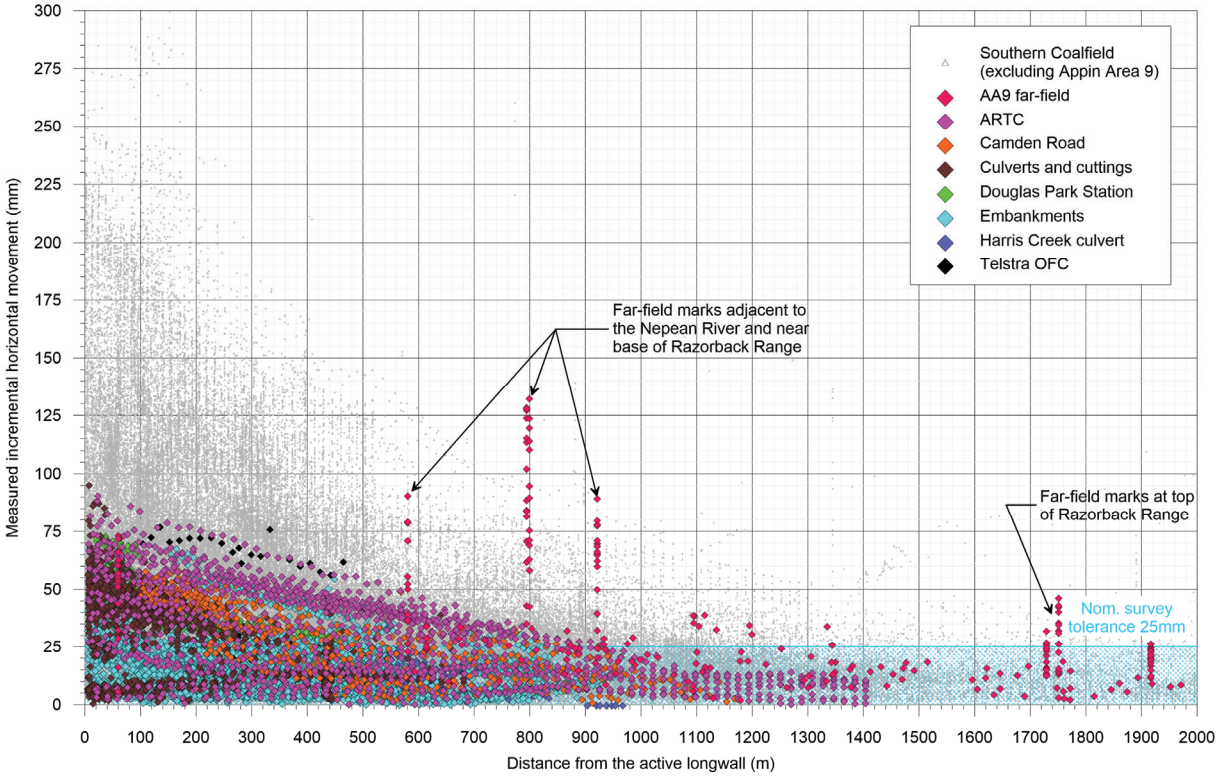

Fig. 2.11 Measured incremental horizontal movements at Appin Area 9

The measured incremental horizontal movements at the AA9 far-field marks adjacent to the Nepean River and Razorback Range were at the upper end of the range of movements measured elsewhere in the Southern Coalfield. These marks have been affected by valley closure effects and the steep topography.

The horizontal movements at the ARTC, Camden Road and Telstra OFC monitoring lines were less than those measured elsewhere in the Southern Coalfield. These measurements have generally been made off the commencing and finishing ends of Longwall 901, which is the first longwall in the series.

2.9. Nepean Twin Bridges monitoring points

The Nepean Twin Bridges are located approximately 0.9 km south-east of the finishing end of Longwall 901. These bridges experienced far-field movements due to the extraction of Longwall 901 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.

The descriptions of the monitoring results are provided in the following sections.

2.9.1. 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 2.8.

The measured incremental horizontal movements at Marks DPBN and DPBS, at the completion of Longwall 901, were 27 mm and 39 mm, respectively. The vectors were orientated towards the north-east and, therefore, are likely to have been influenced by the concurrent mining in Appin Area 7

The absolute horizontal movements at Marks DPBN and DPBS have been measured during mining in Appin Area 7, since the 15th October 2007, and during Longwall 901. The development of the total horizontal movements for these marks, plotted from the start of January 2013, is shown in Fig. 2.12.

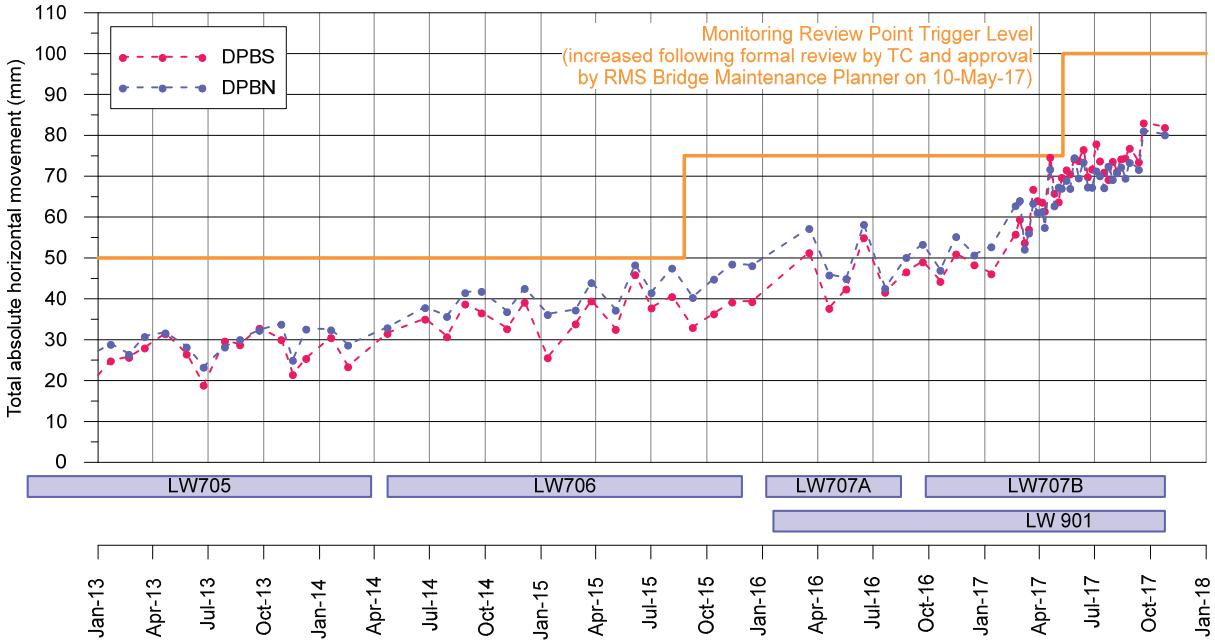

Fig. 2.12 Measured total absolute movements at Marks DPBN and DPBS due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks DPBN and DPBS remained below the Monitoring Review Point Trigger, shown by the orange line in Fig. 2.12. It is noted, that this 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 25th October 2017 after the completion of Longwall 901, is provided in Table 2.11.

Table 2.11 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	82	100

The maximum measured absolute horizontal movement at Marks DPBN and DPBS was less than the Level 1 Trigger at the completion of Longwall 901.

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 incremental valley closure at the Nepean Twin Bridges is illustrated in Fig. 2.13. The nominal survey accuracy is ±3 mm.

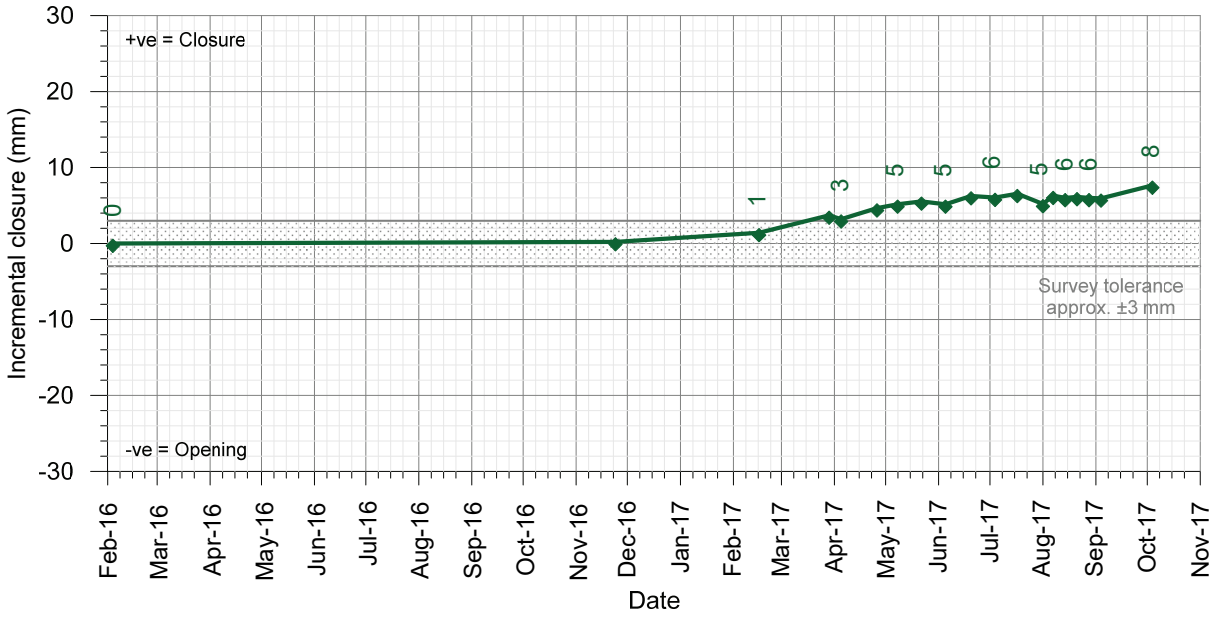

Fig. 2.13 Measured incremental valley closure at the Nepean Twin Bridges

The measured incremental closure at the completion of Longwall 901 was 8 mm. The closure was similar to that measured at the nearby Nep X J-Line, as discussed in Section 2.5. Only low-level movements have been measured to the east of the confluence with Harris Creek. The predicted incremental closure at the Nepean Twin Bridges was less than 20 mm.

2.9.2. 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. 2.14 and Fig. 2.15 (Source: IC).

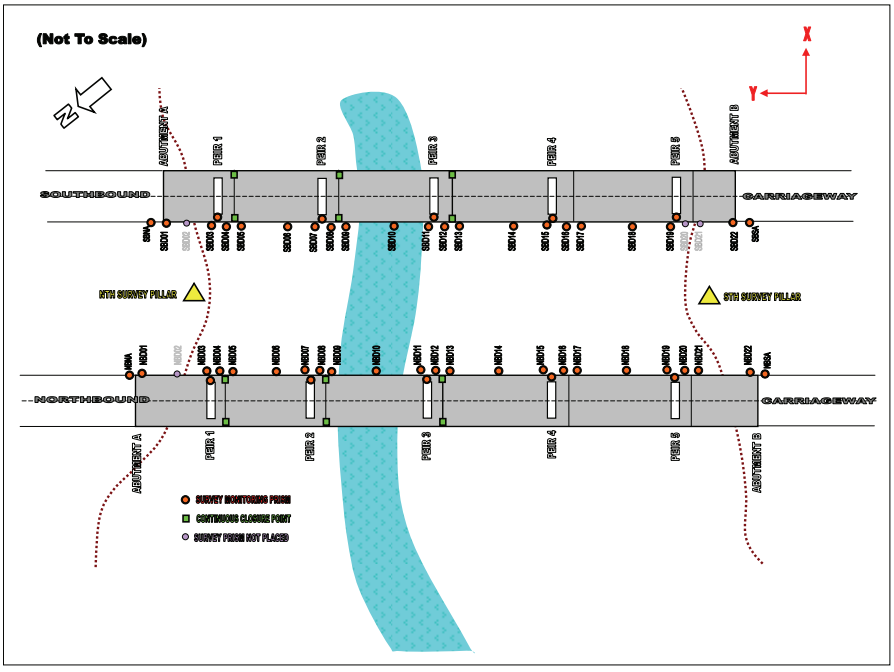

Fig. 2.14 Plan of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IC)

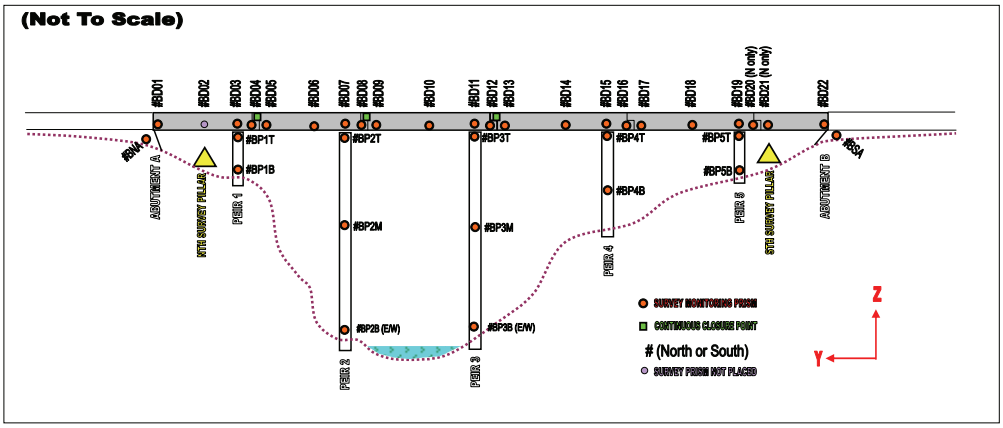

Fig. 2.15 Elevation of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IC)

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 15th October 2007, and during Longwall 901. The development of the total changes in horizontal distance between the marks, plotted from the start of January 2013, is shown in Fig. 2.20. The nominal survey accuracy is ±2 mm.

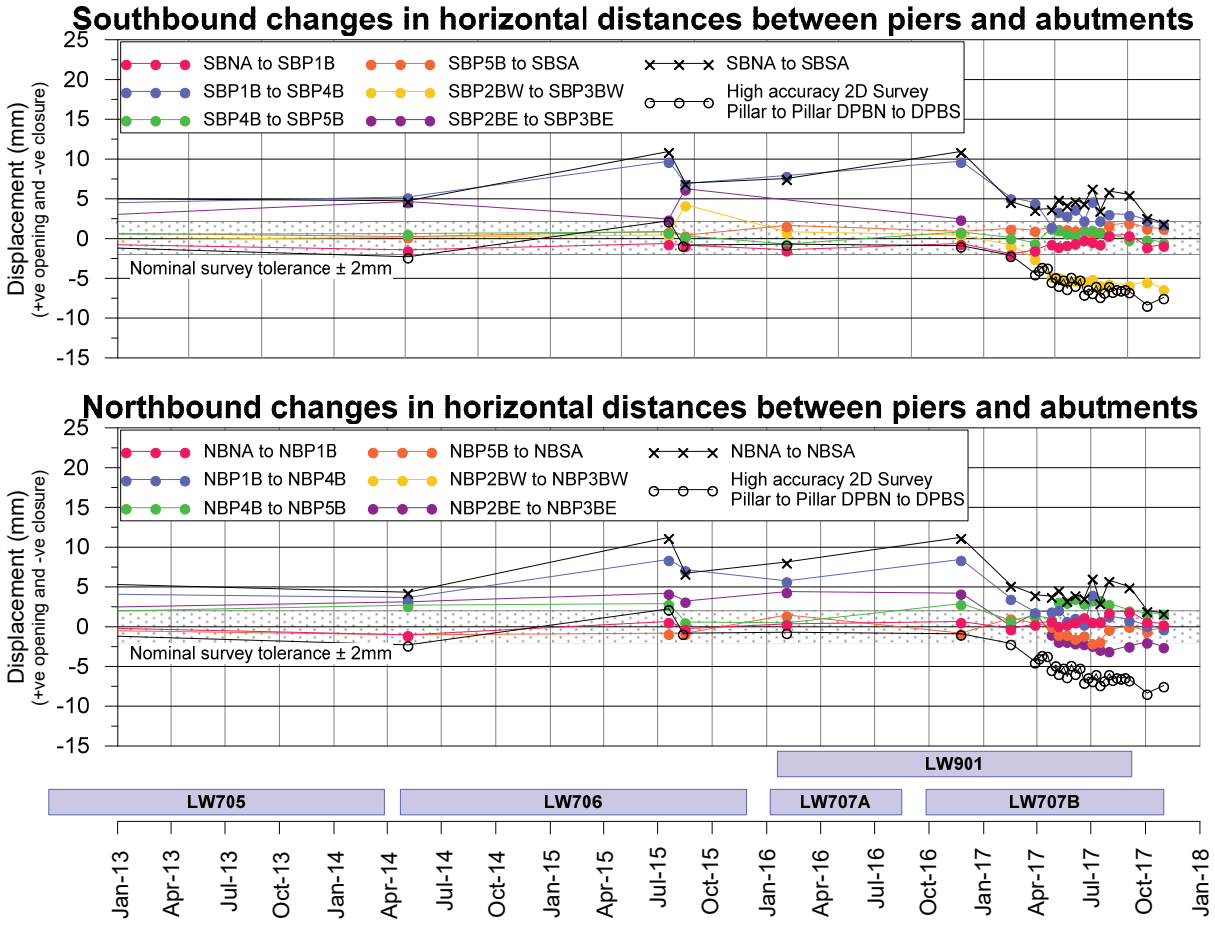

Fig. 2.16 Measured total changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges

The total changes in horizontal distance between the abutments and piers at the completion of Longwall 901 were generally less than ±2 mm and, therefore, were in the order of survey tolerance. The total changes between SBNA and SBSA, between SBP2BW and SPB3BW and between NBNA and NBSA were 6 mm.

2.9.3. 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 Longwall 901 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 PSM883-298L (dated 6th October 2015) through to PSM883-336L (dated 13th October 2017).

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 Longwall 901, is provided in Table 2.12.

Table 2.12 Measured differential movements and trigger for the Nepean Twin Bridges inclinometers

Type	Maximum measured differential movement (mm)	Level 1 Trigger (mm)
Differential movement	2.3 (PSM6 – RST) 3.1 (PSM6 – SAA)	5

The measured differential movements at the inclinometers at Site PSM6 did not exceed the Level 1 Trigger during the extraction of Longwall 901.

2.9.4. Joint monitoring

The differential movements across the movement joints in the Nepean Twin Bridges were measured by PSM during the extraction of Longwall 901 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 29th 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 monitors and the results were provided in the monitoring reports by PSM numbers PSM883-298L (dated 6th October 2015) through to PSM883-336L (dated 13th October 2017).

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 Longwall 901, is provided in Table 2.13.

Table 2.13 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) +0.56 (southbound carriageway)	2
Joint 2 (middle joint)	-0.76 (northbound carriageway) -0.51 (southbound carriageway)	2
Joint 3 (main expansion joint)	-3.10 (northbound carriageway) -1.83 (southbound carriageway)	10

The measured differential movements at the bridge joints did not exceed the Level 1 Triggers during the mining of Longwall 901.

2.10. Moreton Park Road Bridge (South) monitoring points

Moreton Park Road Bridge (South) is located approximately 1 km east of the finishing end of Longwall 901. The bridge experienced far-field movements due to the extraction of Longwall 901 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.

The descriptions of the monitoring results are provided in the following sections.

2.10.1. 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 2.8.

The measured incremental horizontal movement at Marks MPBE and MPBW, at the completion of Longwall 901, were 15 mm and 19 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 15th October 2007, and during Longwall 901. The development of the total horizontal movements for these marks, plotted since the start of January 2013, is shown in Fig. 2.17.

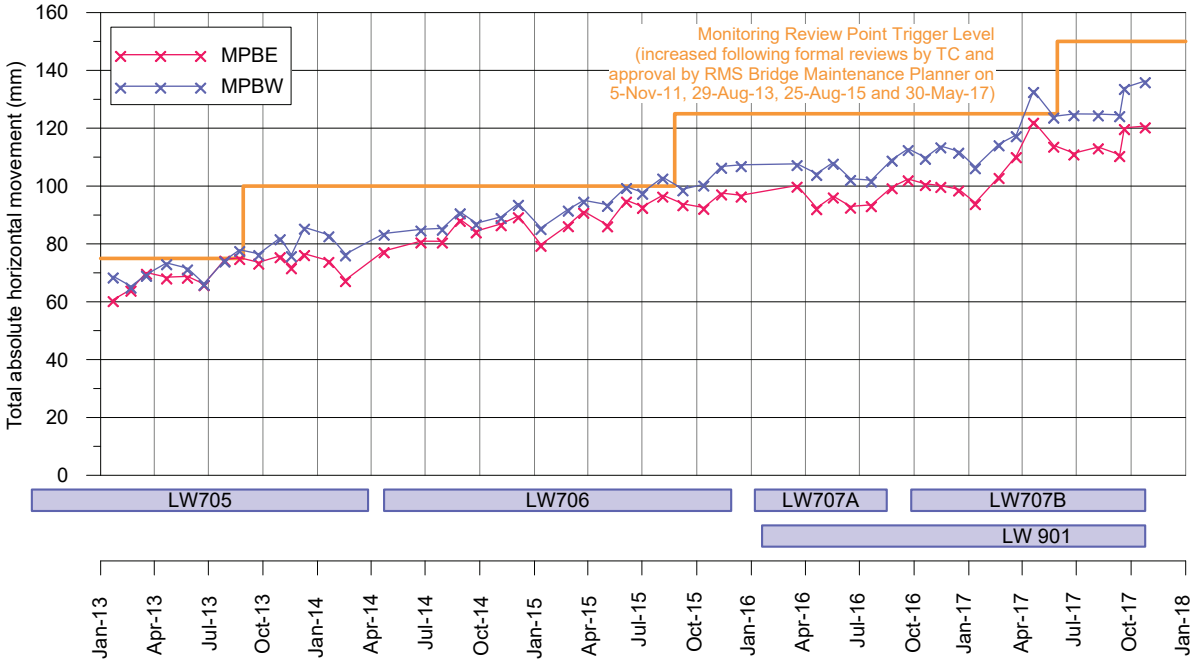

Fig. 2.17 Measured total absolute movements at Marks MPBE and MPBW due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks MPBE and MPBW exceeded the Monitoring Review Point Trigger, shown by the orange line in Fig. 2.12, on two occasions. This 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 25th October 2017 after the completion of Longwall 901, is provided in Table 2.14.

Table 2.14 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	136	150

The maximum measured absolute horizontal movement at Marks MPBE and MPBW was less than the Level 1 Trigger at the completion of Longwall 901.

2.10.2. 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).

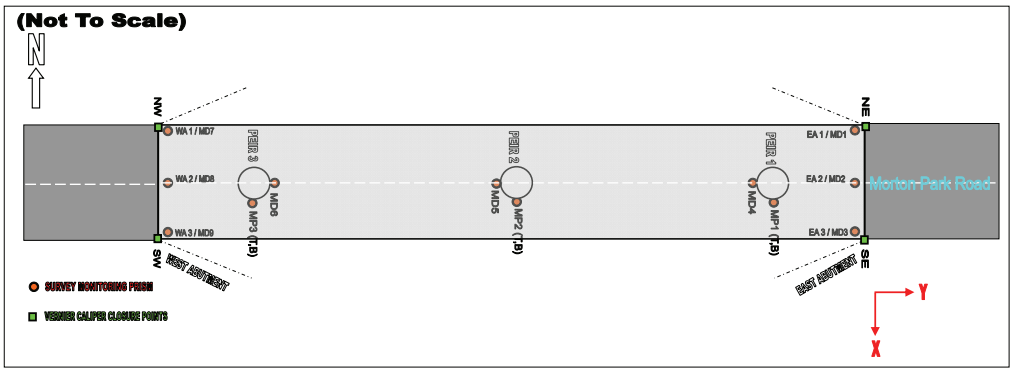

Fig. 2.18 Plan of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IC)

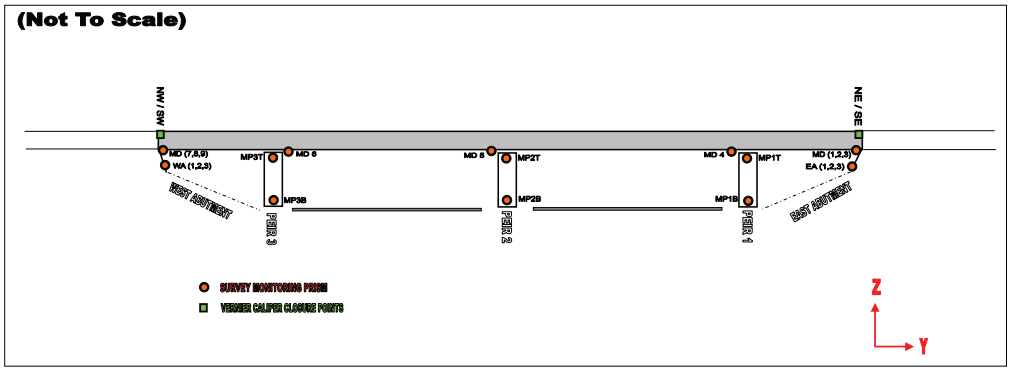

Fig. 2.19 Elevation of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IC)

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 Longwall 901. Marks have been established on the eastern abutment (EA1 to EA3) and on the western abutment (WA1 to WA3). The development of the total changes in horizontal distance between the abutments, plotted since the start of January 2013, is shown in Fig. 2.20. The nominal survey accuracy is ±2 mm.

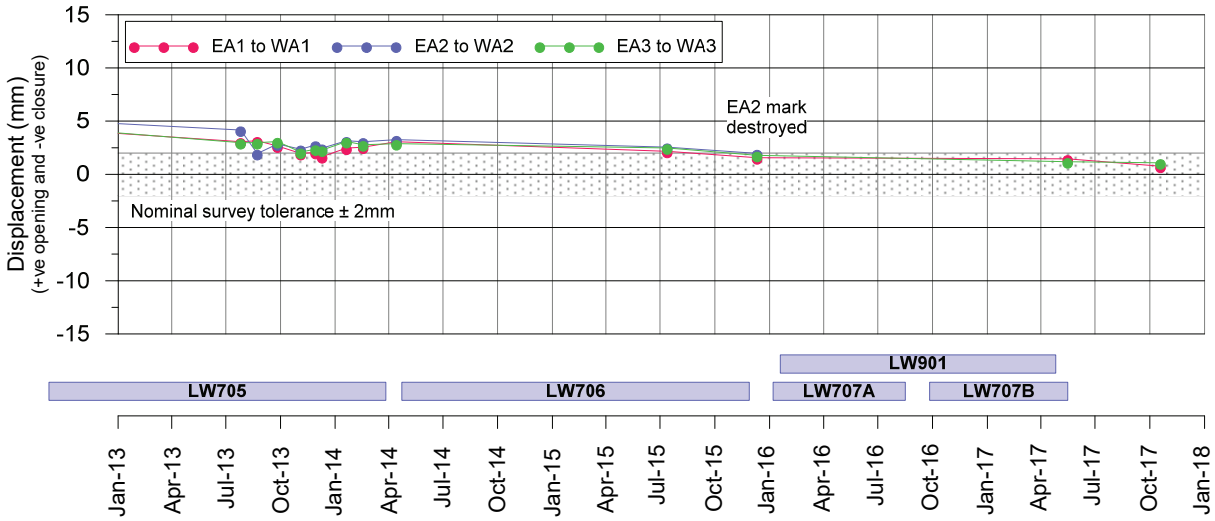

Fig. 2.20 Measured total changes in horizontal distance between the abutments of Moreton Park Road Bridge (South)

The total changes in horizontal distance between the bridge abutments were less than ±2 mm at the completion of Longwall 901. The total measured movements, therefore, were within the order of survey tolerance at the completion of this longwall.

2.11. Airbourne Laser Scan surveys

The changes in surface level due to the extraction of Longwall 901 have been measured using Airbourne Laser Scan (ALS) surveys. The initial surface level contours have been determined from the base survey carried out in June 2007, i.e. prior to the extraction of Longwall 901. The post mining surface level contours have been determined from a subsequent survey carried out in November 2017, approximately two months after the completion of Longwall 901.

The ALS surveys indicate changes in surface level in the order of 400 mm above Longwall 901. There was variability in the measured changes in surface level due to the effects of survey tolerance and the mining-induced horizontal movements.

The ALS surveys have an accuracy for absolute level in the order of ±50 to ±150 mm. The accuracy of the measured changes in surface level (i.e. the difference between two surveys), therefore, is in the order of ±100 to ±300 mm. The contours also contain artefacts (i.e. locally increased or decreased movements), particularly in the locations of steeply incised or sloping terrain, such as at the cliffs, steep slopes, surface incisions, cuttings, embankments and batters.

Longwall 901 is the first longwall in the series in Appin Area 9 and, therefore, the levels of vertical subsidence are less than subsequent longwalls in the series. The survey tolerance of the ALS scan represents a significant portion of the actual subsidence movements in this case. This technique is therefore not particularly informative for Longwall 901.

3.1. Natural features

The natural features near Longwall 901 are shown in Drawing No. MSEC927-02, 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 Longwall 901 are provided in Reports Nos. MSEC448 and MSEC743, which supported the Extraction Plan and Modification Applications. More detailed assessments for the natural features were also provided in other consultants' reports.

Comparisons between the MSEC assessments and the observed impacts for the natural features listed above, resulting from the extraction of Longwall 901, are provided in Table 3.1. The impacts are based on those recorded by IC Environmental Field Team and are described in the report entitled *Appin Area 9 Longwall 901 End of Panel Landscape Report* (IC, November 2017).

Table 3.1 Assessed and observed impacts for the natural features due to Longwall 901

Natural feature	MSEC assessed impacts	Observed impacts
Nepean River	Unlikely that increased **ponding**, **flooding** or **changes in stream alignment** would occur	No observed 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 some sections of the river bed
	Unlikely that **surface water flow diversions** would occur	No observed impacts
	Likely that **gas emissions** would develop along the river	Gas releases (Level 1 impacts according to the TARP) were observed at 25 sites along the Nepean River during the extraction of Longwall 901. Refer to the *Appin Area 9 Longwall 901 End of Panel Landscape Report* for further details
	Water quality – refer to the surface water report by HGeo **Terrestrial ecology** – *refer to the Appin Area 9 Longwall 901 End of Panel Landscape Report*	
Harris Creek	Adverse impacts unlikely	No observed impacts
Tributaries to the Nepean River	Unlikely that increased **ponding**, **flooding** or **scouring** would occur	No observed 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 observed adverse impacts
	Unlikely that **surface water flow diversions** would occur	No observed 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 observed impacts
Cliffs along Harris Creek	Likelihood of mining-induced rock falls considered to be extremely low	No observed impacts
Rock outcrops	Fracturing of exposed bedrock which could result in **rockfalls** where the rock is marginally stable	No observed adverse 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 observed adverse impacts

The recorded impacts on the natural features due to the extraction of Longwall 901 were similar to or less than the MSEC assessments provided in Reports Nos. MSEC488 and MSEC743. Further assessments of natural features have been provided by other specialist consultants on the project, which are described in the relevant reports attached to the *End of Panel* report.

3.2. Built features

The built features near Longwall 901 are shown in Drawing No. MSEC927-03, 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 Longwall 901);
- Heritage sites (railway cottage, Warragunyah and the Mountbatten Group); and
- Houses and associated structures.

The MSEC assessed impacts for the built features resulting from the extraction of Longwall 901 are provided in Reports Nos. MSEC448 and MSEC743, which supported the Extraction Plan and Modification Applications. Comparisons between the MSEC assessments and the observed impacts for the built features listed above, resulting from the extraction of Longwall 901, are provided in Table 3.2.

Table 3.2 Assessed and observed impacts for the built features due to Longwall 901

Built feature	MSEC assessed impacts	Observed impacts
Main Southern Railway	No impacts on the safety or serviceability of the railway after the implementation of the monitoring and management strategies	No observed adverse impacts on safety or serviceability
Menangle Road	Minor cracking and localised heaving of the road surface directly above the longwalls	No observed adverse impacts (not directly mined beneath by Longwall 901)
Nepean Twin Bridges	Impacts unlikely after the implementation of the preventive, monitoring and management strategies	No observed adverse impacts
Moreton Park Road Bridge (South) and Blades Bridge	Impacts unlikely	No observed adverse impacts
Water and sewer pipelines	Minor leakages could occur	No observed adverse impacts
66 kV and 11 kV powerlines	Minor impacts possible requiring some adjustments of cables and poles	No observed adverse impacts
Optical fibre and copper telecommunications cables	Impacts unlikely with the implementation of monitoring and management strategies	No observed adverse impacts
Survey control marks	Vertical and horizontal movements which could require re-establishment	No observed damage to the survey control marks. The marks to be re-established after completion of mining
Business establishments	Adverse impacts unlikely	No observed adverse impacts
Rural structures	Minor impacts on rural structures located directly above longwalls	No observed adverse impacts
Farm dams	Incidence of impact (cracking and leakage) expected to be low	No observed adverse impacts
Groundwater bores	Impacts likely including lowering of piezometric surface, blockage and change in groundwater quality	Impacts on two groundwater bores comprising drop in water level and reduction of pressure. Refer to the *Appin Area 9 Longwall 901 End of Panel Landscape Report*

Built feature	MSEC assessed impacts	Observed impacts
Archaeological sites	Adverse impacts unlikely	Access to site not available, but no adverse impacts reported
Heritage sites	Adverse impacts unlikely	No observed adverse impacts
Houses	Houses will remain safe and serviceable	Houses have remained in safe and serviceable conditions. Three claims have been submitted to SA NSW, to date, for minor impacts on services or other structures associated with the houses (Category R1 or R2 only)

The recorded impacts on the built features due to the extraction of Longwall 901 were similar to or less than the MSEC assessments provided in Reports Nos. MSEC488 and MSEC743. 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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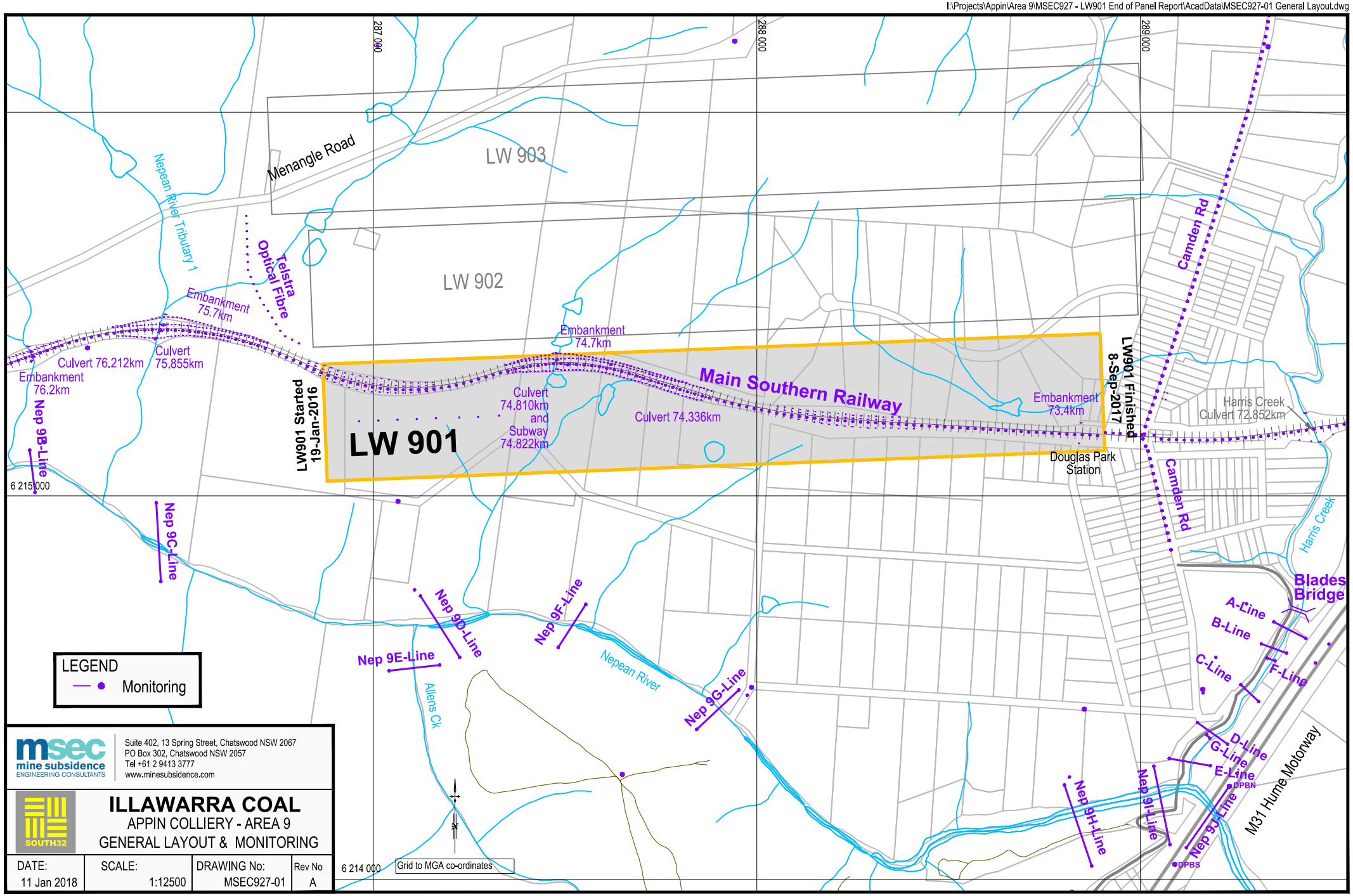

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APPIN COLLIERY - AREA 9

GENERAL LAYOUT & MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
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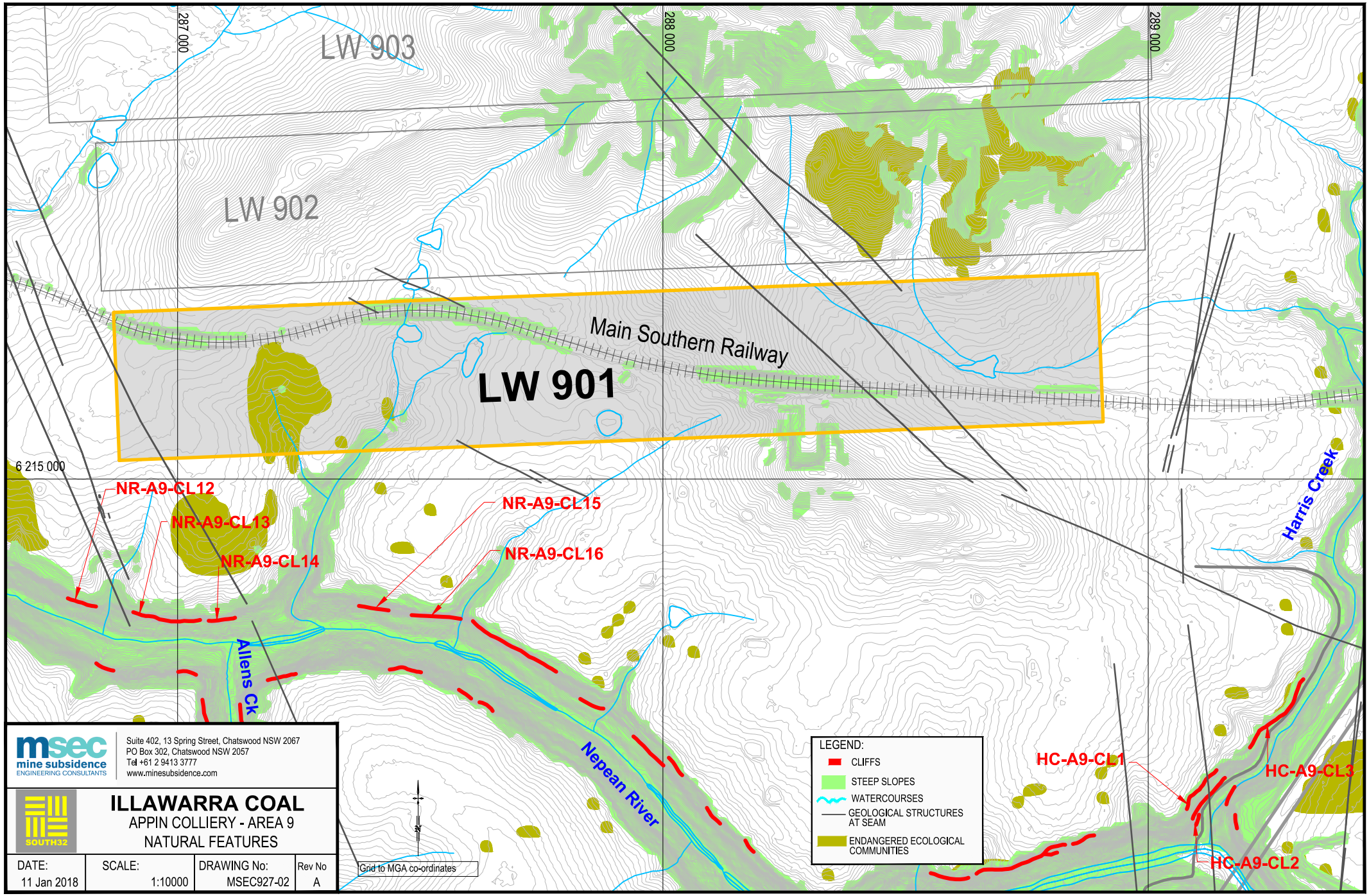

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NATURAL FEATURES

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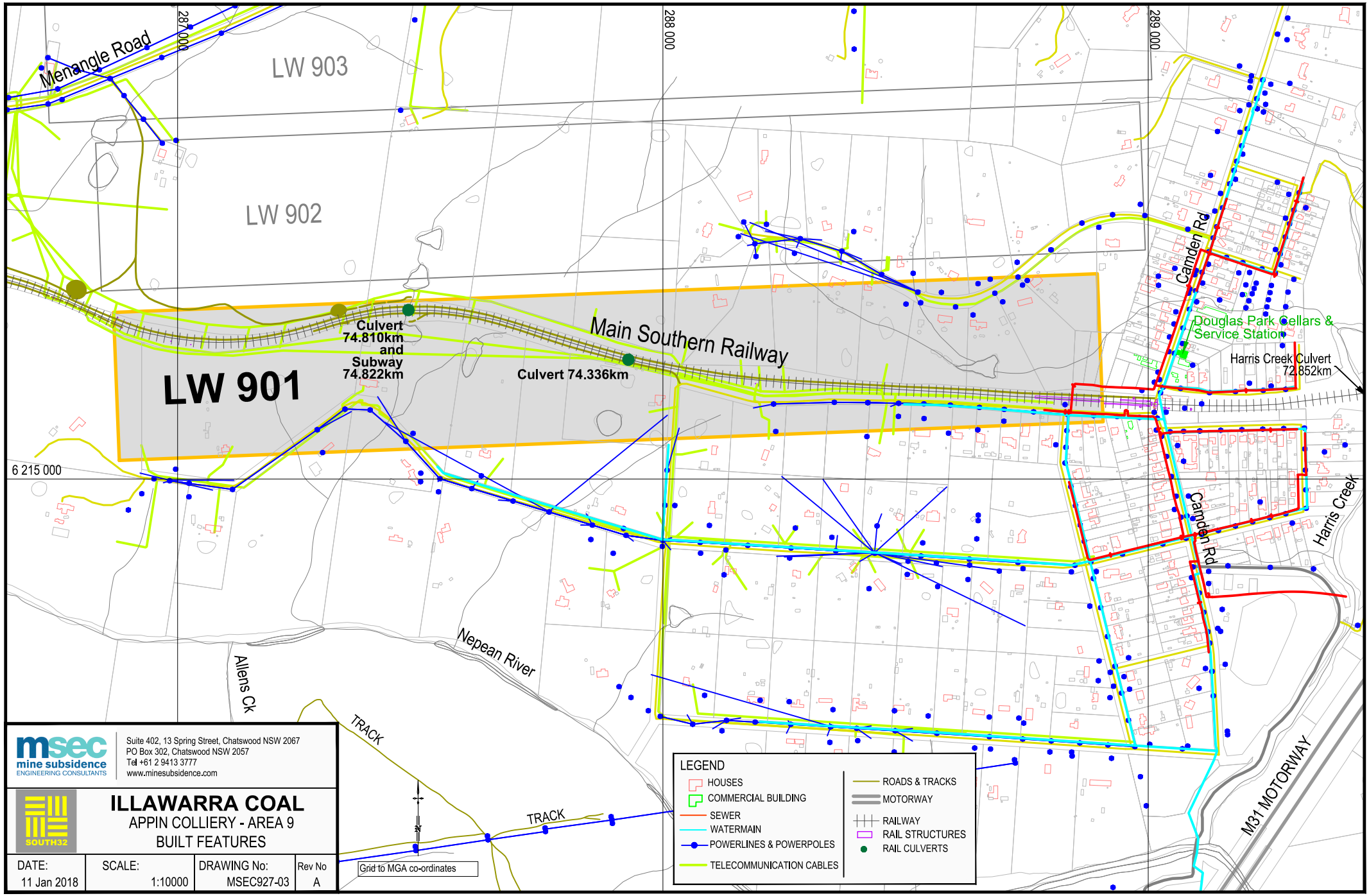

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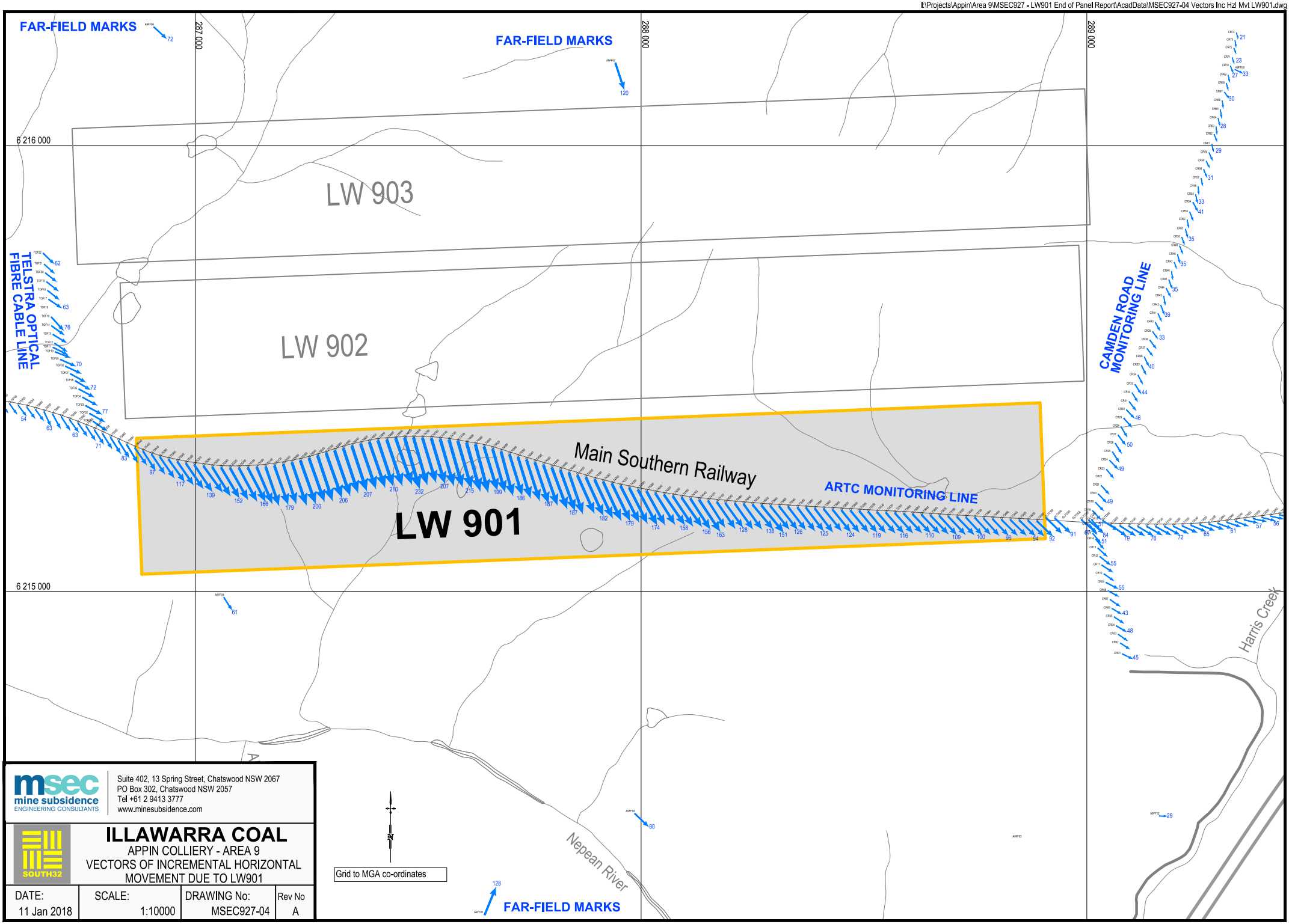

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VECTORS OF INCREMENTAL HORIZONTAL MOVEMENT DUE TO LW901

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