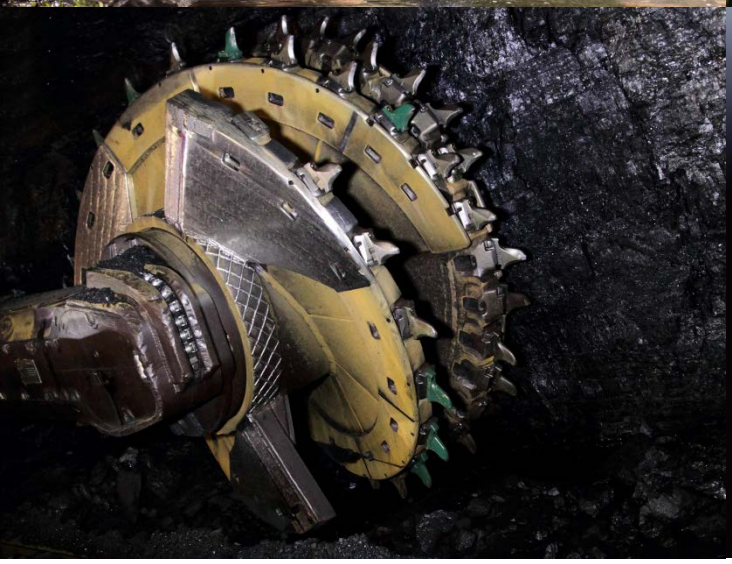

APPIN AREA 7 LONGWALL 706 END OF PANEL REPORT

ATTACHMENT B – SUBSIDENCE REVIEW

mine subsidence ENGINEERING CONSULTANTS

South32

Illawarra Coal

SOUTH32 ILLAWARRA COAL:

Appin Colliery - Longwall 706

End of Panel Subsidence Monitoring Report for Appin Longwall 706

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Revision	Description	Author	Checker	Date
01	Draft Issue	DJK	JB	Feb 16
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Report produced for:- Compliance with conditions attached to the SMP Approval set by the Department of Trade and Investment, Regional Infrastructure and Services.

Previous reports:- MSEC342 (Revision C) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Longwalls 705 to 710 at Appin Colliery in Support of the SMP Application.

MSEC690-01 to MSEC690-29 – Weekly Subsidence Monitoring Review Reports for the M31 Hume Motorway, issued during the extraction of Longwall 706 between the 16th August 2014 and the 26th February 2015.

MSEC691-01 to MSEC691-41 – Weekly Subsidence Monitoring Review Reports for the Main Southern Railway, issued during the extraction of Longwall 706 between the 8th September 2014 and the 20th May 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)

CONTENTS

Tables

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

Figures

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

Drawings

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

Drawing No.	***Description***	***Revision***
MSEC808-01	General Layout and Monitoring	A
MSEC808-02	Natural Features	A
MSEC808-03	Surface Infrastructure	A

1.1. Introduction

South32 Illawarra Coal has completed the extraction of Longwall 706 at Appin Colliery, which is located in the Southern Coalfield of New South Wales. The locations of the longwalls at Appin Colliery are shown in Drawing No. MSEC808-01, in Appendix B. The extraction of Longwall 706 commenced on the 23rd April 2014 and was completed on the 28th November 2015.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by South32 to prepare subsidence predictions and impact assessments for Appin Longwalls 705 to 710. Report No. MSEC342 (Revision C) was issued in June 2008 to support the SMP Application for these longwalls.

The Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) gave South32 approval for the extraction of Longwalls 705 and 706 on the 28th February 2012.

The commencing (i.e. eastern) end of Longwall 706 was shortened by 390 metres from that adopted in the SMP Application and in Report No. MSEC342.

In accordance with Section 18 of the SMP Approval Conditions for Appin Longwalls 705 to 706, this report provides:-

- Comparisons between the observed and predicted subsidence movements at the monitoring lines and points resulting from the extraction of Longwall 706; and
- Comparison between the observed and assessed (i.e. predicted) impacts on the natural and built features within the SMP Area resulting from the extraction of Longwall 706.

Further details on the observed and assessed impacts for some natural features, resulting from the extraction of Longwall 706, are provided in the reports by other consultants. The discussions 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 points which were surveyed during the extraction of Longwall 706. This chapter also provides comparisons between the observed and predicted movements resulting from the extraction of Longwall 706.

Chapter 3 of this report describes the natural and built features in the vicinity of Longwall 706. This chapter also provides comparisons between the observed and assessed impacts for the natural and built features resulting from the extraction of Longwall 706. Further details on the observed and assessed impacts for some natural features are provided in reports by other consultants.

Appendices A and B include all of the figures and drawings associated with this report.

1.2. Mining Geometry

The total void length (i.e. including the installation heading) of Longwall 706 was 3,052 metres and the overall void width (i.e. including the first workings) was 325 metres. The solid width of the chain pillar between Longwalls 705 and 706 was 45 metres. The extent of mining for Longwall 706 is shown in Drawing No. MSEC808-01 in Appendix B.

The depth of cover to the Bulli Seam, directly above Longwall 706, varies between a minimum of 500 metres, above the commencing (eastern) end of the longwall, and a maximum of 615 metres, towards the finishing (western) end of the longwall.

The thickness of the Bulli Seam, within the extent of Longwall 706, varies between 2.9 metres and 3.4 metres. The longwall extracted the full seam thickness.

2.1. Introduction

The mine subsidence movements resulting from the extraction of Appin Longwall 706 were monitored along a number of survey lines and at a number of survey points including the following:-

- The Nepean River Cross Lines;
- Moreton Park Road Line;
- Menangle Road;
- M31 East and West Lines;
- FBG monitoring along the M31 Hume Motorway;
- Slot closure monitoring along the M31 Hume Motorway;
- ARTC monitoring line, strain gauges and tilt sensors;
- ARTC Embankment Points;
- Highway and Railway Cutting Points;
- Partridge VC Rest Area Points;
- Absolute far-field 3D monitoring points adjacent to the Douglas Park Twin Bridges and Moreton Park Road Bridge (South);
- Relative 3D monitoring points on the Douglas Park Twin Bridges and Moreton Park Road Bridge (South);
- Inclinometer monitoring near the Douglas Park Twin Bridges;
- Bridge joint monitoring on the Douglas Park Twin Bridges;
- Visual monitoring of the M31 Hume Motorway, Moreton Park Road, the Douglas Park Twin Bridges and Moreton Park Road Bridge (South);
- Monitoring lines at Water NSW Infrastructure; and
- Monitoring along the Telstra Line.

The locations of these survey lines and survey points are shown in Drawing No. MSEC808-01, in Appendix B. Comparisons between the observed and predicted subsidence movements at these monitoring lines and points are provided in the following sections.

2.2. Nepean River Cross Lines

Differential movements across the Nepean River valley were measured by South32 along six ground monitoring lines, being the NEPX L-Line through to the NEPX Q-Line, during Longwall 706.

The locations of these 2D monitoring lines are shown in Drawing No. MSEC808-01 in Appendix B. A summary of the survey dates for these monitoring lines are provided in Table 2.1.

Table 2.1 Summary of Survey Dates for the Nepean River Cross Lines during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Monthly surveys from the commencement of Longwall 706	28th May 2014 26th June 2014 28th July 2014 3rd September 2014 10th October 2014 30th November 2015	As per approved Longwall 707 monitoring program

The predictions of subsidence, upsidence and closure for the Nepean River, resulting from the extraction of Appin Longwalls 705 to 710, were provided in Report No. MSEC342. The predictions in that report were based on the layout of Longwall 706 that was adopted in the SMP Application. The actual commencing (i.e. eastern) end of this longwall was subsequently shortened by 392 metres. The predictions for the Nepean River provided in this End of Panel Report are based on those presented in Report No. MSEC342 and, therefore, are conservative as they are based on the full approved length.

The purpose of the surveys was to measure mining-induced valley closure movements.

The predicted profiles of incremental closure along the centreline of the river, resulting from the extraction of Longwall 706, have been reproduced in Fig. A.01 in Appendix A. The predicted and the observed incremental closure for each cross line, at the centreline of the river, have also been indicated in this figure.

The predicted profiles of total closure along the centreline of the river, resulting from the extraction of Longwalls 701 to 706, have been reproduced in Fig. A.02 in Appendix A. The predicted and observed total closure for each cross line, at the centreline of the river, has also been indicated in this figure.

Comparisons between the observed and predicted profiles of total closure along each of the Nepean River cross lines, resulting from the extraction of Longwalls 702 to 706, are provided in Figs. A.03 to A.08 in Appendix A.

A summary of the maximum observed and maximum predicted incremental closure movements for each of the Nepean River cross lines, resulting from the extraction of Longwall 706, is provided in Table 2.2.

Table 2.2 Summary of the Maximum Observed and Maximum Predicted Incremental Closure at the Nepean River Cross Lines due to the Extraction of Longwall 706

Location	Observed Closure	Predicted Closure
NEPX L-Line	4 mm	20 mm
NEPX M-Line	20 mm	60 mm
NEPX N-Line	14 mm	60 mm
NEPX O-Line	1 mm	40 mm
NEPX P-Line	6 mm	125 mm
NEPX Q-Line	8 mm	60 mm

A summary of the maximum predicted and maximum observed total closure movements for each of the Nepean River cross lines, resulting from the extraction of Longwalls 702 to 706, is provided in Table 2.3

Table 2.3 Summary of the Maximum Observed and Maximum Predicted Total Closure at the Nepean River Cross Lines after the Extraction of Longwall 706

Location	Observed Closure	Predicted Closure
NEPX L-Line	151 mm	300 mm
NEPX M-Line	127 mm	300 mm
NEPX N-Line	40 mm	225 mm
NEPX O-Line	10 mm	125 mm
NEPX P-Line	14 mm	175 mm
NEPX Q-Line	16 mm	70 mm

The accuracies of the measured closure movements are in the order of ±3 mm. It is noted that the NEPX M-Line and NEPX N-Lines do not utilise prisms and, in consequence, the accuracies of the measured closure movements for these lines are in the order of ±10 mm to ±15 mm.

It can be seen from Fig. A.01 to Fig. A.08 that the maximum observed incremental and total closures along the cross lines were all less than predicted. It is noted that the predictions have some conservatism as they are based on the full approved length of Longwall 706 adopted in the SMP Application and Report No. MSEC342.

2.3. Moreton Park Road Line

The mine subsidence movements along Moreton Park Road were measured by South32 using a 3D monitoring line. The location of the Moreton Park Road Line is shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for the Moreton Park Road Line, during the extraction of Longwall 706, is provided in Table 2.4.

Table 2.4 Summary of Survey Dates for the Moreton Park Road Line during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start of Longwall 706, and then monthly after 300m extraction until 1000m of extraction, a survey at 1500m extraction, and an end of longwall extraction survey	12th February 2013 3rd June 2014 3rd July 2014 7th August 2014 9th September 2014 9th October 2014 8th January 2015 3rd February 2016	As per approved Longwall 707 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the Moreton Park Road Line, resulting from the extraction of Longwall 706, are shown in Fig. A.09 in Appendix A. The observed profiles of total subsidence, tilt and strain along the Moreton Park Road Line, resulting from the extraction of Longwalls 702 to 706, are shown in Fig. A.10 in Appendix A.

The predicted profiles of subsidence and tilt along the monitoring line, at the completion of Longwall 706, are also shown in these figures, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from Figs. A.09 and A.10, that there is reasonable correlation between the shapes of the observed and predicted subsidence profiles on the maingate side of the panel (the maingate is the side of the panel on the leading edge of the longwall series adjacent to solid, unmined coal). However, the observed incremental subsidence above the previously extracted longwalls is slightly greater than that predicted, but this exceedance is less than 10 % of the maxima.

Observed incremental and total subsidence is less than predicted above the chain pillars. While this is conservative from a vertical subsidence prediction point of view, it can lead to differences between predicted and observed incremental and total tilts, curvatures and strains, including:

- Observed incremental and total tilts on either side of the chain pillars exceeding predictions;
- Observed sagging curvature at the base of the subsidence trough exceeding predictions; and
- Observed small incremental sagging curvature above the previous longwall panel.

A summary of the maximum observed and maximum predicted incremental subsidence parameters along the Moreton Park Road Line, resulting from the extraction of Longwall 706, is provided in Table 2.5. A summary of the maximum observed and maximum predicted total subsidence parameters along the Moreton Park Road Line, resulting from the extraction of Longwalls 702 to 706, is provided in Table 2.6.

Table 2.5 Maximum Observed and Predicted Incremental Subsidence Parameters along Moreton Park Road Resulting from the Extraction of Longwall 706

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	616	4.3	0.7	0.8
Predicted	800	4.6	*- Refer to discussions below -*	

Table 2.6 Maximum Observed and Predicted Total Subsidence Parameters along Moreton Park Road Resulting from the Extraction of Longwalls 702 to 706

Type	Maximum Total Subsidence (mm)	Maximum Total Tilt (mm/m)	Maximum Total Tensile Strain (mm/m)	Maximum Total Comp. Strain (mm/m)
Observed	1302	7.7	1.0	4.8
Predicted	1450	4.7	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the Moreton Park Road Line are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the Moreton Park Road Line are in the order of ±15 mm. The accuracies of the measured strains along the Moreton Park Road Line are in the order of ±0.25 mm/m.

The maximum observed incremental subsidence along the road, due to the extraction of Longwall 706, of 591 mm was less than the maximum predicted of 800 mm. The maximum observed incremental tilt of 4.2 mm/m was also less than the maximum predicted of 4.6 mm/m.

Observed ground strains along Moreton Park Road during the mining of Longwall 706 were within the range expected based on regular (i.e. conventional) ground movements, i.e. no irregular or anomalous movements developed along this monitoring line during Longwall 706.

2.4. Menangle Road Line

The mine subsidence movements along Menangle Road were measured by South32 using a 3D monitoring line. The location of the Menangle Road Line is shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for the Menangle Road Line, during the extraction of Longwall 706, is provided in Table 2.7.

Table 2.7 Summary of Survey Dates for the Menangle Road Line during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Monthly after 2,500m of extraction	6th July 2105 6th August 2015 2nd September 2015 1st October 2015 4th November 2015	As per approved Longwall 707 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the Menangle Road Line, resulting from the extraction of Longwall 706, are shown in Fig. A.11 in Appendix A. The predicted profiles of subsidence and tilt along the monitoring line, at the completion of Longwall 706, are also shown in this figure, and were based on the predicted subsidence contours provided in Report No. MSEC342.

A summary of the maximum observed and maximum predicted incremental subsidence parameters along the Menangle Road Line, resulting from the extraction of Longwall 706, is provided in Table 2.8.

Table 2.8 Maximum Observed and Predicted Incremental Subsidence Parameters along Menangle Road Resulting from the Extraction of Longwall 706

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	22	1.1	1.3	1.4
Predicted	40	< 0.5	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the Menangle Road Line are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the Menangle Road Line are in the order of ±15 mm. The accuracies of the measured strains along the Menangle Road Line are in the order of ±0.25 mm/m.

It can be seen from Fig. A.11, that very minor vertical subsidence developed along the road, as predicted. Elevated tilts and strains were observed between Pegs MR7012 and MR7014, where Menangle Road crosses a small watercourse. It is considered that the differential movements are associated with valley closure and upsidence.

Elevated tensile and compressive strain was measured between Pegs MR7083 and MR7085. The values are almost equal in magnitude and are considered to be due to disturbance of Survey Peg MR7084. A localised compressive strain of 1.2 mm/m was also measured between Pegs MR7012 and MR7013 which is within the range expected based on regular ground movements. Elsewhere, the strains measured along the Menangle Road monitoring line were similar to the order of survey tolerance.

2.5. M31 Hume Motorway

The M31 Hume Motorway crosses directly above Longwall 706 as shown in Drawings Nos. MSEC808-01 and MSEC808-03, in Appendix B. The monitoring associated with the Motorway, during the extraction of Longwall 706, included the following:-

- M31 East and West Lines;
- Highway Cutting Points; and
- FBG and slot closure monitoring.

The monitoring results and discussions were provided in the weekly subsidence monitoring review reports for the motorway (MSEC690-01 to MSEC690-29), which were issued during the extraction of Longwall 706 between the 16th August 2014 and the 26th February 2015.

A summary of the monitoring results for the M31 Hume Motorway are provided in the following sections.

2.5.1. M31 East and M31 West Lines

The mine subsidence movements along the M31 Hume Motorway were measured by South32 using two 3D monitoring lines, being the M31 East and M31 West Lines. The locations of these monitoring lines are shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for the M31 East and M31 West Lines, during the extraction of Longwall 706, is provided in Table 2.9.

Table 2.9 Summary of Survey Dates for the M31 East and M31 West Lines during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey full length of monitoring lines at start and end of Longwall 706, then monthly 3D surveys after 500 metres of extraction, plus weekly focused 2D surveys after 600 metres of extraction	24th July 2014, 19th August 2014, then weekly surveys to the 29th December 2014, and then monthly surveys to the 26th February 2015 28th November 2015	As per approved Longwall 707 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the M31 East and M31 West Lines, resulting from the extraction of Longwall 706, are shown in Figs. A.12 and A.13, respectively, in Appendix A. The predicted profiles of incremental subsidence and tilt along these monitoring lines, at the completion of Longwall 706, are also shown in these figures, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from Figs. A.12 and A.13, that there is reasonable correlation between the shapes of the observed and predicted incremental subsidence profiles on the maingate side, but observed subsidence above the chain pillars is less than predicted, as observed generally in Appin Area 7. Please refer to Section 2.3 for additional commentary, which is also applicable for these monitoring lines.

A summary of the maximum observed and maximum predicted incremental subsidence parameters along the M31 East and M31West Lines, resulting from the extraction of Longwall 706, is provided in Table 2.10.

Table 2.10 Maximum Observed and Predicted Incremental Subsidence Parameters along M31 East and M31 West Lines Resulting from the Extraction of Longwall 706

Monitoring Line	Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
M31 East Line	Observed	863	5.8	2.5	3.1
	Predicted	975	5.5	*- Refer to discussions below -*	
M31 West Line	Observed	922	5.0	3.0	3.0
	Predicted	975	5.5	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the M31 East and West Lines are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the M31 East and West Lines are in the order of ±15 mm. The accuracies of the measured strains along the M31 East and West Lines are in the order of ±0.25 mm/m.

The maximum observed incremental subsidence along the M31 East and M31 West Lines of 863 mm and 922 mm, respectively, were less than the predicted maximum subsidence of 975 mm. The maximum observed incremental tilt along the M31 East Line of 5.8 mm/m was slightly greater than the maximum predicted tilt of 5.5 mm/m, but this exceedance only represents an additional 5 % above the maxima. The maximum observed tilt along the M31 West Line was less than the maxima predicted.

The maximum observed incremental tensile strains along the M31 East Line and M31 West Line were 2.5 mm/m and 3.0 mm/m, respectively. The maximum predicted incremental and total conventional tensile strain along the monitoring lines, based on applying a factor of 15 to the maximum predicted curvatures, was 0.7 mm/m. The observed maximum tensile strain on the East Line occurred in a localised location and is considered to be likely due to disturbance of the survey peg.

The maximum observed incremental compressive strains along the M31 East Line and M31 West Line were 3.1 mm/m and 3.0 mm/m, respectively. The maximum predicted total conventional compressive strain along the monitoring lines, based on applying a factor of 15 to the maximum predicted curvatures, was 1.2 mm/m. The observed peak compressive strains were localised between Marks E145R to E146R along the East Line and between Marks W138 to W139 along the West Line with an associated bump in the

observed subsidence profiles, which indicates that non-conventional movements have developed at these locations.

2.5.2. Highway Cutting Points

The Highway Cutting Points are described in Section 2.7.

2.5.3. FBG and Slot Displacement Monitoring

FBG Monitoring

A total of 620 temperature and 620 strain FBG sensors were installed in the top 50 mm of asphalt along each carriageway within the outside shoulder. The sensors are spaced every 10 metres and the temperature and strain were measured every 15 minutes during the mining of Longwall 706.

The temperature compensated FBG strains exceeded the trigger levels in the management plan at two locations during the mining of Longwall 706.

A blue alarm was received on the 15th October 2014 for an exceedance of the average strain at two FBGs 160.1 and 160.2 on the Northbound Carriageway. Upon inspection at the trigger point, a hump, which had been detected in the previous week, was found to have grown. A smaller hump was observed on the Southbound Carriageway opposite the site above Slot SB159. Observed pavement strains were found to correspond with observed increased compressive ground strains on both the East and West monitoring lines in this area.

A blue alarm was received on the 19th October 2014 for an exceedance of the average strain at FBG 154.3 on the Northbound Carriageway. Upon inspection at the trigger point, no deformation to the pavement was found. Intensive visual inspections were undertaken as mining continued and these confirmed that no impacts occurred to the pavement.

A number of additional management measures were undertaken in response to the events.

The additional management measures included re-profiling of the pavement. The motorway remained safe and serviceable during the event, though temporary speed restrictions were imposed for short durations during this time. A small number of additional blue alarms were received during this period.

Slot Displacement Monitoring

Displacement sensors were installed in each pavement slot and were measured every 5 minutes during the mining of Longwall 706. The slot displacements did not exceed the management plan trigger levels for closure at any stage during the mining of Longwall 706, though Slot SB157 was very close. The maximum observed closure of the slots located directly above Longwall 706 was less than 1 mm below the trigger level 60 mm at SB157 and 48 mm at NB156.

2.6. The Main Southern Railway

The Main Southern Railway crosses directly above Longwall 706 as shown in Drawings Nos. MSEC808-01 and MSEC808-03, in Appendix B. The monitoring associated with the railway, during the extraction of Longwall 706, included the following:-

- ARTC 3D ground monitoring line;
- ARTC 3D embankment monitoring points;
- Railway cutting points;
- Strain gauges; and
- Tilt sensors.

The monitoring results and discussions were provided in the weekly subsidence monitoring review reports for the railway (MSEC691-01 to MSEC691-41), which were issued during the extraction of Longwall 706 between the 8th September 2014 and the 20th May 2015.

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

2.6.1. ARTC Line

The mine subsidence movements along the Main Southern Railway were measured by South32 using a 3D ground monitoring line, referred to as the ARTC Line. The location of the monitoring line is shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for the ARTC Line, during the extraction of Longwall 706, is provided in Table 2.11.

Table 2.11 Summary of Survey Dates for the ARTC Line during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 706, with monthly 3D surveys after 700 metres of extraction, plus weekly 2D focused surveys after 850 metres of extraction.	27th August 2014, 16th September 2014, then weekly to the 4th November 2014, then twice weekly to the 9th December 2014, then weekly to the 20th May 2015, and then 1st December 2015	As per approved Longwall 707 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the ARTC Line, resulting from the extraction of Longwall 706, are shown in Fig. A.14 in Appendix A. The predicted profiles of incremental subsidence and tilt along the monitoring line, at the completion of Longwall 706, are also shown in this figure, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from this figure, that there is reasonable correlation between the shapes of the observed and predicted incremental subsidence profiles on the longwall maingate side, but the observed subsidence above the chain pillar is less than predicted, as observed generally in Appin Area 7. Please refer to Section 2.3 for additional commentary, which is also applicable for these monitoring lines.

A summary of the maximum observed and maximum predicted subsidence parameters along the ARTC Line, resulting from the extraction of Longwall 706, is provided in Table 2.12.

Table 2.12 Maximum Observed and Predicted Incremental Subsidence Parameters along the ARTC Line Resulting from the Extraction of Longwall 706

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	929	6.7	1.3	2.8
Predicted	975	6.0	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the ARTC Line are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the ARTC Line are in the order of ±15 mm. The accuracies of the measured strains along the ARTC Line are in the order of ±0.25 mm/m.

The maximum observed incremental subsidence along the ARTC Line of 929 mm was less than the maxima predicted of 975 mm. The maximum observed incremental tilt of 6.7 mm/m was slightly more than the maximum predicted of 6.0 mm/m.

The maximum observed incremental tensile and compressive strains along the ARTC Line were 1.3 mm/m and 2.8 mm/m, respectively. The maximum predicted incremental conventional tensile and compressive strains along this monitoring line, based on applying a factor of 15 to the maximum predicted curvatures, were both 0.6 mm/m.

The observed peak compressive strains were localised between Marks ARTC1122 to ARTC1123 with an associated bump in the observed subsidence profile, which indicates that non-conventional movement has developed at this location.

The Railway Cutting Points are described in Section 2.7.

2.6.2. Automated Track Monitoring

Tilt Sensors

Bi-directional tiltmeters are located in the Down (Southbound) track within the railway cutting at 71 km. They measured changes in grade every 15 minutes during the mining of Longwall 706. While the sensors detected changes in tilt as a result of mining, which correlated with ground survey and track geometry measurements, these measurements did not exceed the trigger levels.

Rail Stress Transducers

Rail stress transducers are located along all four rails of the railway track, spaced every 25 metres to 60 metres. They measured changes in rail strain every 5 minutes during the mining of Longwall 706. 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 706. While some low level (Blue) alarms were triggered during mining, responses had already been planned in anticipation of the alarms.

2.6.3. Embankment Monitoring

The mine subsidence movements along the Embankment were measured by South32 using a 3D ground monitoring line, referred to as the ARTC Embankment. The locations of the monitoring points are shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for the ARTC Embankment, during the extraction of Longwall 706, is provided in Table 2.13.

Table 2.13 Summary of Survey Dates for the Embankment lines during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Monthly absolute 3D surveys after 1000 metres of extraction, plus weekly local 3D surveys after 1250 metres of extraction	30th September 2014, 21st October 2014, 4th November 2014, then weekly to the 12th May 2015, and then 1st December 2015	As per approved Longwall 707 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the Embankment lines, resulting from the extraction of Longwall 706, are shown in Fig. A.15 to Fig. A.18, in Appendix A. The predicted profiles of incremental subsidence and tilt along the monitoring line, at the completion of Longwall 706, are also shown in these figures, and they are based on the predicted subsidence contours provided in Report No. MSEC342.

A summary of the maximum observed and maximum predicted subsidence parameters along the Embankment lines, resulting from the extraction of Longwall 706, is provided in Table 2.14.

Table 2.14 Maximum Observed and Predicted Incremental Subsidence Parameters along the ARTC Embankment Lines Resulting from the Extraction of Longwall 706

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	529	2.4	1.0	0.8
Predicted	740	1.8	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the Embankment lines are in the order of ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the ARTC Line are in the order of ±10 mm. The accuracies of the measured strains along the ARTC Line are typically in the order of ±0.15 mm/m, where bay lengths are around 20 metres.

Please refer to comparisons between predicted and observed subsidence movements in Section 2.6.1, as the findings are similar. It is noted, however, that locations of higher tilts and strains have generally been measured where bay lengths are short (less than 10 metres). The main survey line along the railway corridor is located on the crest of the embankment on the Down side.

2.6.4. Culverts

The mine subsidence movements along a railway culvert were measured by South32 using a 3D ground monitoring line, referred to as the ARTC 70.5km Culvert. The locations of the monitoring points are shown in Drawing No. MSEC808-01 in Appendix B, and the measured changes in horizontal distance along the culvert invert are shown in Fig. 2.1.

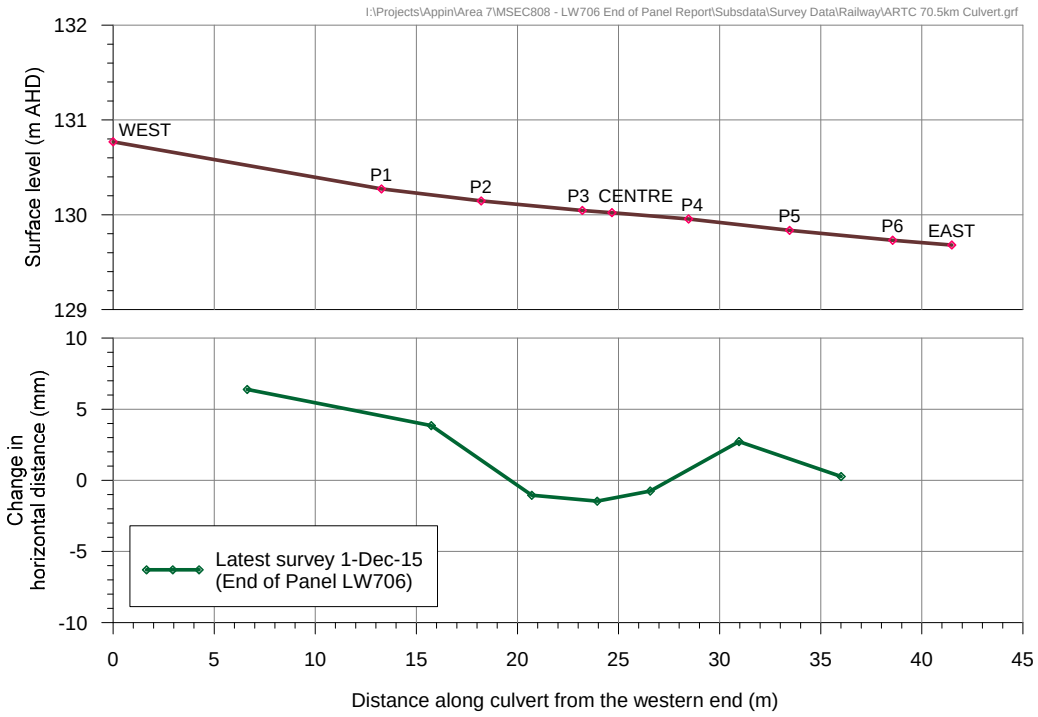


Fig. 2.1 Changes in Horizontal Distance along the ARTC 70.5km Culvert Invert during the Extraction of Longwall 706

The mine subsidence movements along a railway culvert were measured by South32 using a 3D ground monitoring line, referred to as the ARTC 69.0km Culvert. The locations of the monitoring points are shown in Drawing No. MSEC808-01 in Appendix B, and the measured changes in horizontal distance along the culvert invert are shown in Fig. 2.2.

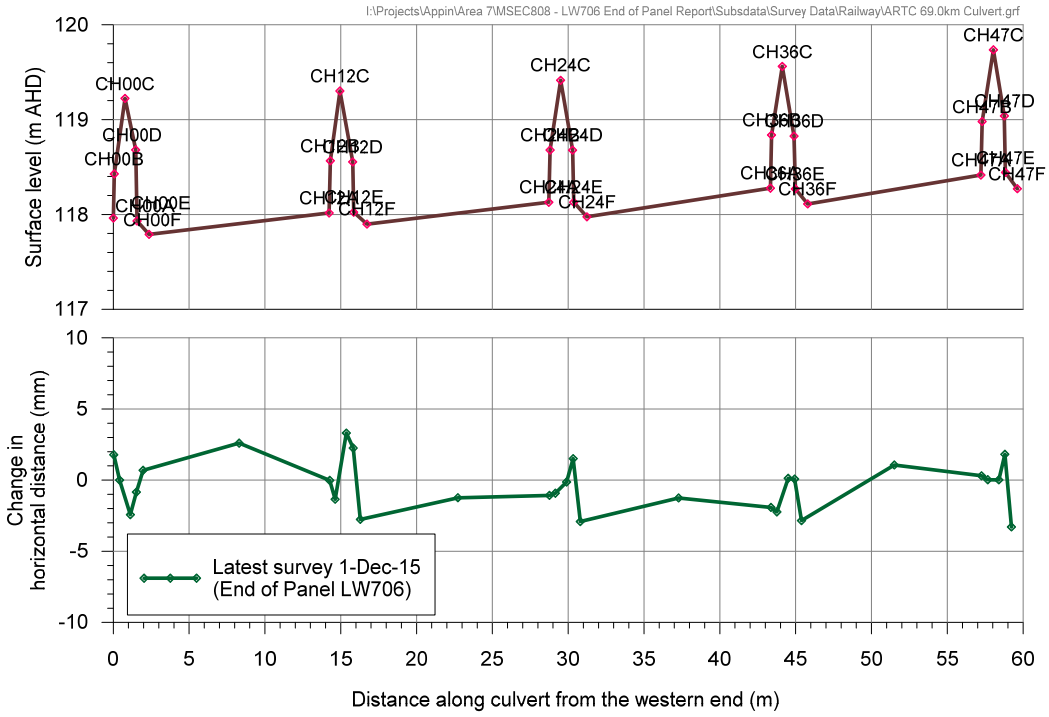


Fig. 2.2 Changes in Horizontal Distance along the ARTC 69.0km Culvert Invert during the Extraction of Longwall 706

2.7. Highway and Railway Cutting Points

The Highway and Railway Cutting Points were measured by South32, during the extraction of Longwall 706, which are 3D monitoring points located on the cuttings along the M31 Hume Motorway and the Main Southern Railway. The locations of these monitoring points are shown in Drawing No. MSEC808-01, in Appendix B.

A summary of the survey dates for these monitoring points is provided in Table 2.15.

Table 2.15 Summary of Survey Dates for the Highway and Railway Cutting Points during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey at end of Longwall 706	8th December 2015	As per approved Longwall 707 monitoring program

The final observed absolute incremental horizontal movements at the Highway and Railway Cutting Points, due to the extraction of Longwall 706, are shown in Fig. 2.3.

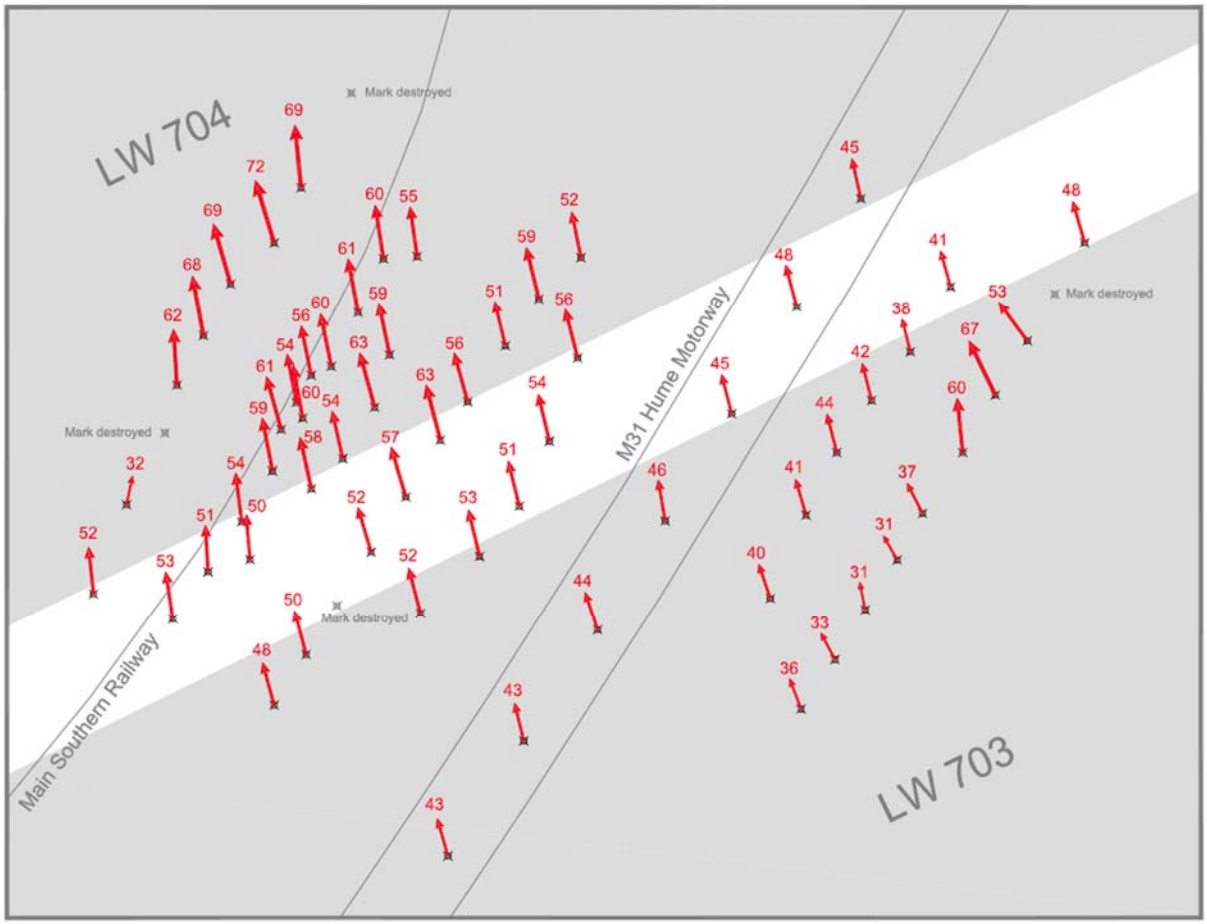


Fig. 2.3 Observed Absolute Incremental Horizontal Movements at the Highway and Railway Cutting Points due to the Extraction of Longwall 706 (8th December 2015)

A summary of the maximum observed absolute incremental horizontal movements at the cutting monitoring points, at any time during or after the extraction of Longwall 706, is provided in Table 2.16.

Table 2.16 Maximum Observed Absolute Incremental Horizontal Movements at the Highway and Railway Cutting Points Resulting from the Extraction of Longwall 706

Longwall	Location	Maximum Observed Incremental Horizontal Movement (mm)
Longwall 706	A01 to A08	72
	B01 to B03	61
	C01 to C08	61
	D01 to D06	63
	E01 to E10	63
	F01 to F05	56
	G01 to G07	48
	H01 to H06	44
	I01 to I10	67

The accuracies of the measured Eastings and Northings at the 3D monitoring points are in the order ±5 mm and, therefore, the accuracies of the measured absolute horizontal movements are in the order of ±7 mm.

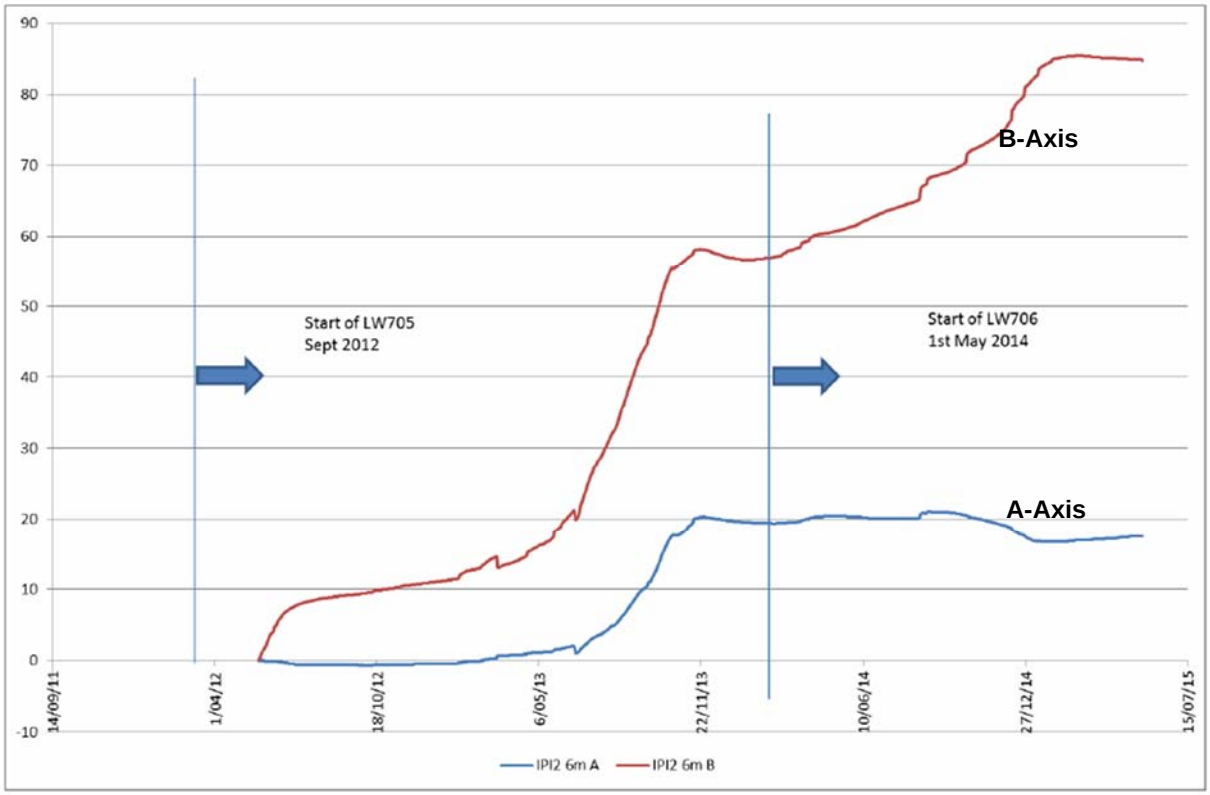
The observed incremental horizontal movements at the highway and railway cutting points versus distance from Longwall 706 are illustrated in Fig. 2.8. It can be seen from this figure that the observed movements were within the range of those observed along the highway and railway monitoring lines, and less than those typically observed elsewhere in the Southern Coalfield.

Fixed In-place Inclinometer

A vertical fixed in-place inclinometer was installed in the floor of the railway cutting near 71 km. The hole intersected a geological fault that was identified in the sides of the railway cutting. Measurements were recorded every hour. The inclinometers comprised tiltmeters generally spaced at 2 m centres, with a concentration of tiltmeters spaced at 0.5 m centres in the zone where the hole is projected to intersect the fault line.

During the mining of Longwall 704, the fixed-in-place inclinometer detected very early small deflections at 8 metres depth, where the borehole intersected the fault zone. Deflection of the B-Axis (parallel to the strike of the fault) at 8 metres depth increased as mining progressed, with the rate of change accelerating when the longwall face had passed the inclinometer by approximately 150 metres. The maximum deflection at the 8 m sensor B-Axis was 147 mm on 4th June, when it reached the limit of its monitoring tolerance and ceased to record.

A new fixed-in-place inclinometer was installed at this time and the readings showed continued deflection where the new borehole intersects the fault at 6 m depth during the mining of Longwalls 705 and 706 (refer Fig. 2.4).



Graph courtesy David Christie

Fig. 2.4 Observed Changes in Fixed In-Place Inclinometer between 6 and 6.5 metres depth during Longwalls 705 and 706

2.7.1. Highway Cutting 2

The Highway Cutting 2 Points were measured by South32 during the extraction of Longwall 706, which are 3D monitoring points located on the cuttings along the M31 Hume Motorway. The locations of these monitoring points are shown in Drawing No. MSEC686-01 in Appendix B.

A summary of the survey dates for these monitoring points is provided in Table 2.17.

Table 2.17 Summary of Survey Dates for the Highway Cutting 2 Points during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey at end of Longwall 706	24th July 2014 25th August 2014 22rd September 2014 20th October 2014 24th November 2014 15th December 2014 19th January 2015 26th February 2015 28th November 2015	As per approved Longwall 707 monitoring program

The final observed absolute incremental horizontal movements at the Highway Cutting 2 Points, due to the extraction of Longwall 706, are shown in Fig. 2.5.

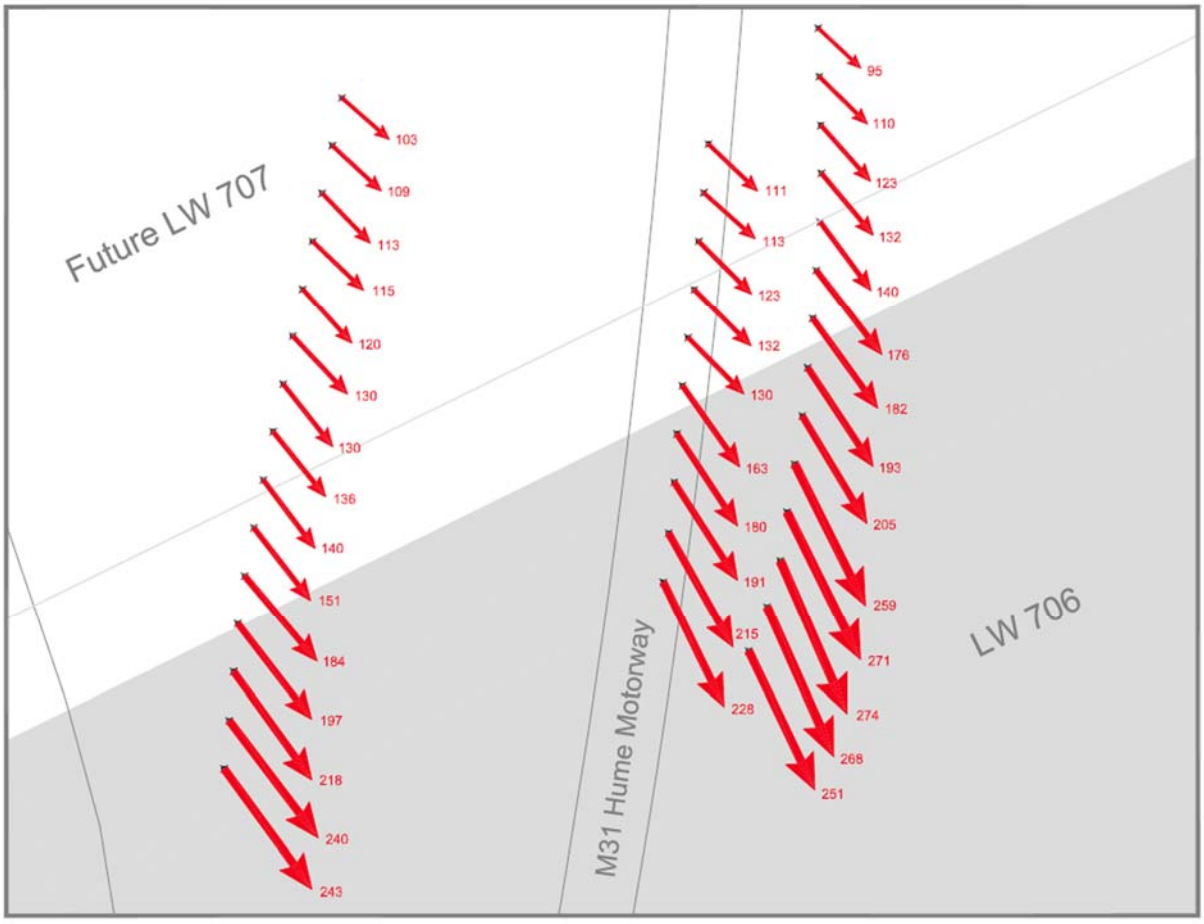


Fig. 2.5 Observed Absolute Incremental Horizontal Movements at the Highway Cutting 2 Points due to the Extraction of Longwall 706 (28th November 2015)

A summary of the maximum observed absolute incremental horizontal movements at the cutting monitoring points, at any time during or after the extraction of Longwall 706, is provided in Table 2.18.

Table 2.18 Maximum Observed Absolute Incremental Horizontal Movements at the Highway Cutting 2 Points Resulting from the Extraction of Longwall 706

Longwall	Location	Maximum Observed Incremental Horizontal Movement (mm)
Longwall 706	W144 to W158	243
	G101 to G110	228
	E146R to E160R	274

The accuracies of the measured Eastings and Northings at the 3D monitoring points are in the order ±5 mm and, therefore, the accuracies of the measured absolute horizontal movements are in the order of ±7 mm.

2.8. Partridge VC Rest Area

The Partridge VC Rest Area points were measured by South32 during the extraction of Longwall 706. The locations of these monitoring points are shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for theses monitoring points is provided in Table 2.19.

Table 2.19 Summary of Survey Dates for the Partridge VC Rest Area Monitoring Points during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 706, with monthly surveys during mining after 500 metres of extraction	24th July 2104 25th August 2014 22nd September 2014 20th October 2014 24th November 2014 15th December 2014 28th November 2015	As per approved Longwall 707 monitoring program

Minor vertical and horizontal displacements were measured during the mining of Longwall 706. This was expected given that the Rest Area is located above future Longwall 707.

2.9. Far-field 3D Marks

The far-field mine subsidence movements were measured by South32 using a number of 3D points in the vicinity of Longwall 706. The locations of these monitoring points are shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for the far-field 3D monitoring points, during the extraction of Longwall 706, is provided in Table 2.20.

Table 2.20 Summary of Survey Dates for the Far-field 3D Monitoring Points during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 706, with monthly surveys during mining after 300 metres of extraction	24th June 2104 30th July 2014 29th August 2014 25th September 2014 6th November 2014 5th December 2014 12th January 2015 27th February 2015 25th March 2015 4th May 2015 2nd June 2015 2nd July 2015 5th August 2015 8th September 2015 13th October 2015 12th November 2015 15th December 2015	As per approved Longwall 707 monitoring program

The loci of observed absolute incremental horizontal movements at the far-field 3D monitoring points, during the extraction of Longwall 706, are shown in Fig. 2.6.

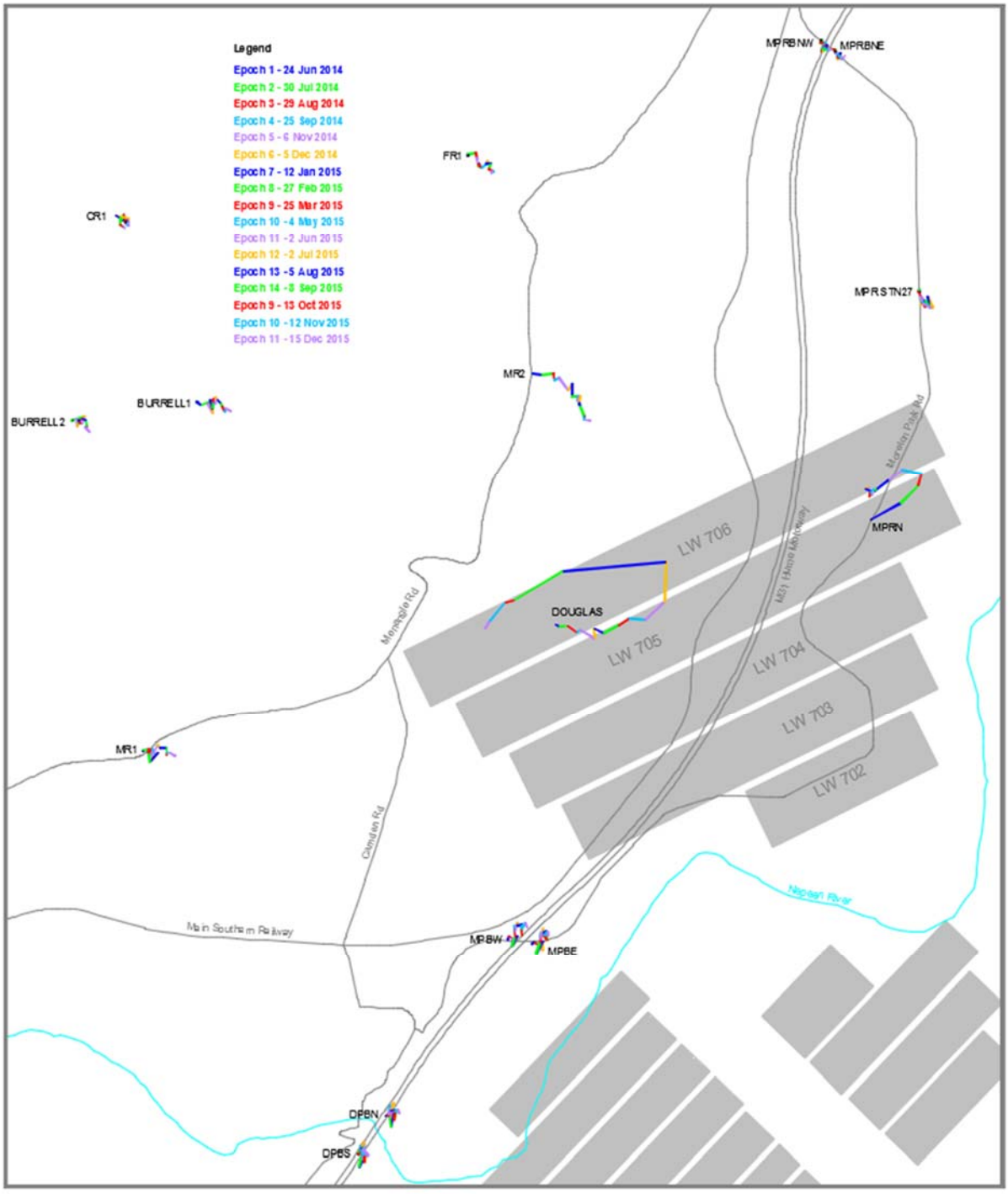


Fig. 2.6 Loci of Observed Absolute Incremental Horizontal Movements at the Far-field 3D Monitoring Points during the Extraction of Longwall 706 (24th June 2014 to 15th December 2015)

The final observed absolute incremental horizontal movements at the far-field 3D monitoring points, due to the extraction of Longwall 706, are shown in Fig. 2.7.

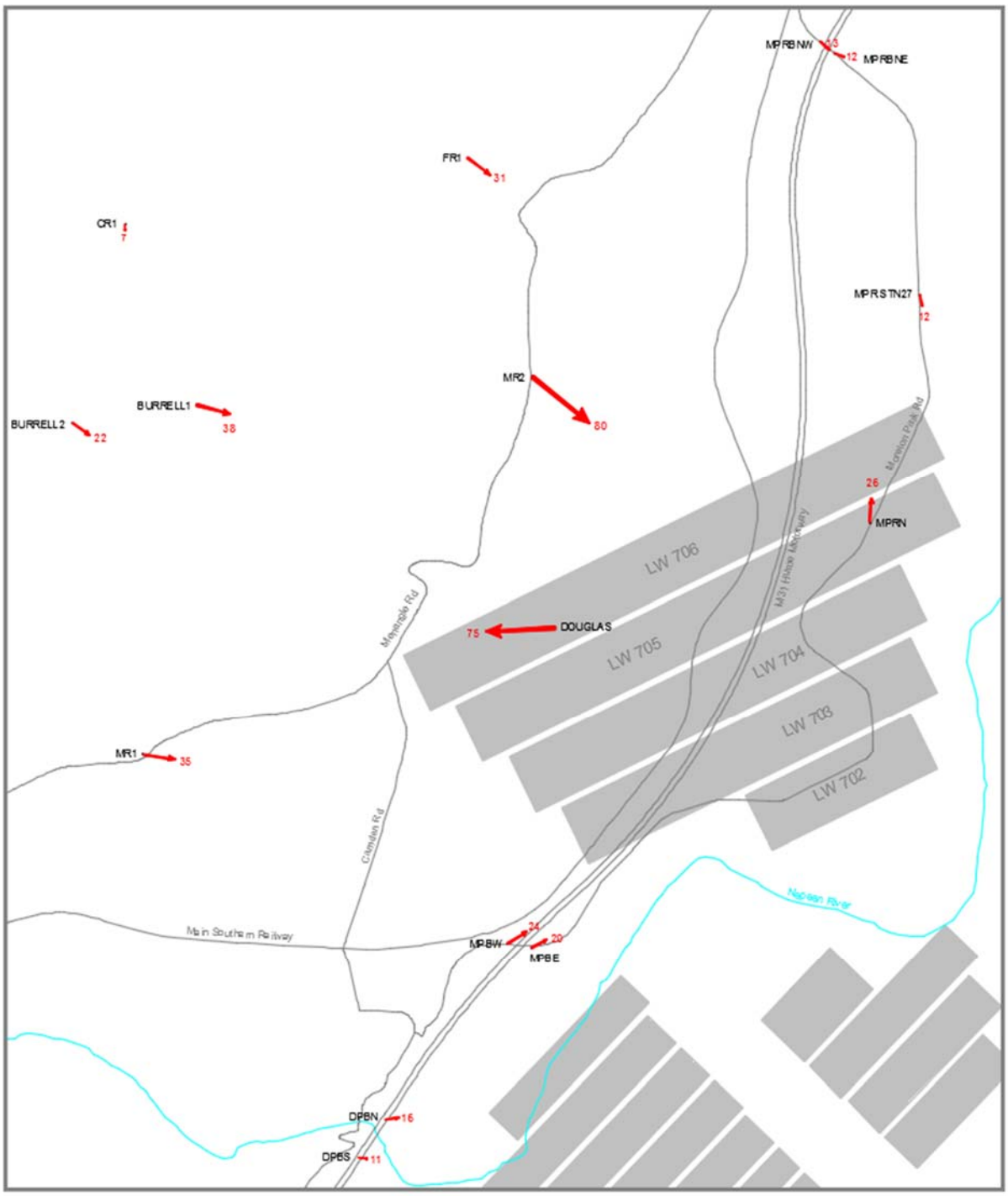


Fig. 2.7 Observed Absolute Incremental Horizontal Movements at the Far-field 3D Monitoring Points due to the Extraction of Longwall 706 (15th December 2015)

A summary of the maximum observed absolute incremental horizontal movements at the far-field 3D monitoring points, after the completion of Longwall 706, is provided in Table 2.21.

Table 2.21 Maximum Observed Absolute Incremental Horizontal Movements at the Far-field 3D Monitoring Points Resulting from the Extraction of Longwall 706

Longwall	Location	Maximum Observed Incremental Horizontal Movement (mm)
Longwall 706	BURRELL1	38
	DOUGLAS	75
	DPBN	16
	DPBS	11
	MPBE	20
	MPBW	24
	MR1	35
	MR2	80
	BURRELL2	22
	CR1	7
	FR1	31
	MPRN	26
	MPR STN27	12
	MPRBNE	12
	MPRBNW	13

The accuracies of the measured Eastings and Northings at the far-field 3D monitoring points are in the order ±5 mm and, therefore, the accuracies of the measured absolute horizontal movements are in the order of ±7 mm.

A comparison between the observed incremental horizontal movements for the far-field 3D marks (magenta points), due to the extraction of Longwall 706, with those previously measured elsewhere in the Southern Coalfield (grey points) is provided in Fig. 2.8. The incremental horizontal movements at the M31 East Line (blue points), M31 West Line (cyan points), ARTC Line (green points) and the highway and railway cutting marks (orange points), due to the extraction of Longwall 706, are also shown in this figure for comparison.

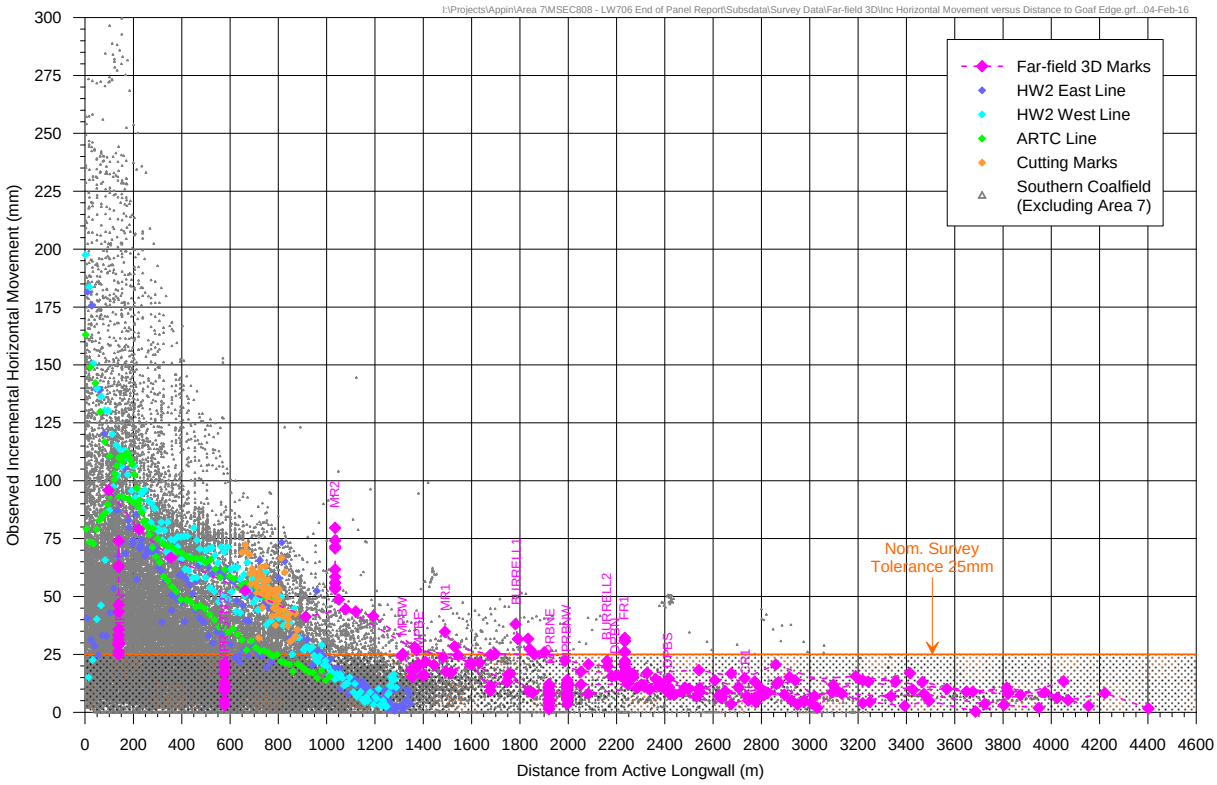


Fig. 2.8 Observed Absolute Incremental Horizontal Movements versus Distance to Nearest Longwall Goaf Edge with Solid Coal between Mark and Extracted Longwall, with Longwall 706 results overlaid

It can be seen from this figure that the observed incremental horizontal movements at the far-field marks, due to the extraction of Longwall 706, were within the range of those previously observed in the Southern Coalfield.

2.10. Douglas Park Twin Bridges over the Nepean River

The Douglas Park Twin Bridges are located approximately 2.1 kilometres south-west of the finishing (western) end of Longwall 706. The locations of these bridges are shown in Drawing No. MSEC808-01, in Appendix B, where the Hume Motorway crosses the Nepean River. The monitoring associated with the Douglas Park Twin Bridges, during the extraction of Longwall 706, included the following:-

- Absolute 3D bridge monitoring points;
- Relative 3D bridge monitoring points;
- Inclinometer monitoring;
- Bridge joint monitoring; and
- Visual inspections.

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

2.10.1. Absolute 3D Monitoring for the Douglas Park Twin Bridges

The absolute 3D horizontal movements at the Douglas Park Twin Bridges were monitored by South32 at Points DPBN and DPBS, which are located adjacent to the northern and southern ends, respectively, of the bridges. The locations of these monitoring points are shown in Drawing No. MSEC808-01, in Appendix B.

Marks DPBN and DPBS were measured as part of the far-field 3D surveys, which were discussed in Section 2.9. The observed incremental horizontal movements for these marks are illustrated in Fig. 2.6 and Fig. 2.7. It can be seen from these figures that the bridge has moved towards the east as the result of the extraction of Longwall 706.

A summary of the maximum observed incremental and total horizontal movements at Marks DPBN and DPBS, after the completion of Longwall 706, is provided in Table 2.22.

Table 2.22 Maximum Observed Absolute Incremental and Total Horizontal Movements at Marks DPBN and DPBS after the Completion of Longwall 706

Mark	Maximum Observed Incremental Horizontal Movement due to Longwall 706 (mm)	Maximum Observed Total Horizontal Movement due to Longwalls 701 to 706 (mm)
DPBN	16	48
DPBS	11	39

The development over time of absolute horizontal movement at Marks DPBN and DPBS is shown in Fig. 2.9.

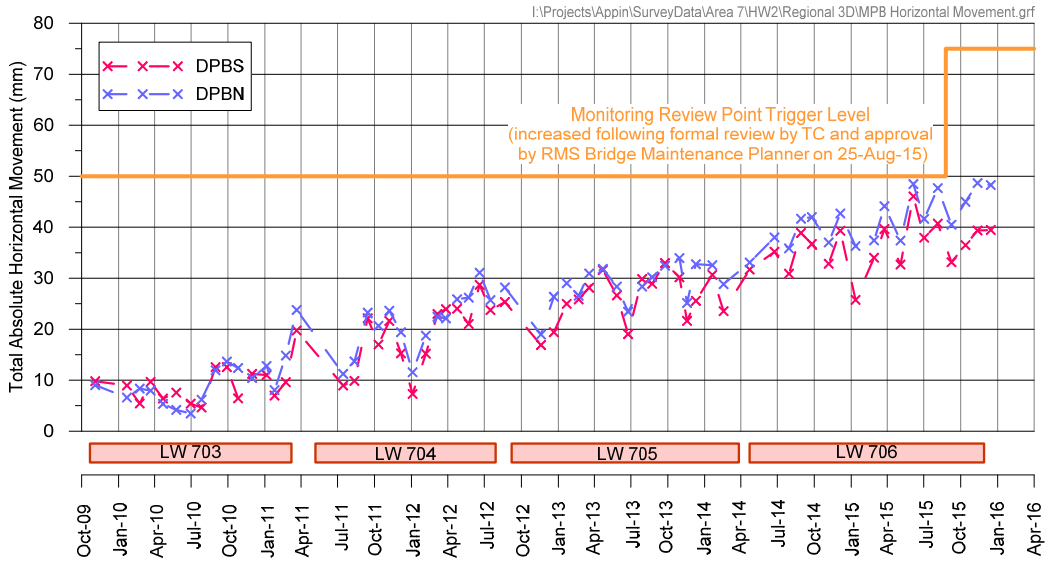


Fig. 2.9 Development of absolute horizontal movement at Marks DPBN and DPBS

The Trigger Action Response Plan (TARP) for the Douglas Park Twin Bridges, which was developed by the RMS chaired Technical Committee, provided triggers for absolute and relative horizontal movements of the far-field 3D Points DPBN and DPBS adjacent to the bridges. A summary of the Level 1 Triggers and the observed horizontal movements at these monitoring points, resulting from the extraction of Longwall 706, are provided in Table 2.23.

A formal review was undertaken by the Technical Committee on 25 August 2015, where it was agreed to increase the Monitoring Review Point trigger level from 50 mm to 75 mm. The decision was based on observations that differential horizontal movements between survey marks on the Bridges remained low.

Table 2.23 Summary of the Level 1 Triggers and the Observed Horizontal Movements at Marks DPBN and DPBS after the Completion of Longwall 706

Type	Level 1 Triggers (mm)	Maximum Observed Horizontal Movements (mm)
Absolute Horizontal Movement of Points DPBN and DPBS	75	49
Relative Horizontal Movement between Points DPBN and DPBS	5	< 2

It can be seen from the above table, that the maximum observed absolute and relative horizontal movements at the far-field 3D monitoring Points DPBN and DPBS did not exceed the *Level 1 Triggers*.

2.10.2. Relative 3D Monitoring for the Douglas Park Twin Bridges

The mine subsidence movements at the Douglas Park Twin Bridges were measured by South32 using relative 3D marks fixed directly to the bridge structure. The locations of the monitoring points on the bridges are shown in Fig. 2.10 and Fig. 2.11.

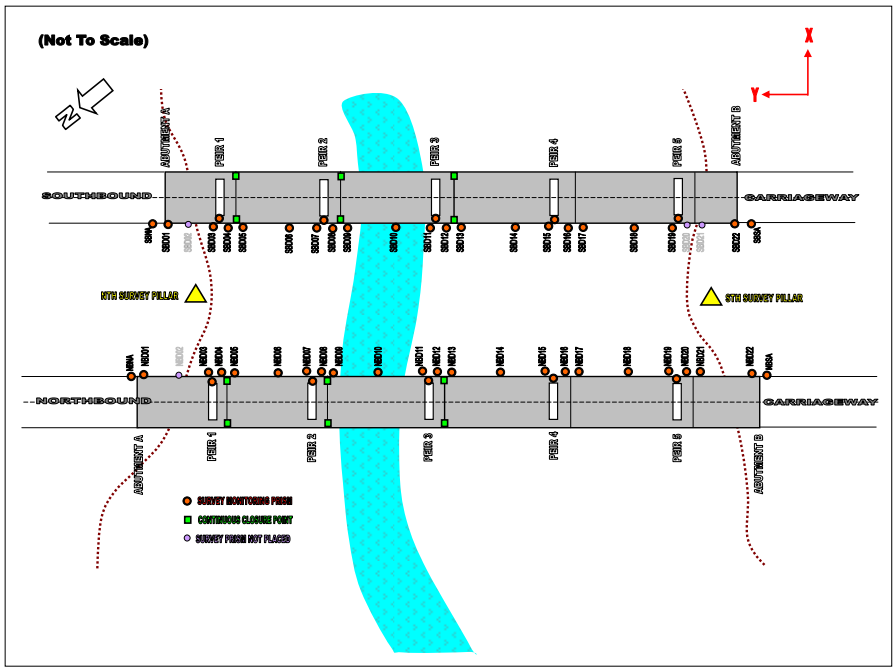


Fig. 2.10 Plan of the Relative 3D Monitoring Points on the Douglas Park Twin Bridges (Courtesy of South32)

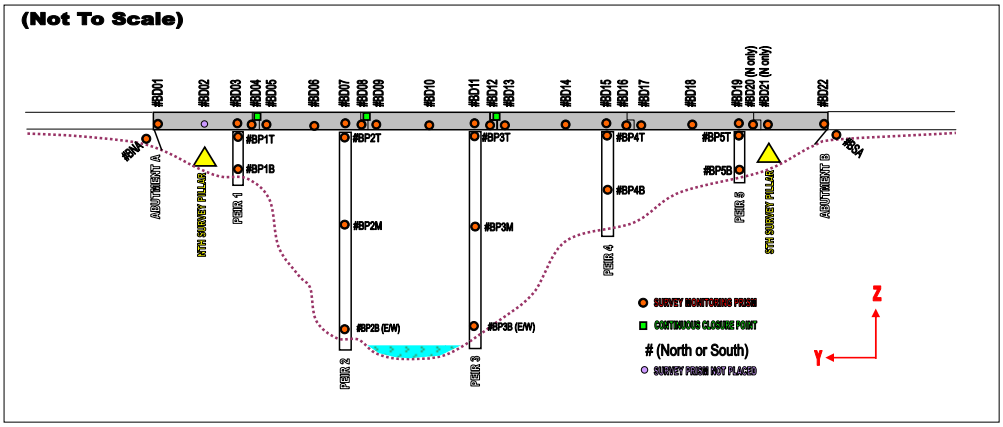


Fig. 2.11 Elevation of the Relative 3D Monitoring Points on the Douglas Park Twin Bridges (Courtesy of South32)

A summary of the survey dates for these monitoring points, during the extraction of Longwall 706, is provided in Table 2.24.

Table 2.24 Summary of Survey Dates for the Relative 3D Monitoring Points on the Douglas Park Twin Bridges during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 706, and by exception where the observed movements exceed the *Level 1 Triggers* at either the far-field 3D monitoring points, at the inclinometers, or at the bridge joint displacement monitors	6th May 2015 (End of LW705) 20th July 2015 17th August 2015	As per approved Longwall 707 and Longwall 901 monitoring programs

Measured differential horizontal movements are very small and close to survey tolerance. The highest accuracy surveys of differential horizontal movements are straight 195 m long 2D horizontal distance measurements between survey pillars at Pegs DPBN and DPBS, which are situated between the two bridges at abutment level. Measured changes between the pillars are within survey tolerance. The relative 3D surveys are slightly less accurate and while variations exist between surveys, the results are close to survey tolerance but consistently tensile in nature for the last four surveys.

2.10.3. Inclinometers near the Douglas Park Twin Bridges

The differential movements at two inclinometers near the Douglas Park Twin Bridges were monitored during the extraction of Longwall 706, being PSM2 and PSM6. There are two other inclinometers, being PSM1 and PSM4, which were not measured during the extraction of this longwall. The inclinometers were installed and maintained by Pells Sullivan and Meynink (PSM), measured by South32 and the results interpreted by PSM.

The inclinometers comprise boreholes with plastic casings which allow probes to measure the differential tilt or inclination over the lengths of the boreholes. Further details on the inclinometers and the results are provided in the monitoring reports by PSM numbers PSM883-264L through PSM883-298L.

A summary of the survey dates for the inclinometers is provided in Table 2.25.

Table 2.25 Summary of Survey Dates for the Inclinometers during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Monthly surveys from the commencement of Longwall 706 until the completion of Longwall 706 and the agreement with the RMS chaired Technical Committee for cessation.	Monthly during LW706	As per approved Longwall 707 and Longwall 901 monitoring programs

The TARP for the Douglas Park 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 observed total differential movements at the inclinometers, at any time during the extraction of Longwall 706, is provided in Table 2.26.

Table 2.26 Summary of the Level 1 Trigger and the Maximum Observed Total Differential Movements at the Inclinometers during the Extraction of Longwall 706

Type	Level 1 Trigger (mm)	Maximum Observed Differential Movement (mm)
Differential Movement	5	3.2 (PSM2) 1.4 (PSM6)

It can be seen from the above table, that the Level 1 Trigger was not exceeded during the extraction of Longwall 706.

2.10.4. Joint Monitoring for the Douglas Park Twin Bridges

The differential movements across the movement joints in the Douglas Park Twin Bridges were measured by PSM during the extraction of Longwall 706. 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), with the locations indicated in Fig. 2.10.

The bridge joint monitor readings commenced on the 29th November 2007 (during the mining of Longwall 701) and measurements have been taken at 5 or 10 minute intervals. Further details on the bridge joint monitors and the results are provided in the monitoring reports by PSM numbers PSM883-264L through PSM883-298L.

The TARP for the Douglas Park 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 Trigger* and the maximum observed differential movement across the bridge movement joints, resulting from the extraction of Longwall 706, is provided in Table 2.27.

Table 2.27 Summary of the Level 1 Trigger and the Maximum Observed Differential Movement across the Bridge Movement Joints Resulting from the Extraction of Longwall 706

Location	Level 1 Trigger (mm)	Maximum Observed Differential Movement Across the Bridge Movement Joints (mm)
Joint 1 (Northern Joint)	2	< 0.1 (Northbound Carriageway) +0.2 (Southbound Carriageway)
Joint 2 (Middle Joint)	2	-0.4 (Northbound Carriageway) -0.5 (Southbound Carriageway)
Joint 3 (Main Expansion Joint)	10	-2.5 (Northbound Carriageway) -1.5 (Southbound Carriageway)

It can be seen from the above table, that the Level 1 Triggers were not exceeded as the result of mining Longwall 706.

2.11. Moreton Park Road Bridge (South)

Moreton Park Road Bridge (South) is located approximately 1,340 metres southeast of the finishing (western) end of Longwall 706. The location of the bridge is shown in Drawings Nos. MSEC808-01 and MSEC808-03, in Appendix B. The monitoring associated with Moreton Park Road Bridge (South), during the extraction of Longwall 706, included the following:-

- Absolute 3D bridge monitoring points;
- Relative 3D bridge monitoring points; and
- Visual inspections.

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

2.11.1. Absolute 3D Monitoring Points for Moreton Park Road Bridge (South)

The absolute 3D horizontal movements at the Moreton Park Road Bridge (South) were monitored by South32 at Points MPBE and MPBW, which are located adjacent to the eastern and western ends, respectively, of the bridge. The locations of these monitoring points are shown in Drawing No. MSEC808-01, in Appendix B.

The surveys for Points MPBE and MPBW were carried out as part of the far-field surveys, which were described in Section 2.9. The maximum observed absolute incremental horizontal movements at Points MPBE and MPBW, at any time during or after the extraction of Longwall 706, were 21 mm and 25 mm, respectively, as shown in Fig. 2.7.

The Trigger Action Response Plan (TARP) for the Moreton Park Road Bridge (South), which was developed by the RMS chaired Technical Committee, provided triggers for the absolute horizontal movements of the far-field 3D Points MPBE and MPBW adjacent to the bridge. The Level 1 Trigger for the absolute total horizontal movement was 100 mm, as agreed by the Technical Committee on the 29th August 2013, during the extraction of Longwall 705. During the mining of Longwall 706, the Level 1 Trigger was revised to 125 mm on 25th August 2015, as agreed by the Technical Committee following assessment of monitoring results and approval by the RMS Bridge Maintenance Planner.

The development of absolute horizontal movement at Marks MPBE and MPBW is shown in Fig. 2.12.

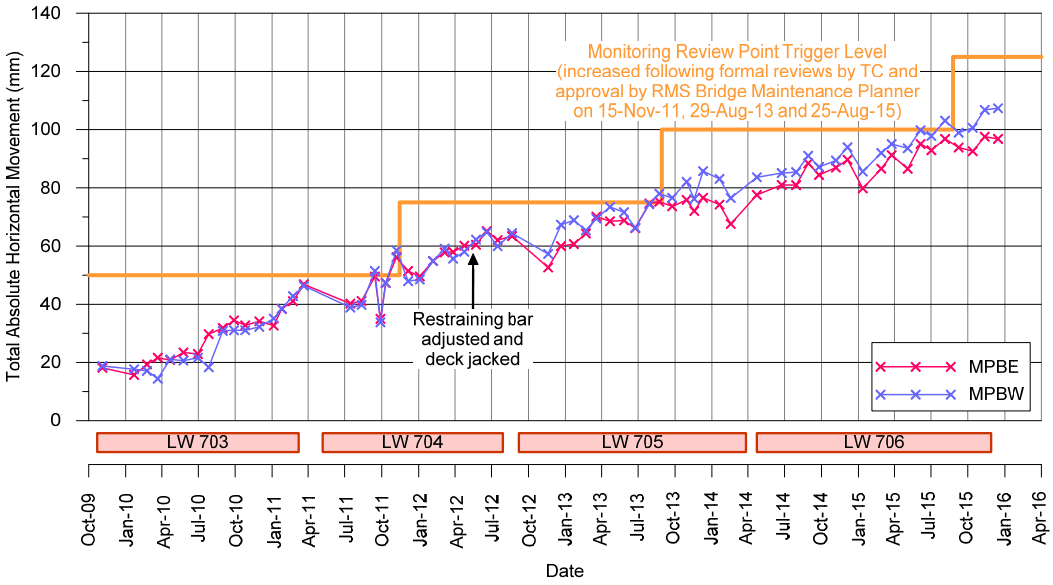


Fig. 2.12 Development of absolute horizontal movement at Marks MPBE and MPBW

A summary of the Level 1 Trigger and the observed absolute total horizontal movements at Points MPBE and MPBW, after the completion of Longwall 706, are provided in Table 2.28.

Table 2.28 Summary of the Level 1 Trigger and the Observed Absolute Total Horizontal Movements at the Marks MPBE and MPBW after the Completion of Longwall 706

Type	Level 1 Triggers (mm)	Maximum Observed Horizontal Movements (mm)
Absolute Horizontal Movement of Points MPBE and MPBW	125	97 (MPBE) 107 (MPBW)

2.11.2. Relative 3D Monitoring Points for the Moreton Park Road Bridge (South)

The mine subsidence movements of the Moreton Park Road Bridge (South) were measured by South32 using relative 3D marks fixed directly to the bridge structure. The locations of the monitoring points on the bridges are shown in Fig. 2.13 and Fig. 2.14 (figures courtesy of South32).

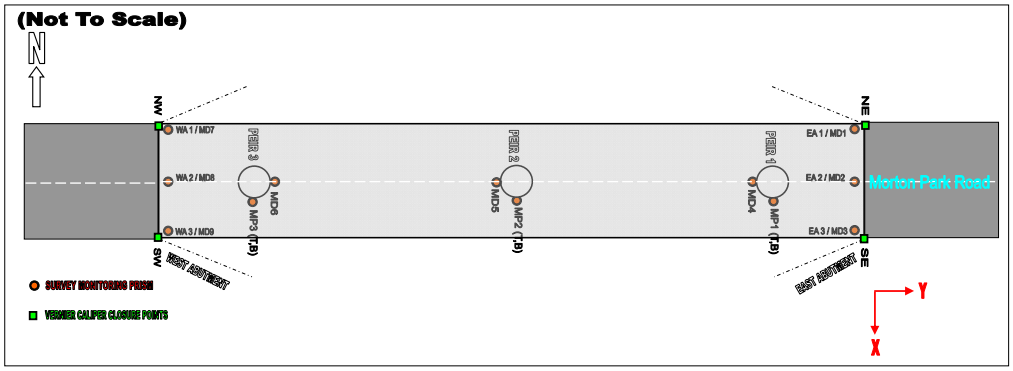


Fig. 2.13 Plan of the Relative 3D Monitoring Points on the Moreton Park Road Bridge (South) (Courtesy of South32)

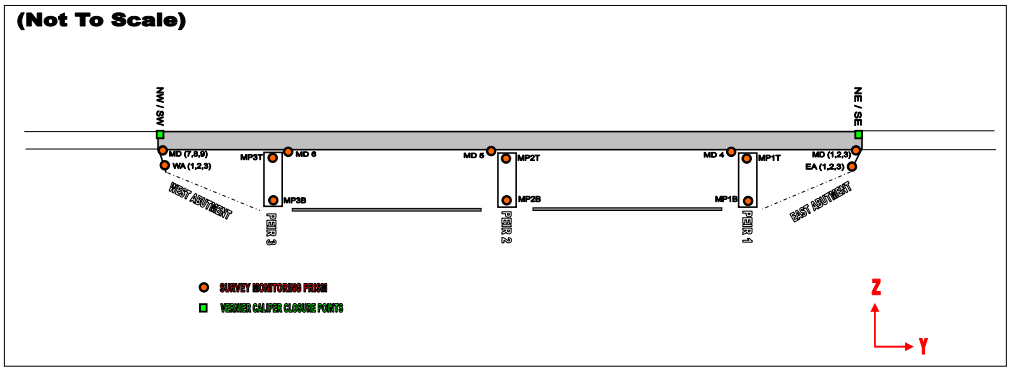


Fig. 2.14 Elevation of the Relative 3D Monitoring Points on the Moreton Park Road Bridge (South) (Courtesy of South32)

A summary of the survey dates for these monitoring points, during the extraction of Longwall 706, is provided in Table 2.29.

Table 2.29 Summary of Survey Dates for the Relative 3D Monitoring Points on the Moreton Park Road Bridge (South) during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 706	13th July 2015	As per approved Longwall 707 and Longwall 901 monitoring programs

The observed total changes in the horizontal distance between the abutments, during the extraction of Longwalls 701 to 706, are illustrated in Fig. 2.15. It can be seen from this figure, that there has been a small amount of abutment spreading, in the order of 5 mm, which primarily developed during the extraction of the previous Longwalls 703 and 704. The results vary slightly between surveys and the cause is thought to be related to changes in moisture and/or temperature.

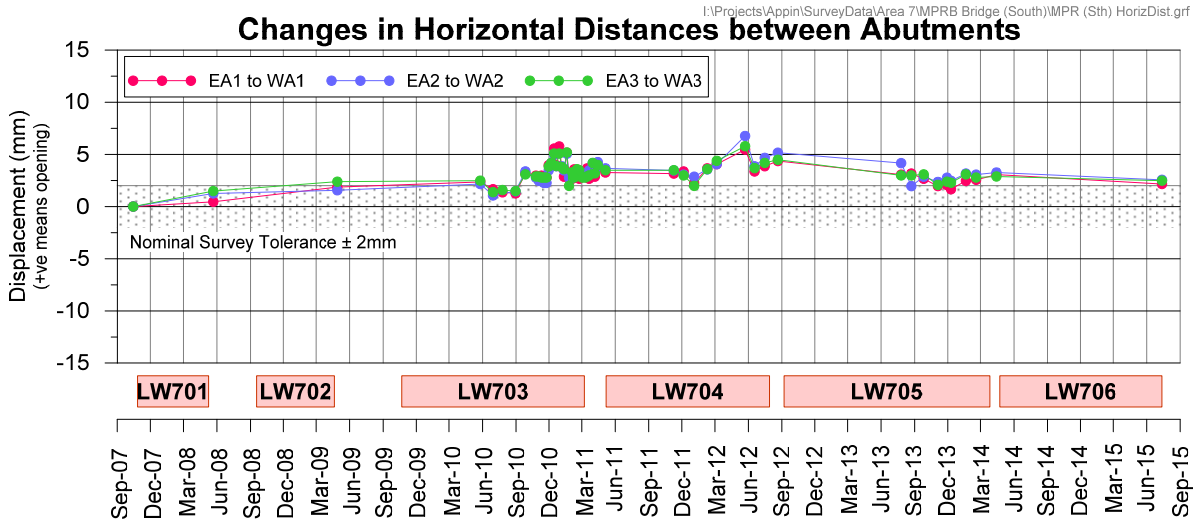


Fig. 2.15 Observed Changes in Horizontal Distances between Abutments

Relative 3D surveys have also detected a horizontal rotation of the deck. The deck movements are not considered to be due to subsidence during the mining of Longwalls 701 to 706, as the deck is moving independently of the abutment and bases of the column supports.

2.12. Water NSW Infrastructure

Water NSW infrastructure in the vicinity of Longwall 706 includes the Upper Canal, Devines Tunnels, wrought iron aqueducts, bridges and concrete aqueducts. The locations of the Water NSW infrastructure are shown in Drawing No. MSEC808-01, in Appendix B.

2.12.1. Wrought Iron Aqueducts and Bridges

The movements at the Ousedale Creek, Mallaty Creek, Leafs Gully and Nepean Creek Aqueducts and Bridges were monitored by South32 using local 3D surveys. A summary of the survey dates for the monitoring points on these aqueducts and bridges is provided in Table 2.30.

Table 2.30 Summary of Survey Dates for the Aqueducts and Bridges during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 706 and monthly surveys during Longwall 706 and West Cliff Longwall 37, for the first 500 metres of extraction, then reducing to six monthly surveys.	30th June 2014 8th August 2014 17th September 2014 13th March 2015 15th September 2015	As per approved Longwall 707 monitoring program

A summary of the maximum observed incremental net subsidence, net uplift and closure at the Ousedale Creek, Mallaty Creek, Leafs Gully and Nepean Creek Aqueducts and Bridges, during the extraction of Longwall 706, is provided in Table 2.31. It is noted that the net vertical movements have been taken at the marks at the bases of the structures only (i.e. the marks closest to the ground) and do not include the marks on the aqueduct pipes or at the tops of the structures which were influenced by the changes in water flows through the aqueducts, especially prior to and after canal shutdowns. The closure or opening movements have been taken as the changes in distance between the headwalls.

Table 2.31 Maximum Observed Incremental Net Subsidence, Net Uplift and Closure at the Wrought Iron Aqueducts and Bridges during Longwall 706

Location	Maximum Observed Incremental Net Subsidence (mm)	Maximum Observed Incremental Net Uplift (mm)	Maximum Observed Incremental Closure (mm)
Ousedale Creek Aqueduct	3	< 2	+2 (opening)
Ousedale Creek Bridge	< 2	< 2	< 2
Mallaty Creek Aqueduct	< 2	< 2	+4 (opening)
Mallaty Creek Bridge	< 2	< 2	< 2
Leafs Gully Aqueduct	< 2	< 2	< 2
Leafs Gully Bridge	< 2	< 2	< 2
Nepean Creek Aqueduct	< 2	< 2	-2 (closure)
Nepean Creek Bridge	< 2	< 2	< 2

The survey tolerance for net subsidence, net uplift, closure and opening were around 2 mm.

The maximum observed incremental subsidence at the Ousedale Creek Aqueduct, during the mining of Longwall 706, was 3 mm which was slightly greater than the order of survey tolerance. The measured movements at the remaining ground monitoring points at this aqueduct were in the order of survey tolerance, i.e. not measurable.

The incremental changes in the distances between the aqueduct headwalls, during the mining of Longwall 706, were +2 mm (opening) for the Ousedale Creek Aqueduct, +4 mm (opening) for the Mallaty Creek Aqueduct and -2 mm (closure) for the Nepean Creek Aqueduct. The movements at the Ousedale and Nepean Creek Aqueducts were similar to the order of survey tolerance. The incremental opening at the Mallaty Creek Aqueduct resulted in a reduction of the existing net closure from 10 mm to 6 mm.

The observed incremental movements at the remaining aqueducts and bridges were in the order of survey tolerance, i.e. not measureable.

2.12.2. Concrete Aqueducts C and D

The movements at Concrete Aqueducts C and D were monitored by South32 using local 3D surveys. The survey dates for these aqueducts were the same as those for the wrought iron aqueducts and bridges, which are provided in Table 2.30.

The incremental movements at Mark 1WB for Concrete Aqueduct C, during the mining of Longwall 706, were 5 mm in the vertical and 3 mm in the horizontal. The notes from the survey indicate that this mark appears to be compromised. The remaining observed incremental net vertical and horizontal movements at the Concrete Aqueducts C and D, during the extraction of Longwall 706, were less than 3 mm, which are similar to the order of survey tolerance, i.e. not measurable.

2.13. Telstra infrastructure

The mine subsidence movements along the Telstra optical fibre line were measured by South32 using a 3D ground monitoring line, referred to as the Telstra Line. The locations of the monitoring points are shown in Drawing No. MSEC808-01 in Appendix B.

A summary of the survey dates for the Telstra Line, during the extraction of Longwall 706, is provided in Table 2.32.

Table 2.32 Summary of Survey Dates for the Telstra Line during Longwall 706

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey monthly after 1000 metres of extraction of LW706	20th March 2015, 6th May 2105, 5th June 2015, 2nd July 2015, 24th July 2015, 1st September 2015, 22nd September 2015, 28th October 2015 3rd December 2015	As per approved Longwall 707 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the Telstra Line, resulting from the extraction of Longwall 706, are shown in Fig. A.19 in Appendix A. The predicted profiles of incremental subsidence and tilt along the monitoring line, at the completion of Longwall 706, are also shown in this figure, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from this figure, that the observed profiles of subsidence and tilt were reasonably similar to the profiles predicted.

A summary of the maximum observed and maximum predicted subsidence parameters along the Telstra Line, resulting from the extraction of Longwall 706, is provided in Table 2.33.

Table 2.33 Maximum Observed and Predicted Incremental Subsidence Parameters along the Telstra Line Resulting from the Extraction of Longwall 706

Type	Maximum Incremental Subsidence at Tower (mm)	Maximum Incremental Tilt at Tower (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	646	5.8	1.3	4.5
Predicted	900	5.0	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the Telstra Line are in the order of ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the Telstra Line are in the order of ±10 mm. The accuracies of the measured strains along the Telstra Line are in the order of ±0.25 mm/m. The accuracies of the ground survey measurements of tilt at the tower are in the order of ±1.0 mm/m.

The observed changes in tilt across the base of the Telstra Tower, during the extraction of Longwall 706, are illustrated in Fig. 2.16.

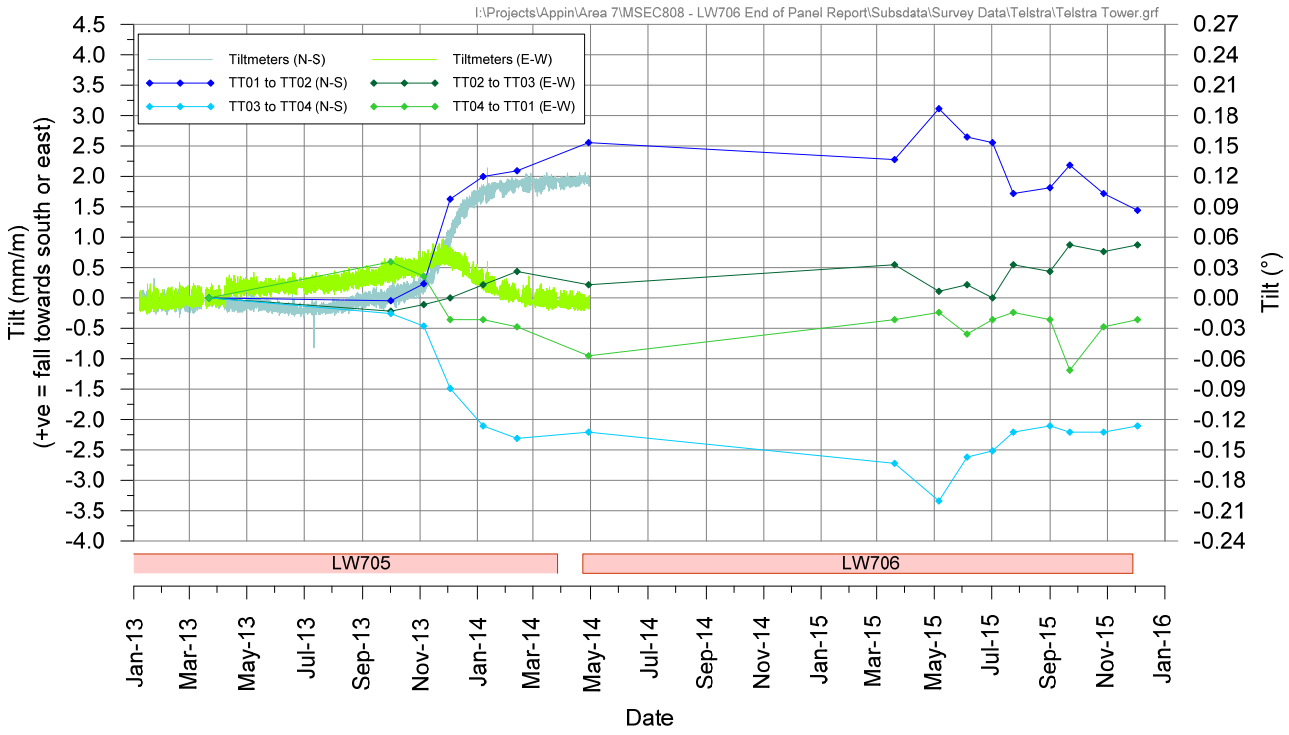


Fig. 2.16 Observed Changes in Tilt at Telstra Tower

It can be seen that there was a reasonable correlation between ground surveys of tilt at the Tower and high accuracy tiltmeter measurements.

The observed tilts are within predictions and substantially less than the operating tolerances of the antennae.

3.1. Natural Features

The natural features in the vicinity of Longwall 706 are shown in Drawing No. MSEC808-02, in Appendix B, which include:-

- The Nepean River,
- Creeks,
- Cliffs and rock outcrops,
- Steep slopes, and
- Archaeological Sites.

The MSEC assessments for the natural features, resulting from the extraction of Appin Longwalls 705 to 710 were provided in Report No. MSEC342. More detailed assessments for some natural features were also provided in other consultants reports. Comparisons between the MSEC assessments and the observed impacts for the natural features, listed above, are provided in Table 3.1. The observed impacts are based on those recorded by field investigations undertaken for the *End of Panel* report.

Table 3.1 Summary of the MSEC Assessments and the Observed Impacts for the Natural Features Resulting from the Extraction of Longwall 706

Natural Feature	MSEC Assessed Impacts	Observed Impacts
The Nepean River	**Minor fracturing** could occur in the bed of the river	No fracturing observed, however, the flooded valley and sediment profile limits observations of the river bed
	The potential for **surface water flow diversion** assessed as very low	No observable loss or diversion of water from the Nepean River – refer to report by Geoterra
	The **surface water level** is expected to remain essentially unchanged. Uplift of the banks could result in some desiccation of the banks	No observed change in water level by South32 apart from normal fluctuations associated with rainfall and Water NSW discharges
	Possible that mining-induced **springs** could occur	No additional iron staining or iron seeps were observed in the Nepean River
	Possible that isolated **gas emissions** could occur	Gas releases were observed at four sites, which are located closer to Longwalls 702 to 705. Whilst the gas releases were observed during the mining of Longwall 706, their locations are close to where gas releases have been previously observed during the mining of Longwalls 701 to 704 and Tower Longwall 16. Refer to report by *South32* for further details.
	Water quality –Refer to Surface Water Report (by Geoterra) **Terrestrial ecology** – Refer to Landscape Report (by South32)	
Creeks	Potential for some **ponding**, **flooding** and **desiccation** above the longwalls	No impacts observed in the monitored streams
	Fracturing could occur in the beds of the smaller creeks above the longwalls	No impacts observed in the creeks.
Cliffs and Rock Outcrops	Potential for **cliff instabilities** assessed as very low	No observed impacts
Steep Slopes	Potential for **soil slippage**	No observed impacts
Archaeological Sites	Low likelihood of impacts on open sites, scarred tree and shelters.	No observed impacts. Refer to Cultural Heritage Report (by *Niche)*

Minor surface cracking was reported on a private property during the mining of Longwall 706.

It can be seen from Table 3.1, that the recorded impacts on the natural features, resulting from the extraction of Longwall 706, were similar to or less than the MSEC assessments. Further assessments of

some natural features have been provided by other consultants, and these are described in the *End of Panel* report.

A comparison between predicted and observed groundwater impacts is provided in a report by *GeoTerra*.

3.2. Built Features

The built features in the vicinity of Longwall 706 are shown in Drawings No MSEC808-03, in Appendix B. The features which are located within the predicted 20 mm incremental subsidence contour, due to the extraction of Longwall 706, or which may be sensitive to far-field or valley related movements include:-

- Moreton Park Road and drainage culverts,
- Menangle Road and drainage culverts,
- M31 Hume Motorway and associated infrastructure,
- Main Southern Railway and associated infrastructure,
- The Douglas Park Twin Bridges,
- Moreton Park Road Bridge (South),
- Low voltage powerlines,
- Copper telecommunications cables,
- Optical fibre cables – Telstra (2 off), Optus, NextGen and Powertel,
- Building structures, pools, tanks and farm dams,
- Heritage structures (including the Mountbatten Group),
- Groundwater bores (including GW101437 and GW104154),
- Pumps in the Nepean River,
- The Upper Canal, Cataract Tunnel and associated infrastructure, and
- Survey control marks.

The MSEC assessments for the built features, resulting from the extraction of Appin Longwalls 705 to 710, were provided in Report No. MSEC342. Comparisons between the assessed and observed impacts for the built features located within either the 35 degree angle of draw line from Longwall 706, or within the predicted incremental 20 mm subsidence contour due to Longwall 706, are provided in Table 3.2. The built features in the vicinity of Longwall 706, which have been considered sensitive to far-field or valley related movements, have also been included in this table.

Table 3.2 Summary of the Assessed and Observed Impacts for Built Features Resulting from the Extraction of Longwall 706

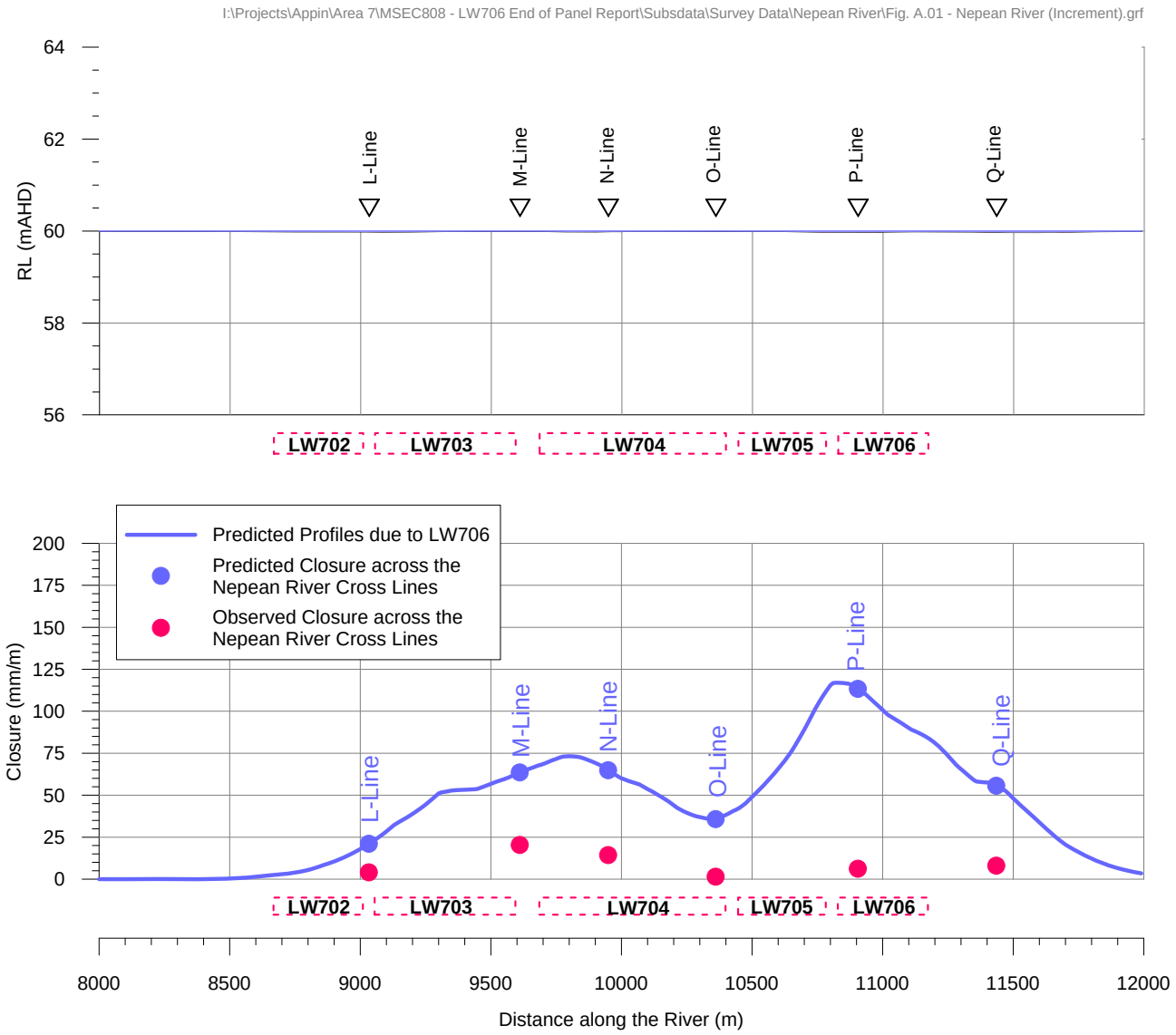
Built Feature	MSEC Assessed Impacts	Observed Impacts
Moreton Park Road	Minor cracking and localised heaving of the road surface may occur in some locations above the longwalls	No impacts observed during the mining of LW706
Menangle Road	No impacts expected during LW706	Cracking observed to pavement on steep slope on Menangle Road at a site located more than 400 m from closest edge of LW706. Cracks are not considered to be due to mine subsidence due to offset distance and available monitoring data.
M31 Hume Motorway	No impacts on the safety or serviceability of the motorway after the implementation of the management strategies	No adverse impacts to safety or serviceability. Humps formed on both carriageways and these were remediated by re-shaping of the pavement surface as part of Management Plan responses.
Main Southern Railway	No impacts on the safety or serviceability of the railway after the implementation of the management strategies	Changes in track geometry recorded and remediated in accordance with the Management Plan. No adverse impacts to safety and serviceability.
Douglas Park Twin Bridges	Impacts unlikely after the implementation of the TARP	No adverse impacts observed

Built Feature	MSEC Assessed Impacts	Observed Impacts
Moreton Park Road Bridge (South)	Impacts unlikely after the detailed investigation, analysis and implementation of the TARP	No adverse impacts observed
Low voltage powerlines	Impacts unlikely, but minor mitigation measures may be required	No reported impacts
Copper telecommunications cables	Impacts unlikely	Small levels of signal loss measured
Optical fibre cables	Impacts unlikely with the implementation of the management strategies including OTDR monitoring and mitigation	Small levels of signal loss measured
Building structures	Category A Tilt Impacts. Typically Category 0 Strain Impacts, with 11 x Category 1 Strain Impacts, 5 x Category 2 Strain Impacts.	*Houses and Non-Residential Structures* Building structures remained in safe and serviceable condition during mining. To date, no new claims to the MSB for impacts to building structures due to the mining of Longwall 706.
Pools	Inground pools could be more susceptible to ground strains	No reported impacts
Water tanks	Impacts unlikely	No reported impacts
Farm dams	Potential for minor cracking or leakage	No reported impacts
Heritage structures	No heritage sites located near LW706	No reported impacts
Groundwater bores	Potential for blockage or reduction in the capacity of the groundwater bores	Refer to Groundwater Report (by Geoterra)
Pumps in the Nepean River	Impacts unlikely	No reported impacts
The Upper Canal, Cataract Tunnel and associated infrastructure	Impacts unlikely	No reported impacts
Survey control marks	Small fair-field horizontal movements which could require re-establishment	Small far-field horizontal movements

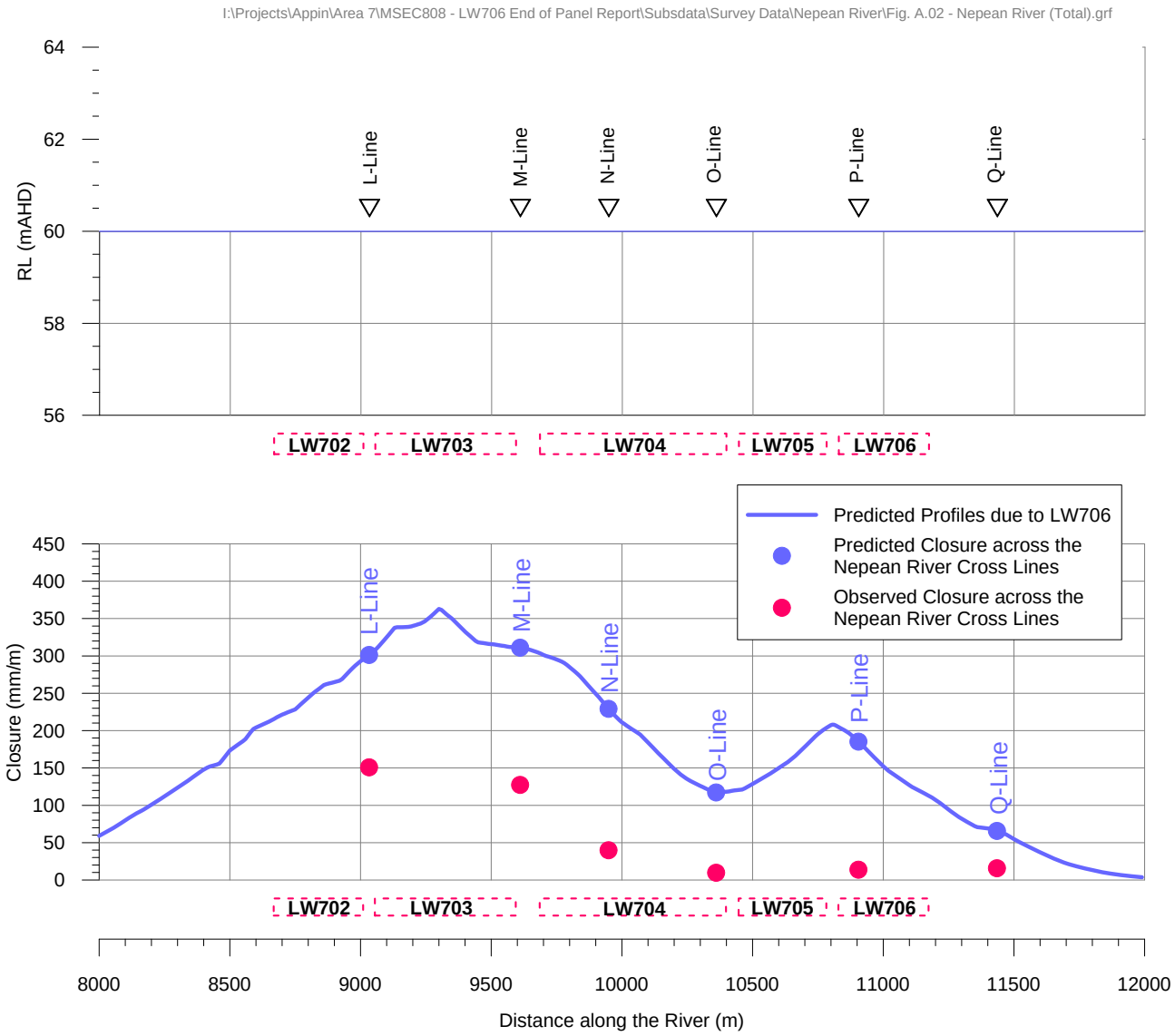
It can be seen from Table 3.2, that the observed impacts on the built features, resulting from the extraction of Longwall 706, were generally similar to or less than the assessed (i.e. predicted) impacts.

APPENDIX A. FIGURES

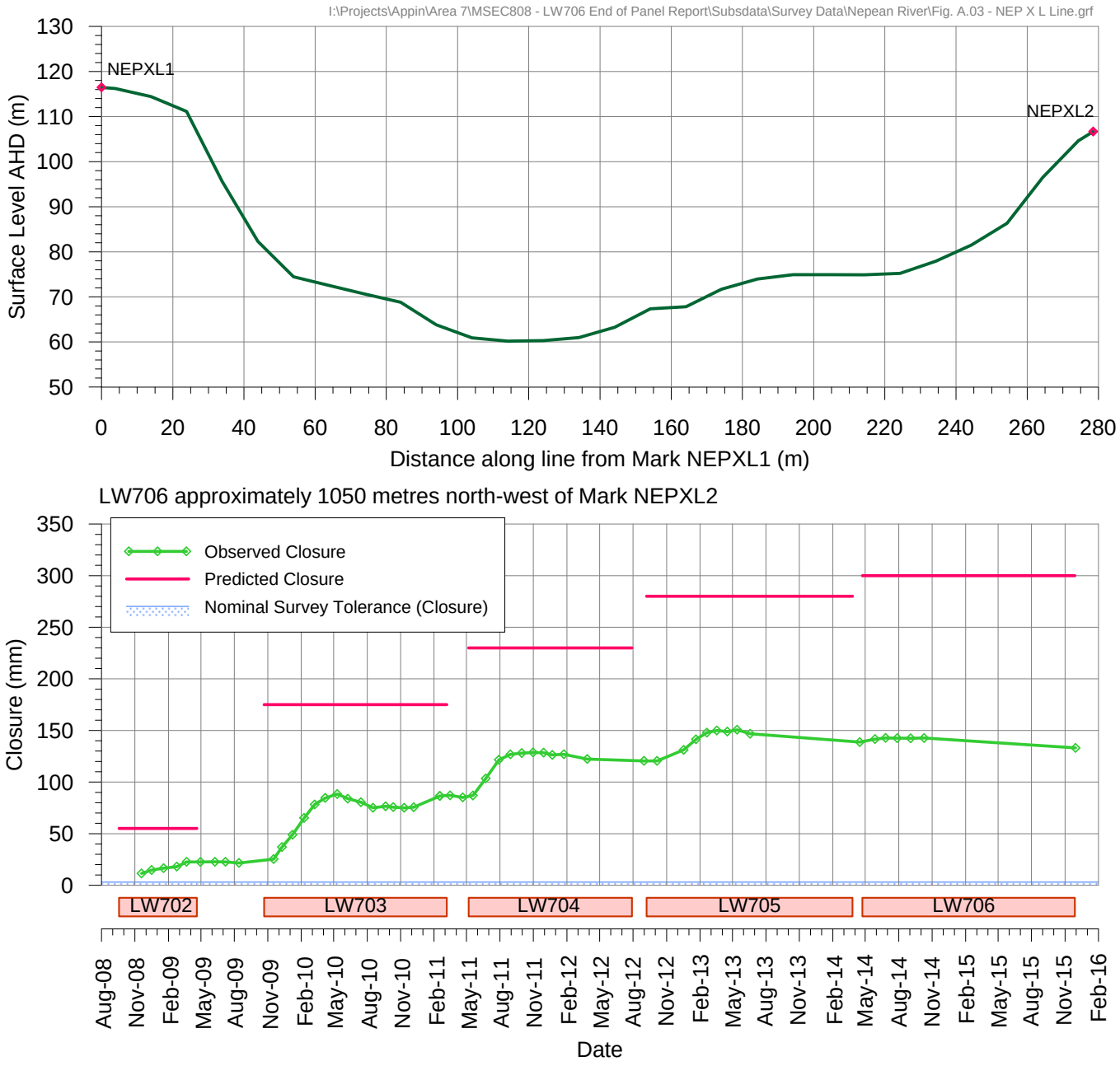
Appin Colliery - Longwall 706
Predicted and Observed Incremental Closure along the Centreline of the Nepean River



Appin Colliery - Longwall 706
Predicted and Observed Total Closure along the Centreline of the Nepean River



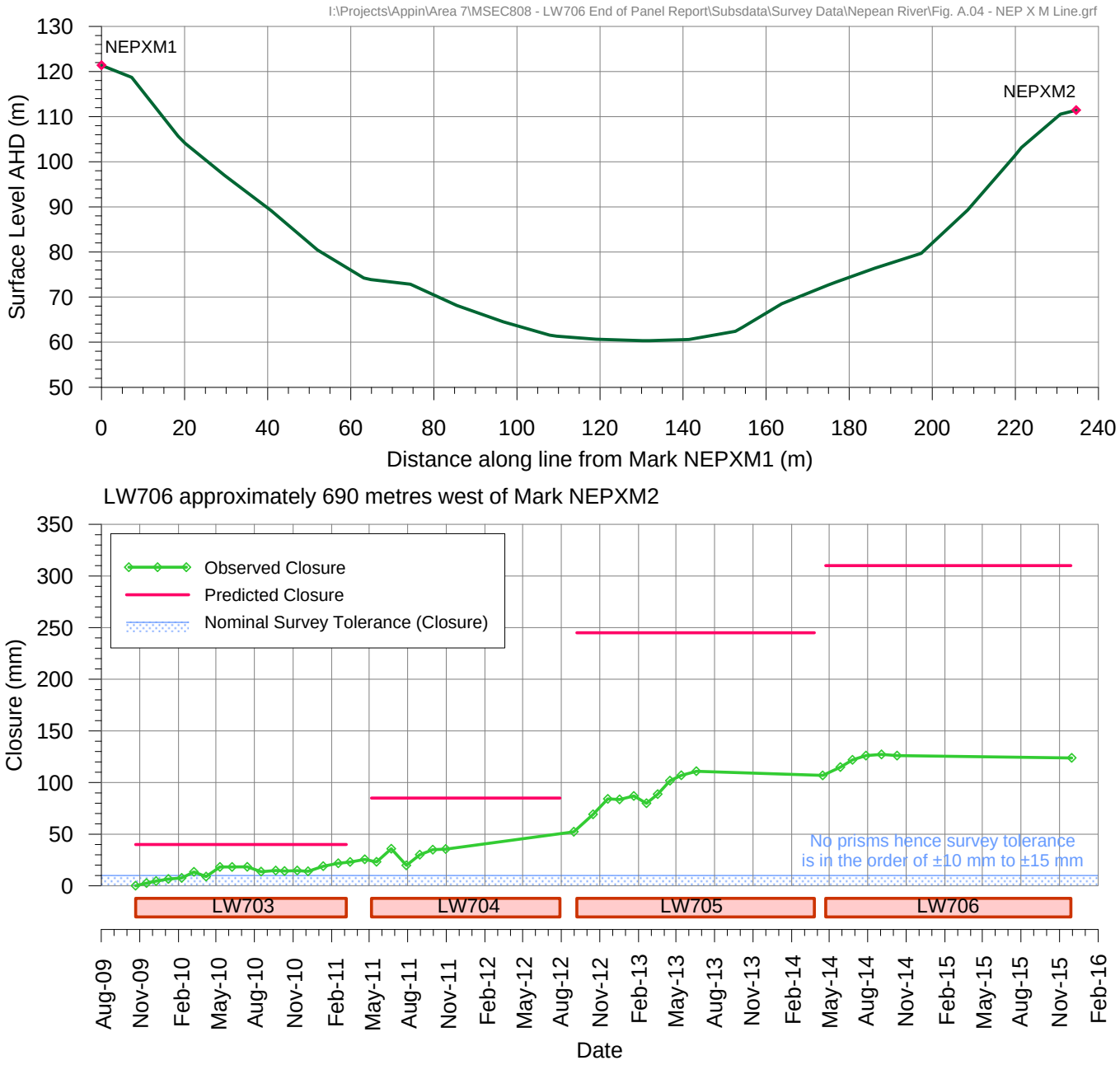
Appin Colliery - Longwall 706
Nepean River L-Line Total Closure Profiles



msec

Fig. A.03

Appin Colliery - Longwall 706
Nepean River M-Line Total Closure Profiles



msec

Fig. A.04

Appin Colliery - Longwall 706
Nepean River N-Line Total Closure Profiles

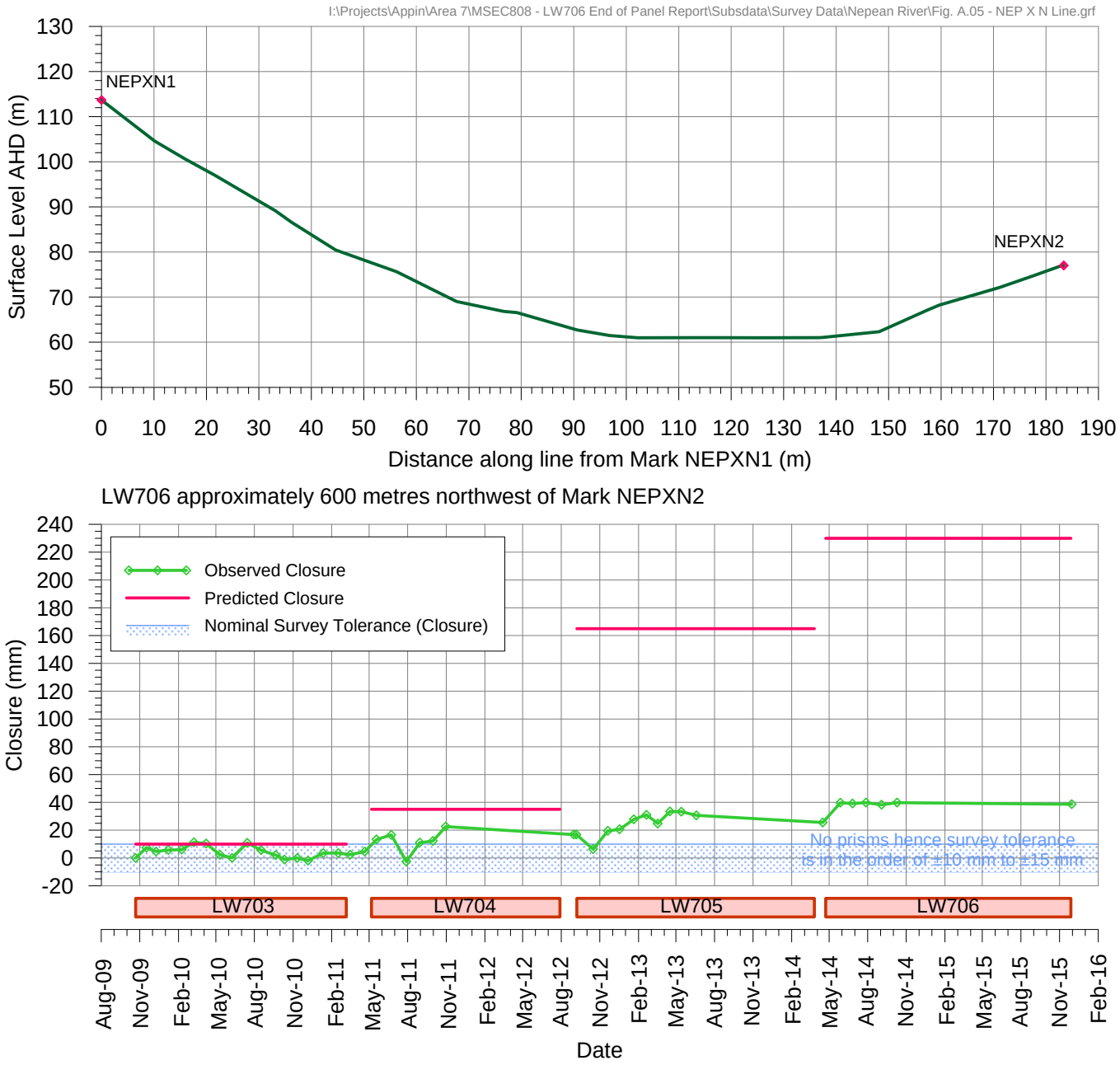


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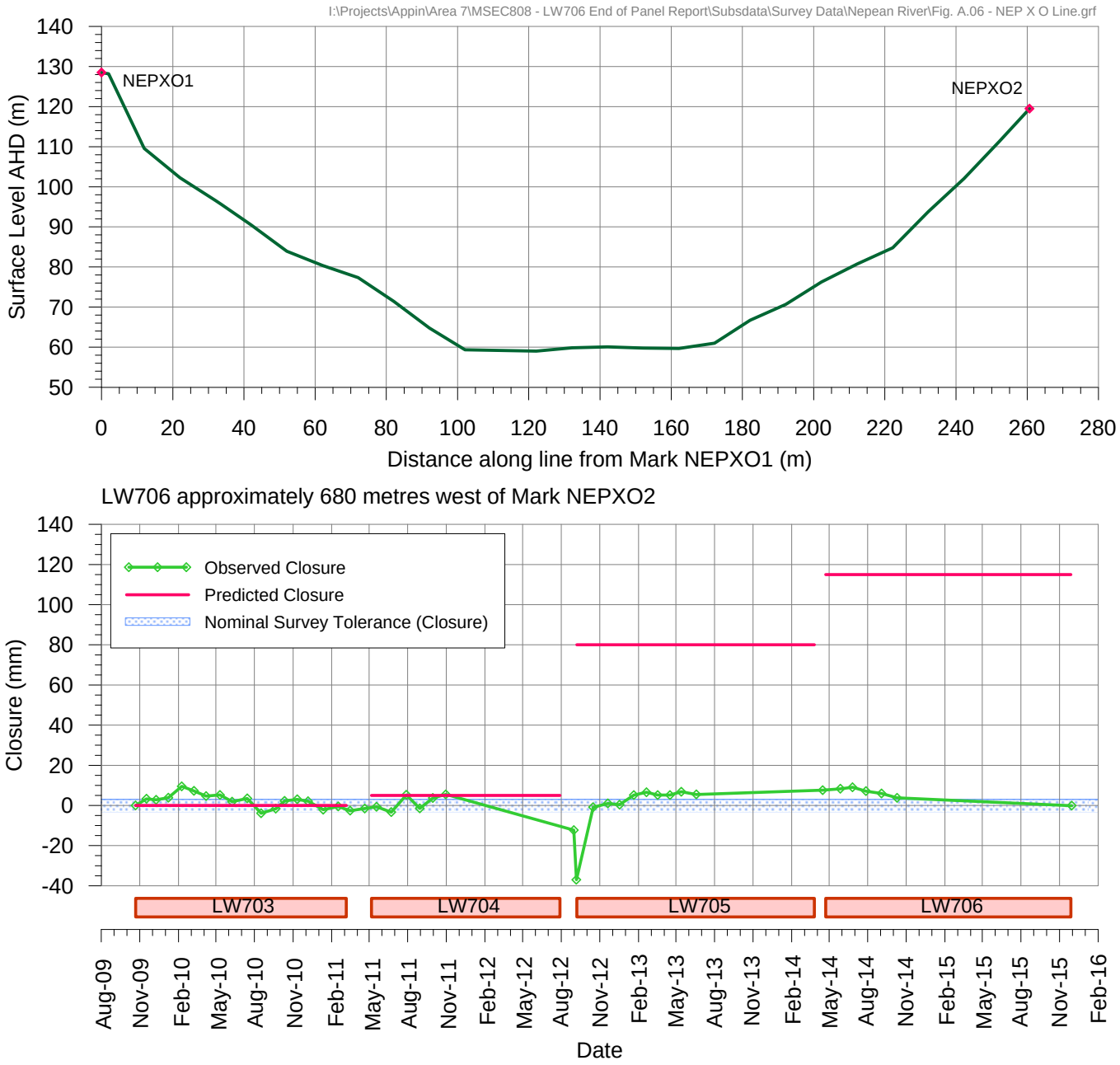
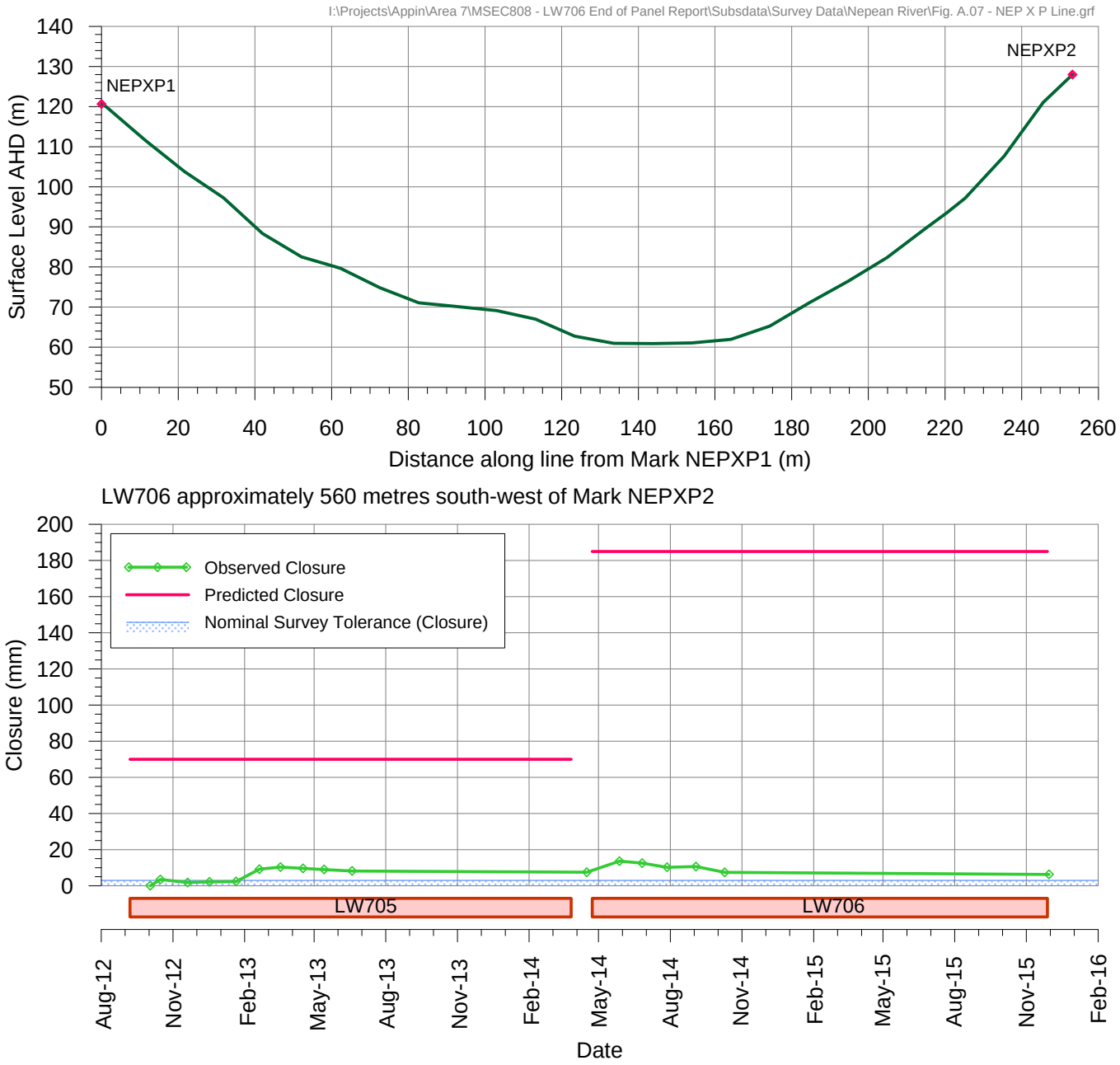
Fig. A.05

Appin Colliery - Longwall 706
Nepean River O-Line Total Closure Profiles

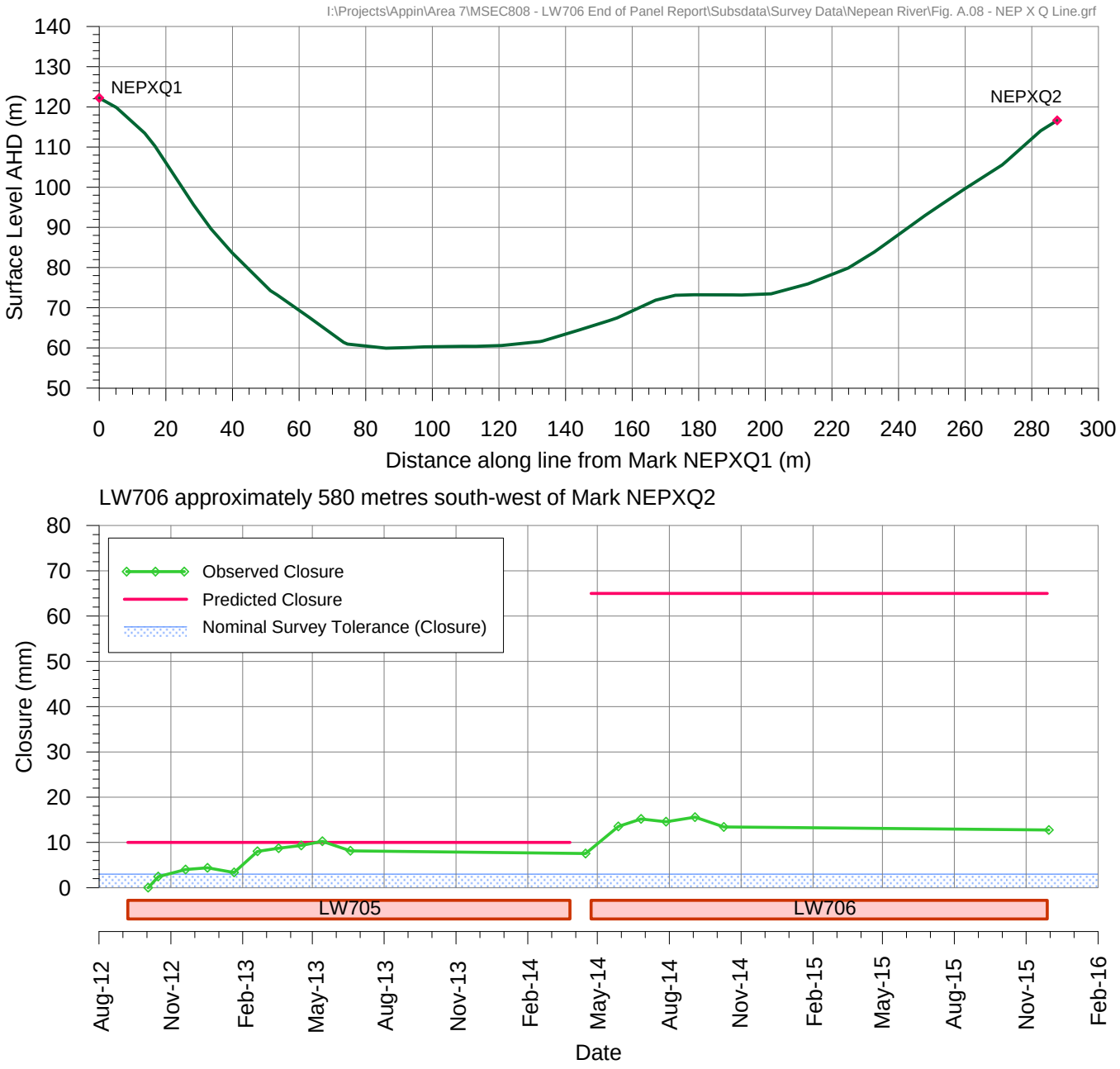


Appin Colliery - Longwall 706
Nepean River P-Line Total Closure Profiles



LW706 approximately 560 metres south-west of Mark NEPXP2

Appin Colliery - Longwall 706
Nepean River Q-Line Total Closure Profiles



LW706 approximately 580 metres south-west of Mark NEPXQ2

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along Moreton Park Road during Appin Longwall 706

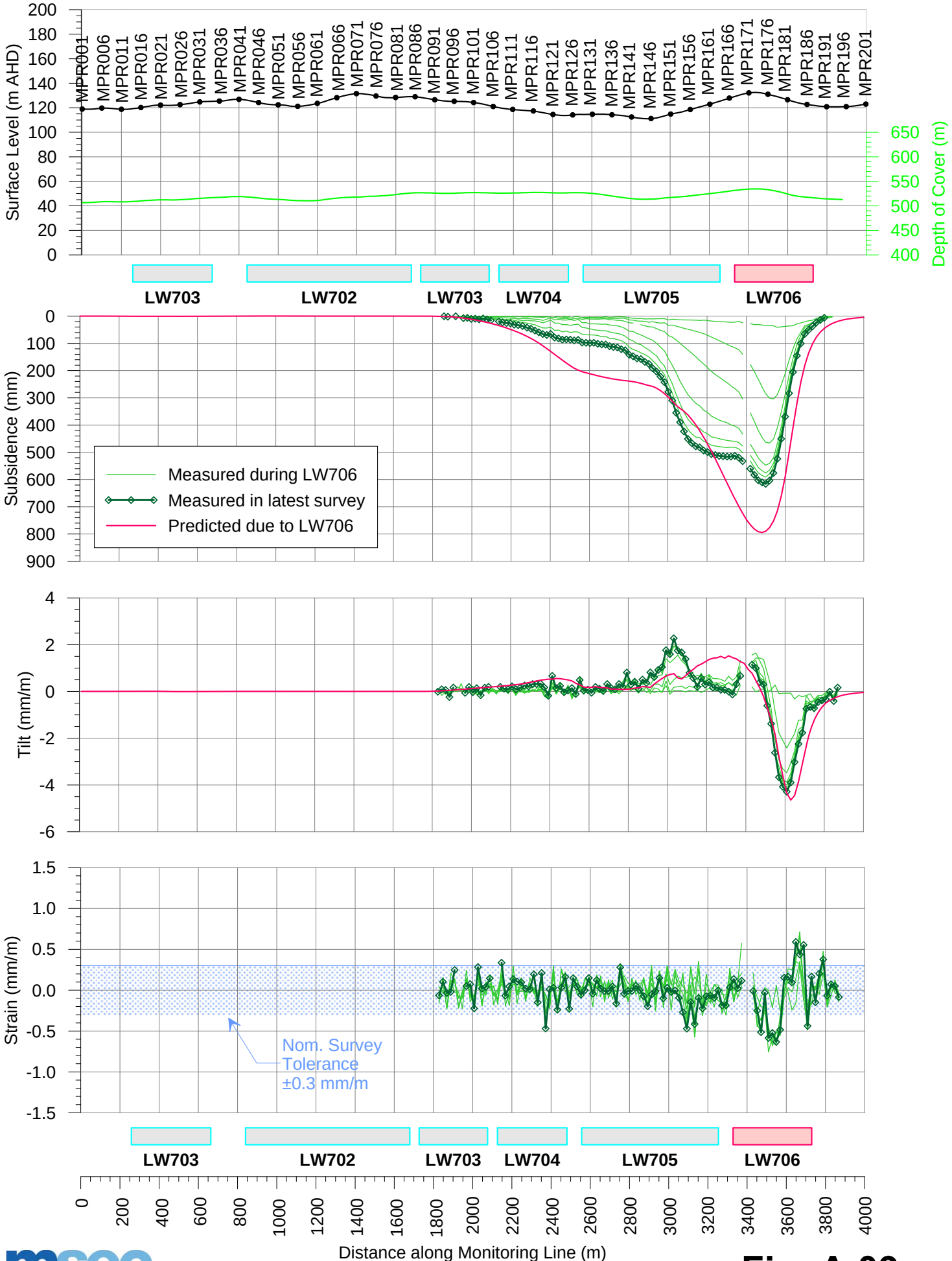


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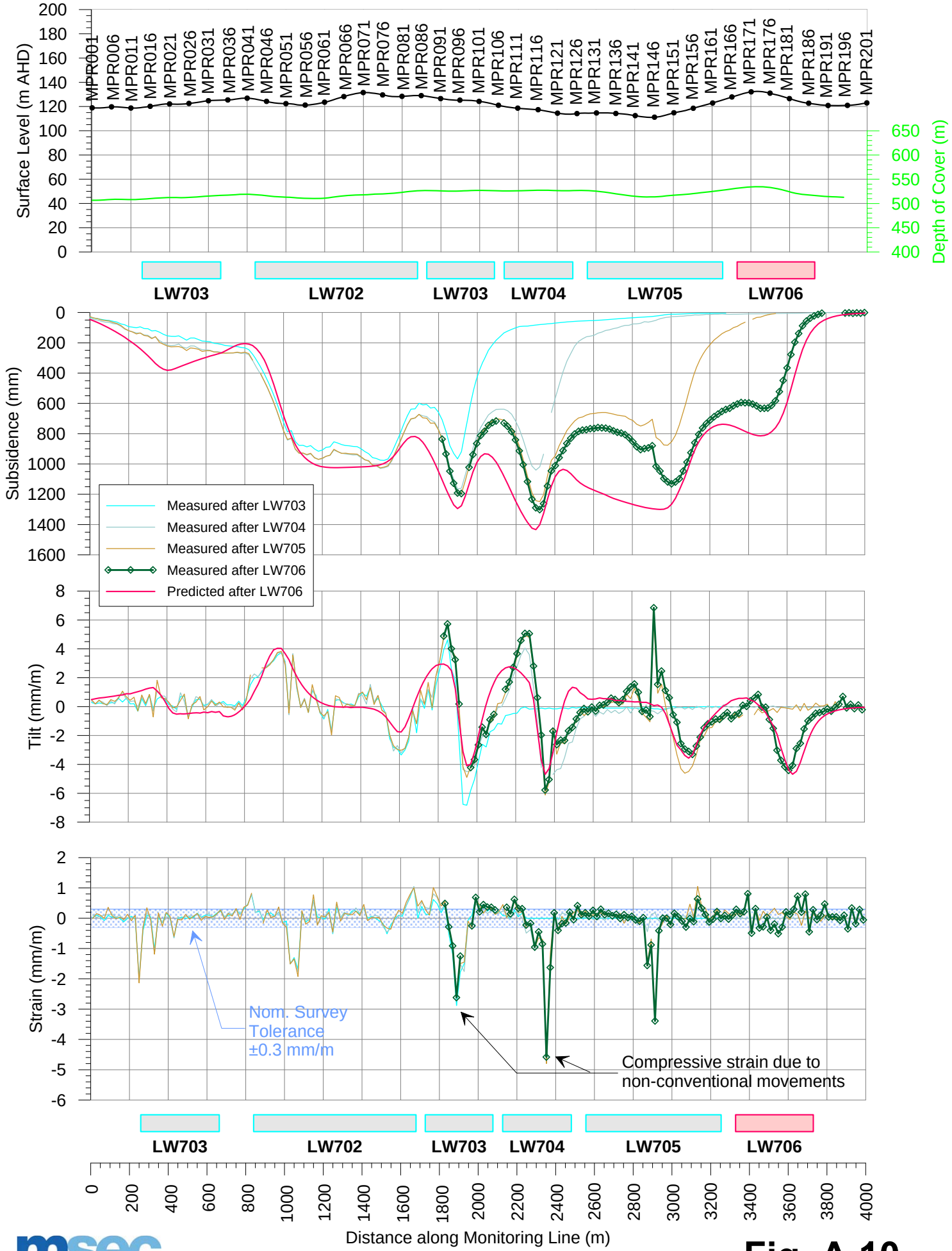
Fig. A.09

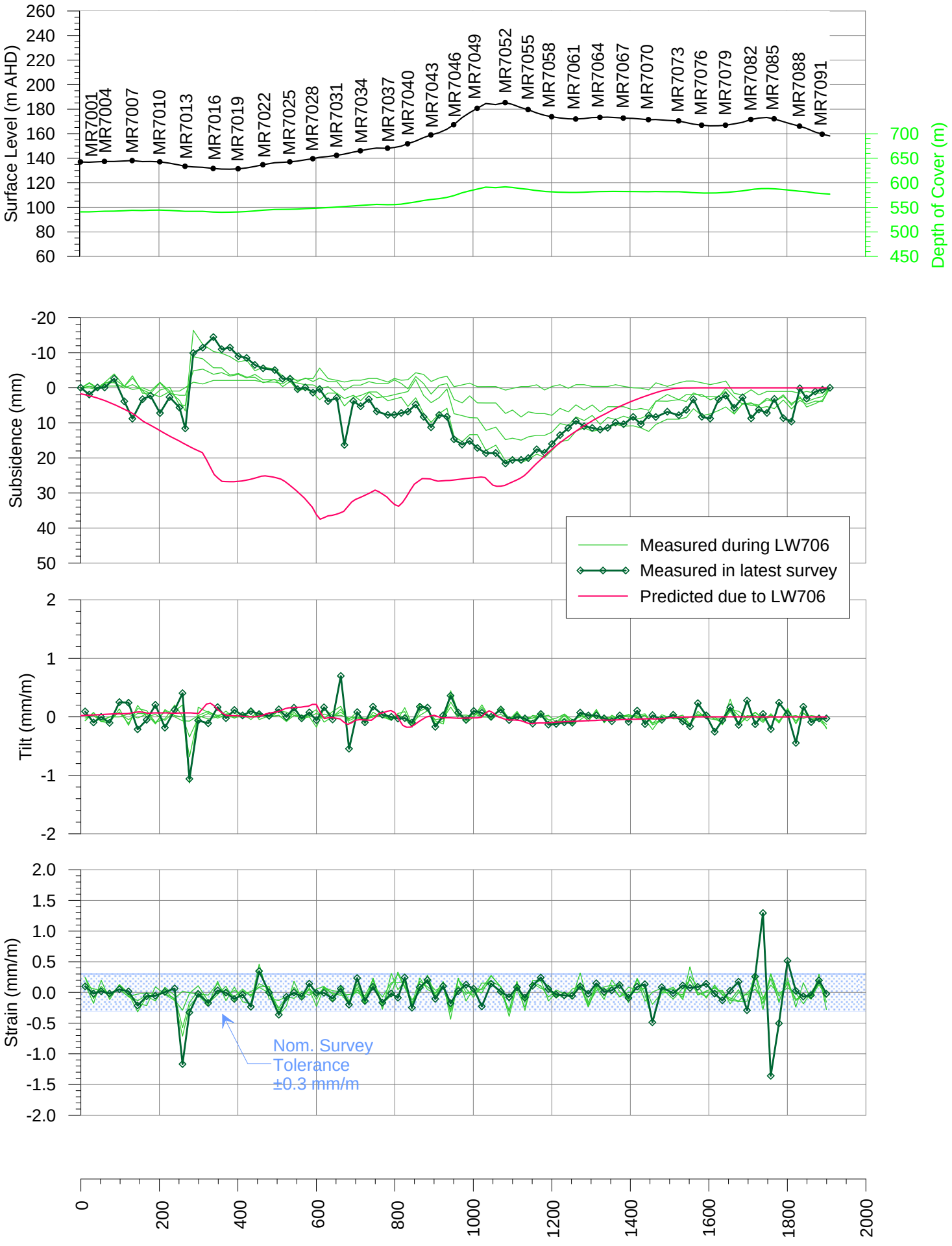
Observed and Predicted Profiles of Total Subsidence, Tilt and Strain along Moreton Park Road during Appin Longwall 706



msec

Fig. A.10

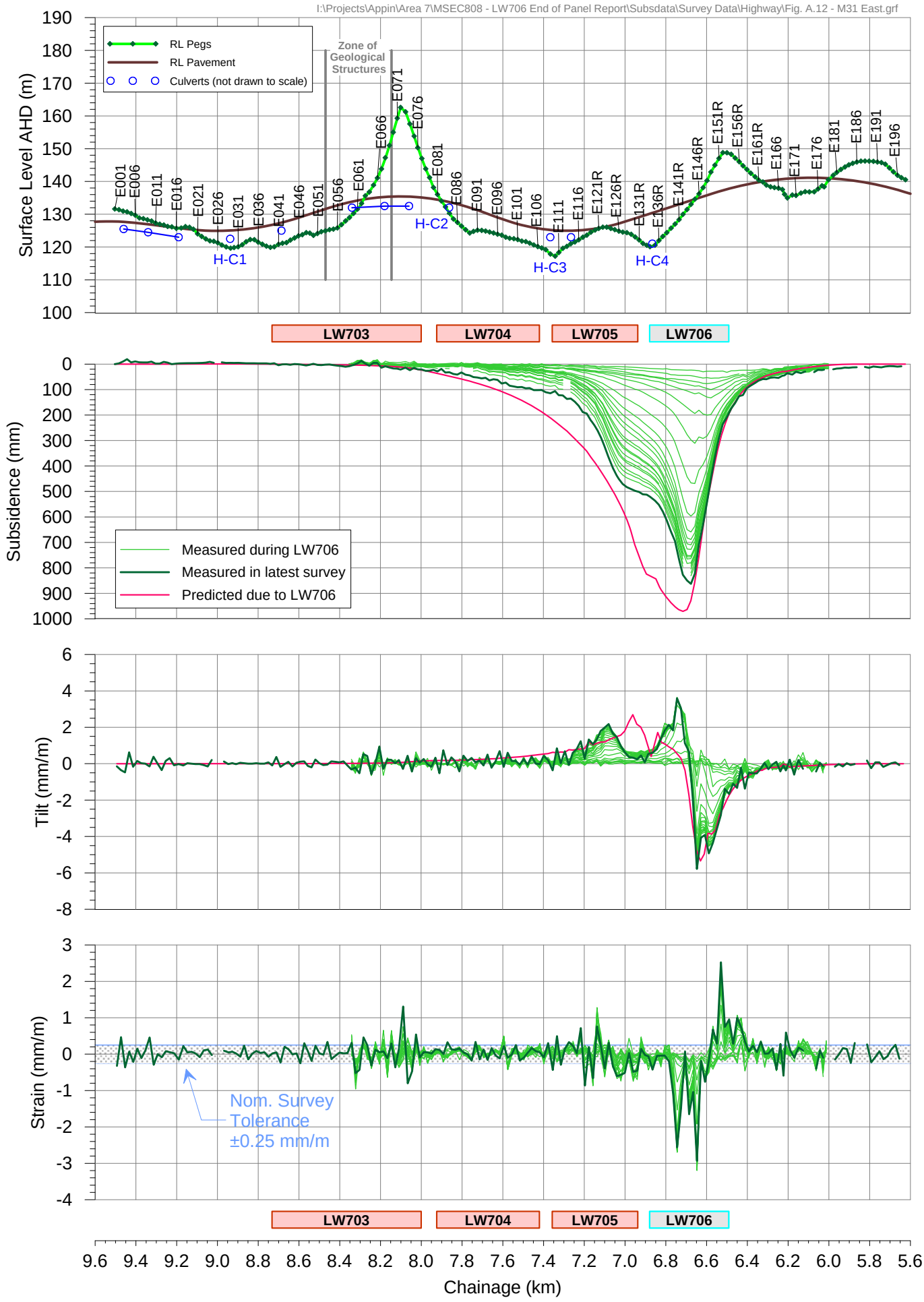
Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along Menangle Road during Appin Longwall 706



msec

Fig. A.11

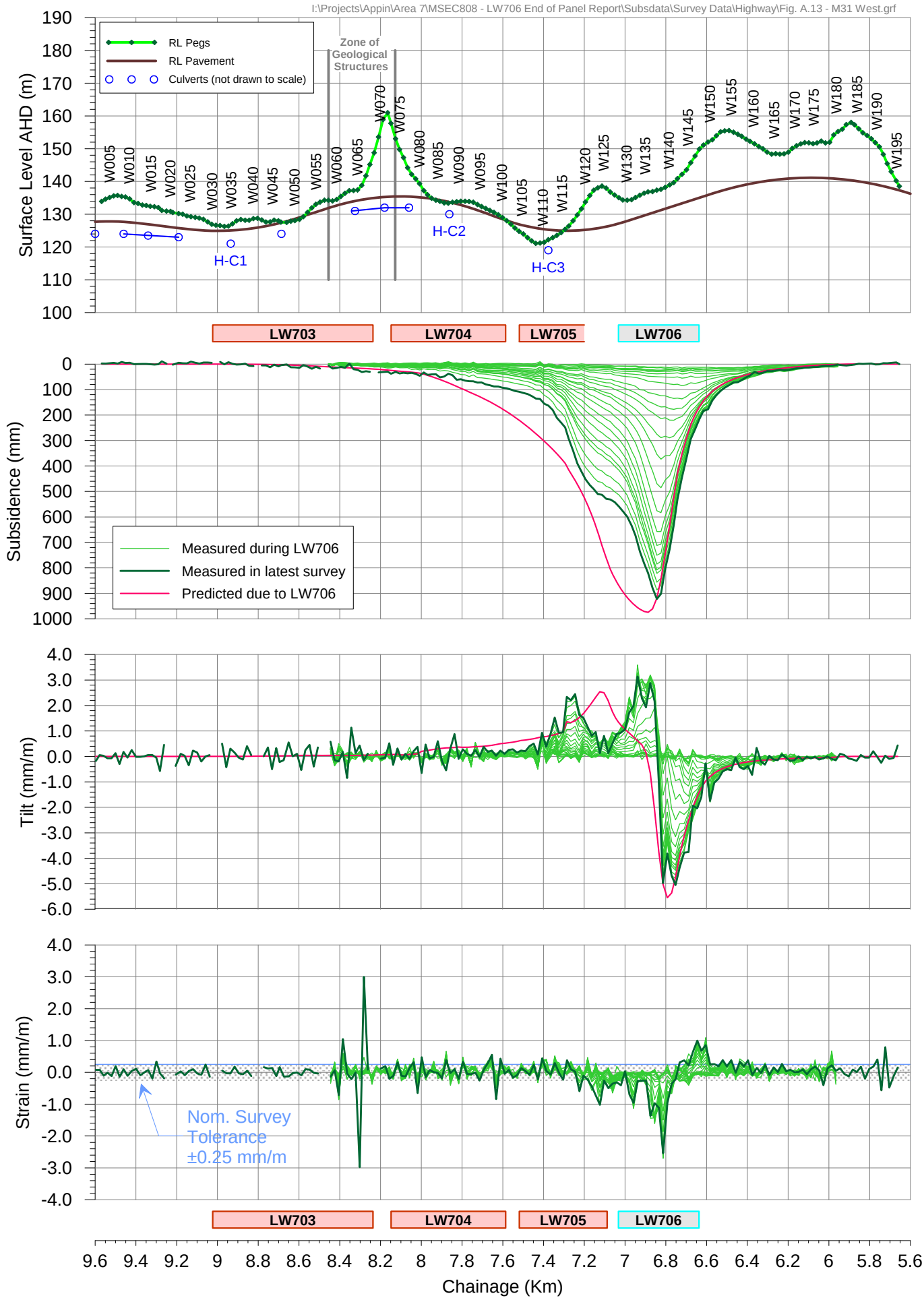
Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the M31 East Line during Appin Longwall 706



msec

Fig. A.12

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the M31 West Line during Appin Longwall 706



msec

Fig. A.13

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the ARTC Line during Appin Longwall 706

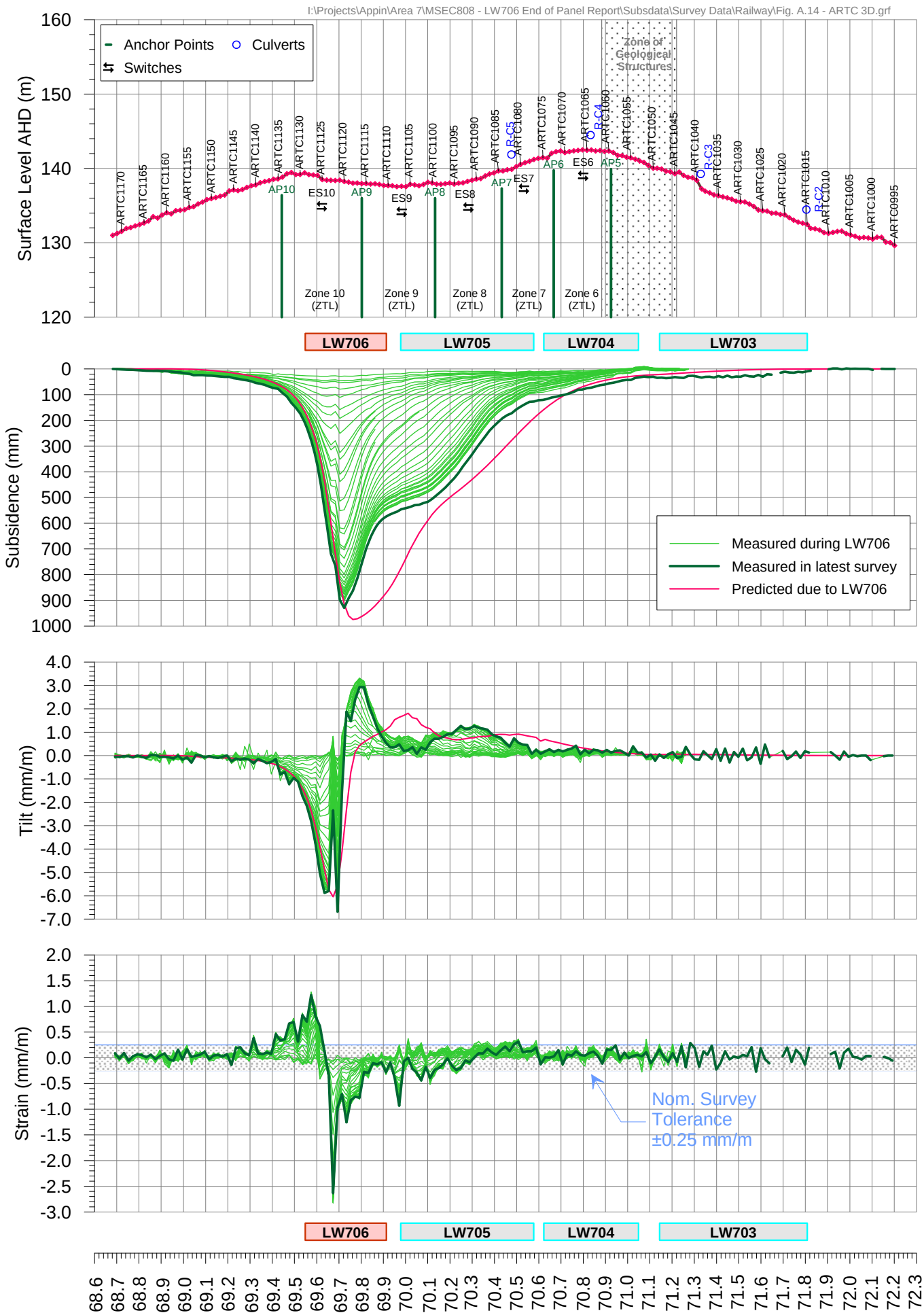


Fig. A.14

Observed Profiles of Incremental Subsidence, Tilt and Strain along Up Base of Embankment during Appin LW706

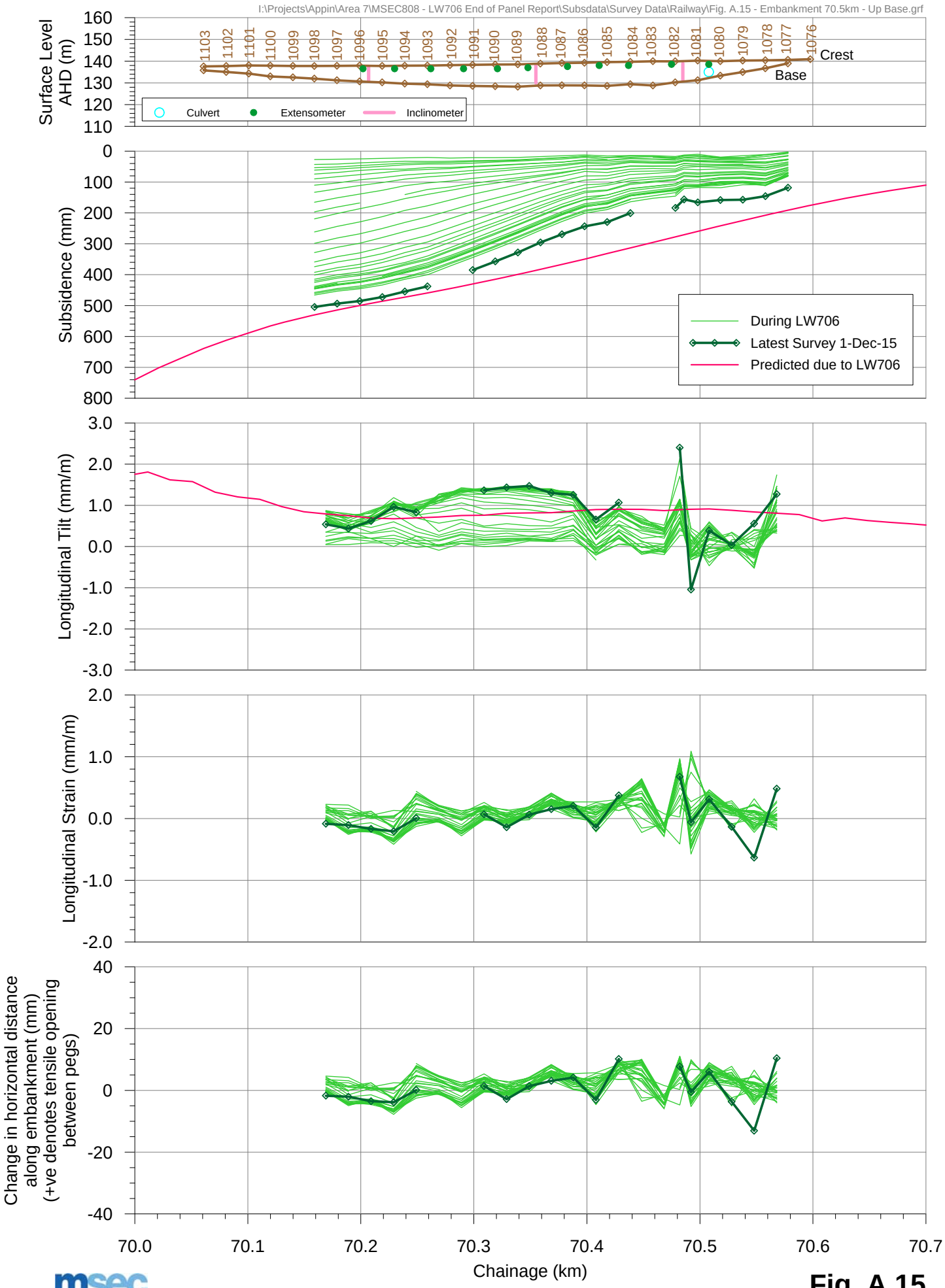


Fig. A.15

Observed Profiles of Incremental Subsidence, Tilt and Strain along Up Crest of Embankment during Appin LW706

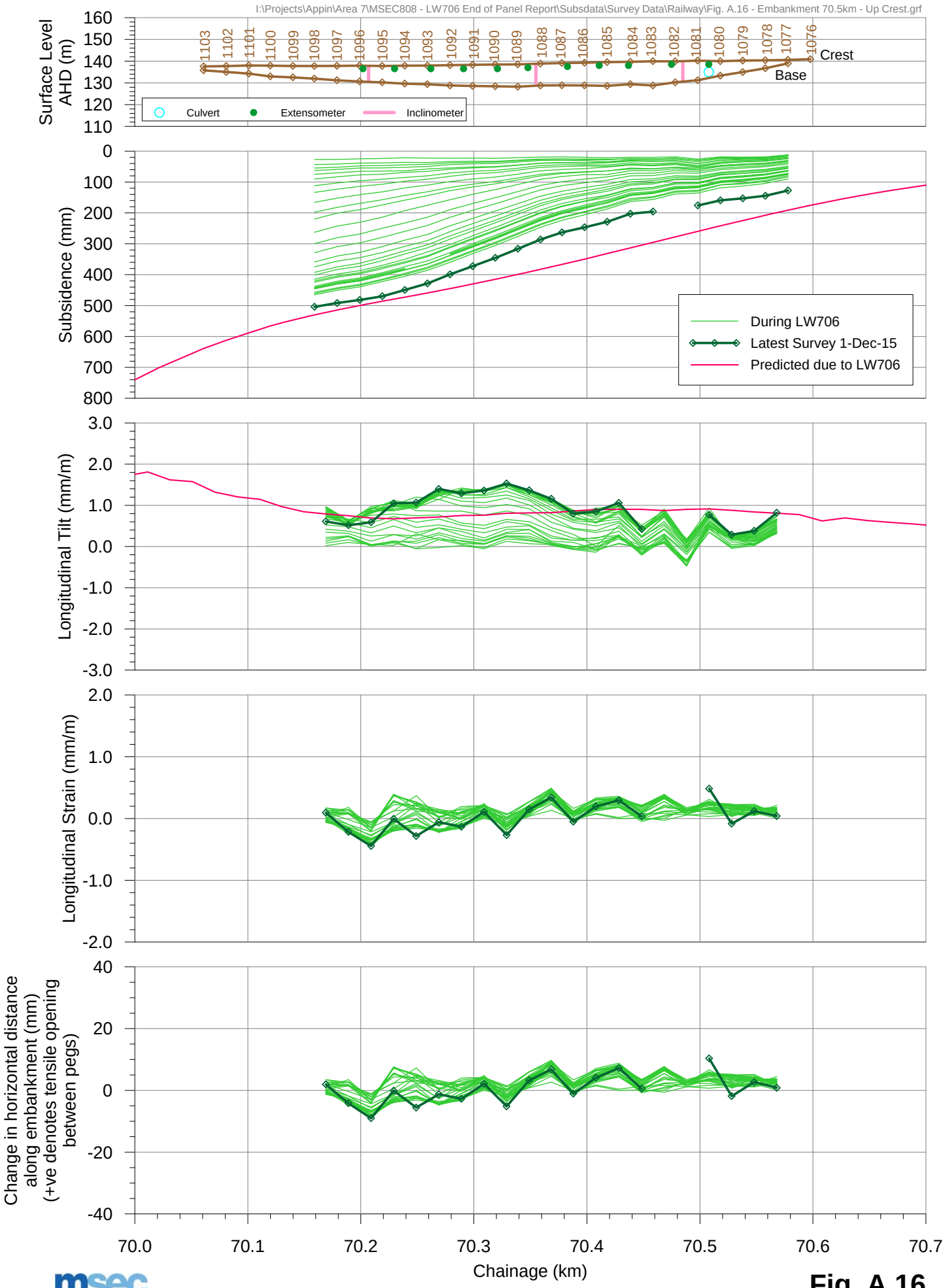


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Fig. A.16

Observed Profiles of Incremental Subsidence, Tilt and Strain along Down Crest of Embankment during Appin LW706

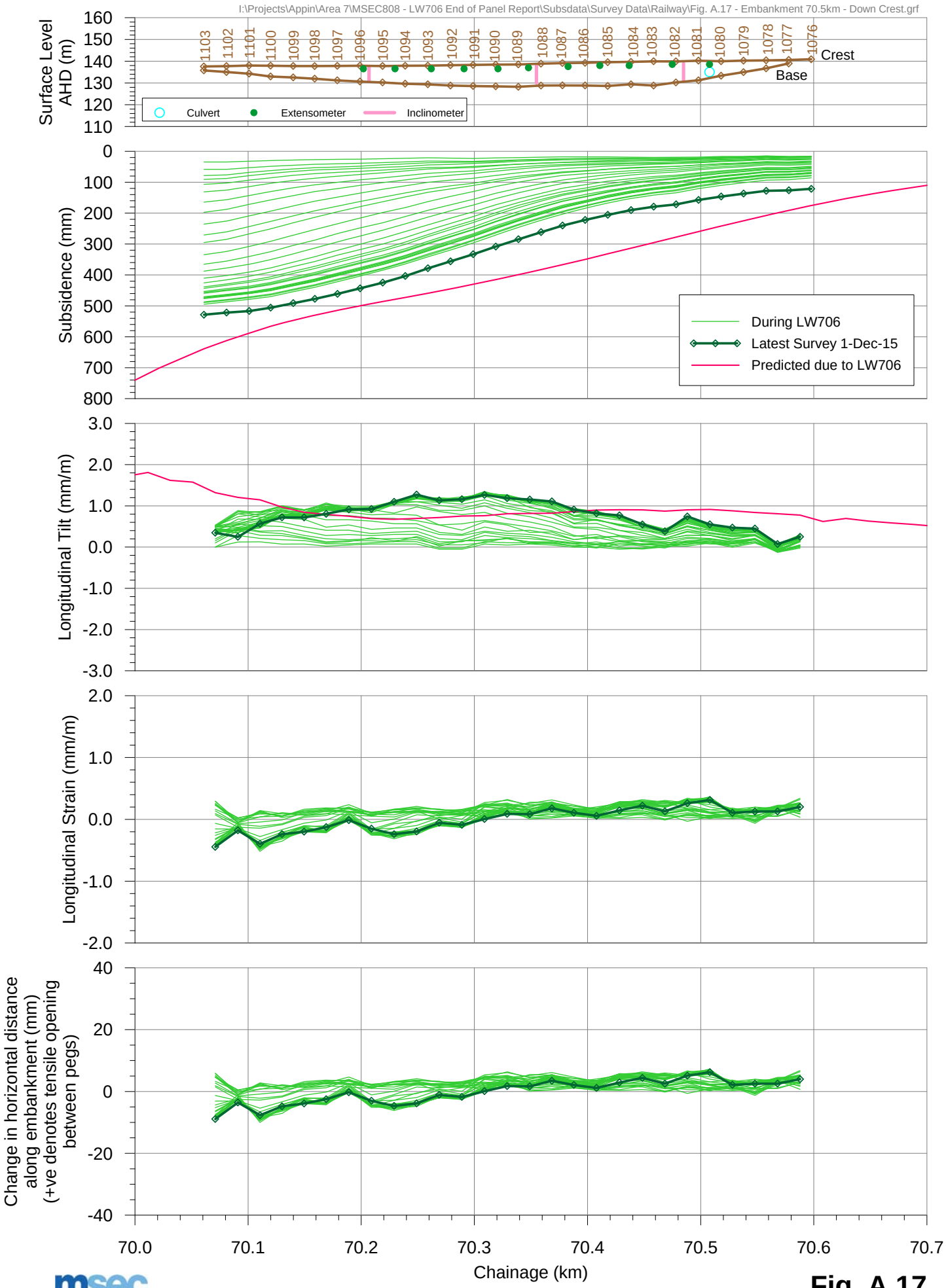

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Fig. A.17

Observed Profiles of Incremental Subsidence, Tilt and Strain along Down Base of Embankment during Appin LW706

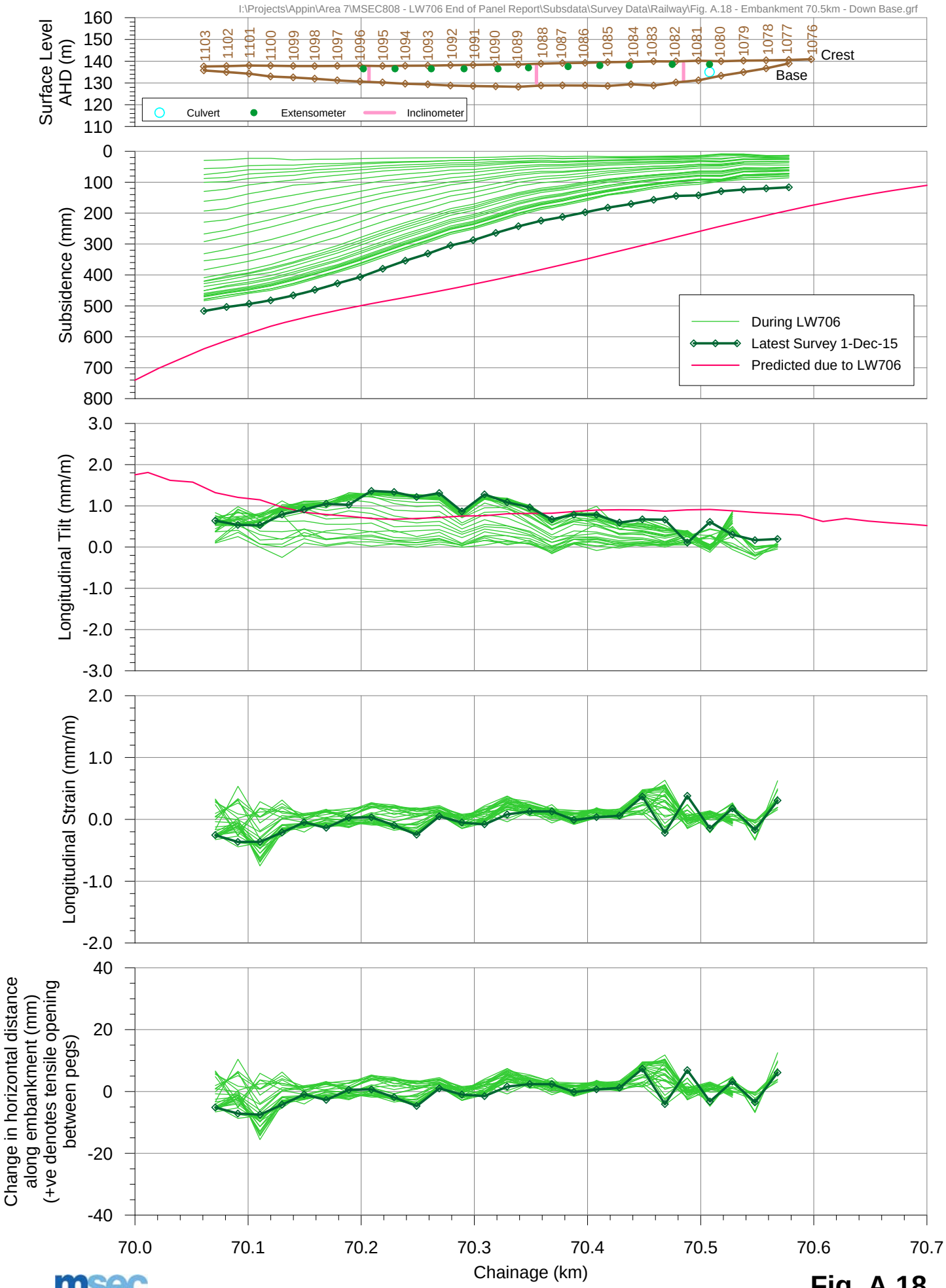

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Fig. A.18

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the Telstra Line during Appin Longwall 706

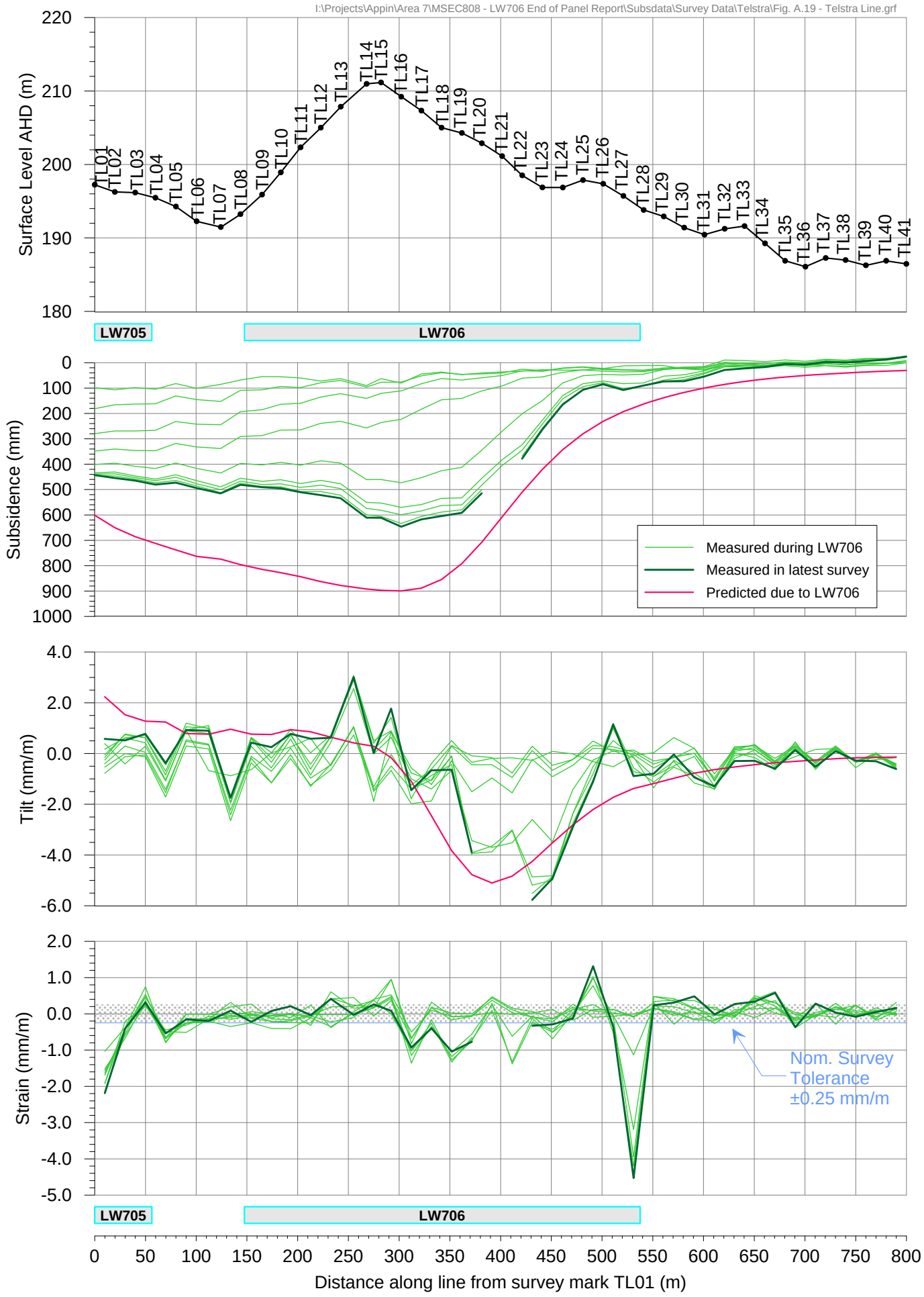

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Fig. A.19

APPENDIX B. DRAWINGS

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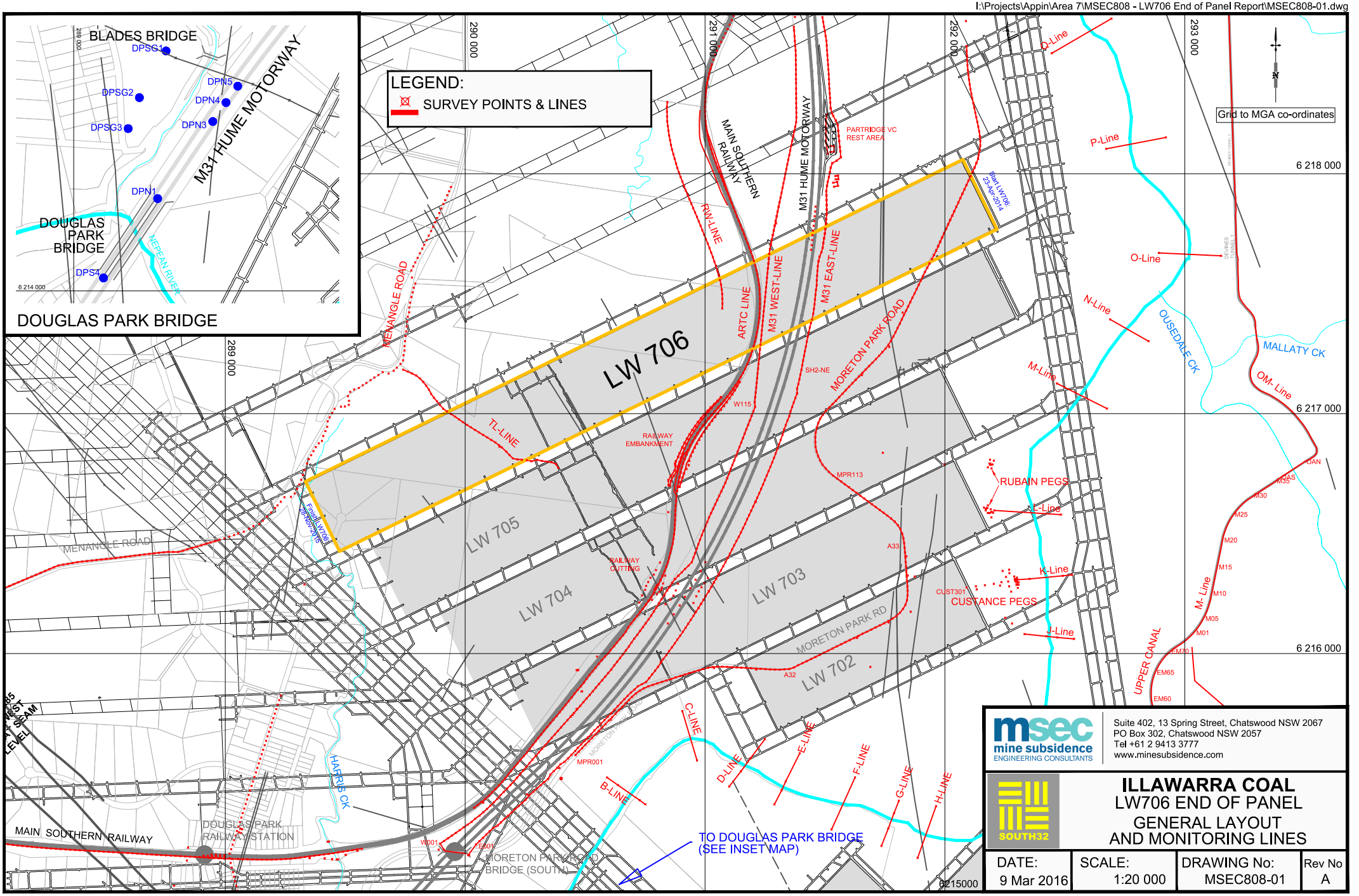

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SOUTH32

ILLAWARRA COAL
LW706 END OF PANEL
GENERAL LAYOUT AND MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
9 Mar 2016	1:20 000	MSEC808-01	A

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NATURAL FEATURES

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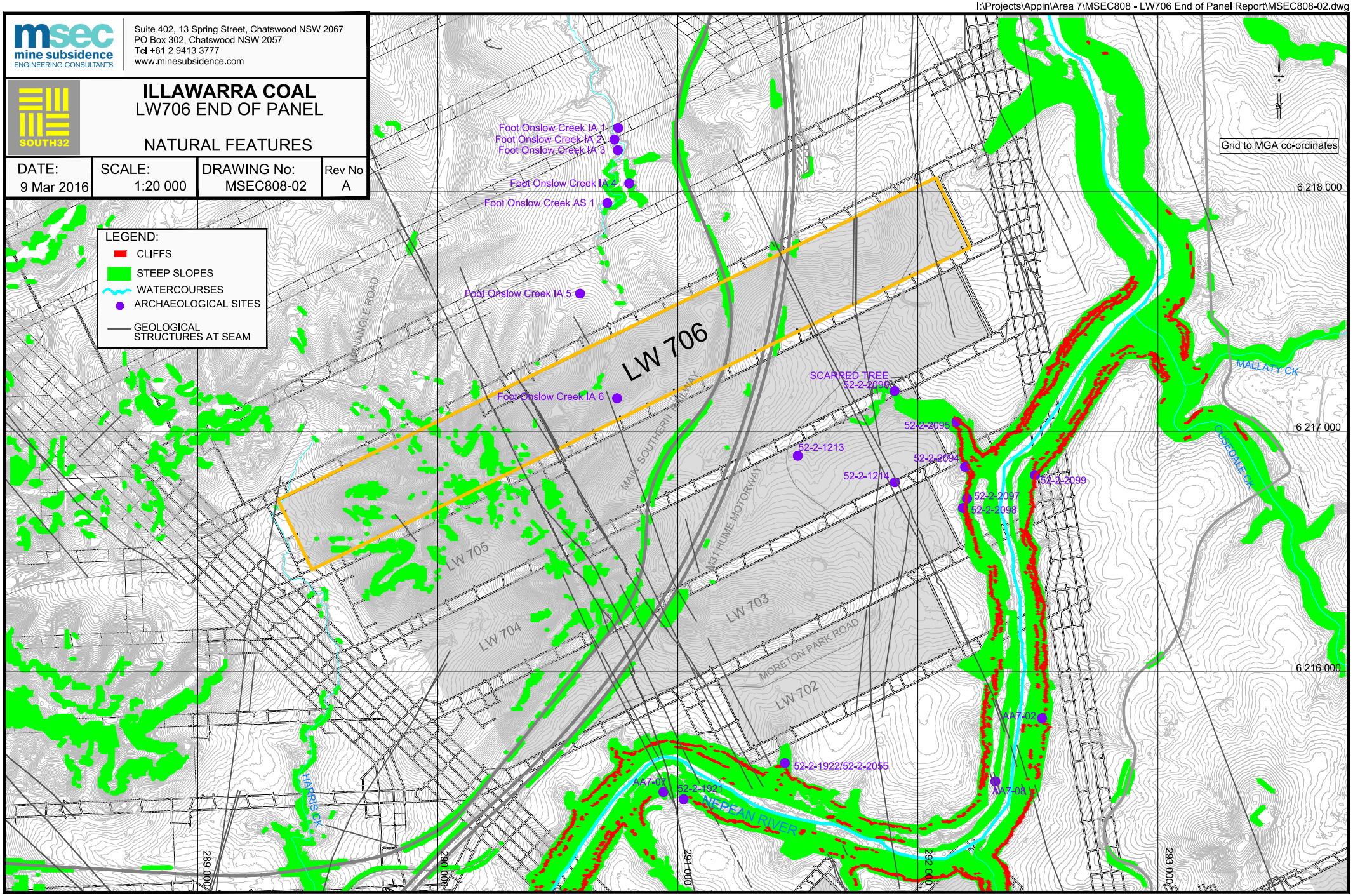
9 Mar 2016	1:20 000	MSEC808-02	A



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LW706 END OF PANEL
SURFACE INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
9 Mar 2016	1:20 000	MSEC808-03	A