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West Cliff Colliery - Longwall 38

End of Panel Subsidence Monitoring Report for West Cliff Longwall 38

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	JB / BM	-	30th Mar 16
A	Final Issue	JB	BM	5th May 16

Report produced to:- Support the End of Panel Report for Longwall 38 in accordance with the conditions attached to the Extraction Plan Approval.

Associated reports:- MSEC404 (Revision D – August 2009) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Bulli Seam Operations in Support of the Part 3A Application.

MSEC533 (Revision B – June 2013) – West Cliff Collieries – Longwalls 37 and 38 Subsidence Predictions and Impact Assessments for the Natural Features and Surface Infrastructure in Support of the Extraction Plan.

MSEC718 (Revision A – August 2014) – The Effects of the Proposed Modified Commencing End of Longwall 38 on Previous Subsidence Predictions and Impact Assessments.

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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1.1. Introduction

Illawarra Coal (IC) has completed the extraction of Longwall 38 at West Cliff Colliery. The locations of the longwalls in Area 5 at the colliery are shown in Drawing No. MSEC807-01, in Appendix B. Longwall 38 is located on the eastern side of the Georges River, whereas the previously extracted Longwalls 29 to 37 are located on the western side of the river. The extraction of Longwall 38 commenced on the 3rd February 2015 and was completed on the 1st February 2016.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by Illawarra Coal (IC) to prepare subsidence predictions and impact assessments for the proposed Longwalls 37 and 38 at West Cliff Colliery. These two longwalls were included as part of the Bulli Seam Operations Project. Report No. MSEC404 (Revision D) was issued in August 2009 in support of the Bulli Seam Operations Part 3A Application, which was approved by the Department of Planning and Infrastructure on 22nd December 2011.

Report No. MSEC533 (Revision B) was issued in June 2012, which supported the Extraction Plan Application for Longwalls 37 and 38. The Department of Planning and Environment (DoPE) and Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) granted IC approval for extraction of Longwalls 37 and 38 on the 24th and 28th March 2014, respectively.

IC then shorten the commencing (i.e. northern) end of Longwall 38 by 59 metres. Report No. MSEC718 (Rev. A) was issued in August 2014 in support of the Variation to the Approved Extraction Plan. The DoPE and DTIRIS granted IC approval for this variation on the 16th and 14th October 2014, respectively.

This report provides the following information for the completion of Longwall 38:-

- Comparisons between the observed and predicted subsidence movements (i.e. effects) at the monitoring lines and monitoring points resulting from the extraction of Longwall 38; and
- Comparisons between the observed and assessed (i.e. predicted) impacts on the natural and built features resulting from the extraction of Longwall 38.

Further details on the observed and the assessed impacts for the natural features, resulting from the extraction of Longwall 38, are provided in reports by other consultants. The discussions provided in this report should be read in conjunction with those provided in 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 38. This chapter also provides comparisons between the observed and predicted movements resulting from the extraction of this longwall.

Chapter 3 of this report describes the natural and built features in the vicinity of Longwall 38. This chapter also provides comparisons between the observed and assessed impacts for the surface features resulting from the extraction of this longwall. Further details on the observed and assessed impacts for natural features are provided in reports by other consultants.

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

1.2. Mining Geometry

The overall approved void width of Longwall 38 (including the first workings) was 306 metres. The longwall is located on the eastern side of the Georges River, away from the previously extracted Longwalls 29 to 37 and, therefore, does not have a chain pillar. The overall length of the longwall (including the installation heading) was 2,514 metres.

The depth of cover to the Bulli Seam varies between 470 metres and 500 metres directly above Longwall 38. The seam thickness within the goaf area of this longwall varies between 2.45 metres and 2.65 metres. IC extracted the full seam thickness for Longwall 38.

The geological structures which have been mapped at seam level are shown in Drawing No. MSEC807-01, in Appendix B. O'Hares Fault is located to the north of the commencing end of Longwall 38. The results of the surface seismic surveys indicate that the throw of this normal fault varies between around 15 metres and 76 metres, with the up throw (i.e. footwall) block on the southern side and the down throw (i.e. hanging wall) block on the northern side of this structure. The fault was encountered in the main headings for West Cliff Longwalls 20 to 24, further to the east, and it is projected that the dip of the fault is around 75 degrees to 80 degrees, which is typical for normal faults.

2.1. Introduction

The mine subsidence movements resulting from the extraction of West Cliff Longwall 38 were measured along a number of monitoring lines and points including the following:-

- The Georges River cross lines;
- Exley Road monitoring line;
- Blackburn Road monitoring line;
- Wedderburn Airfield Line; and
- Harland's Dam monitoring points.

The locations of these monitoring lines and points are shown in Drawing No. MSEC807-01, 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. The Georges River Cross Lines

The mine subsidence movements across the Georges River valley were measured by IC at 11 monitoring lines, being the G-Line to the P-Line and the R-Line. The Q line was not installed as it was not possible to access the proposed location of the monitoring site.

The locations of the Georges River cross lines are shown in Drawing No. MSEC807-01, in Appendix B. A summary of the survey dates for these monitoring lines, during the extraction of Longwall 38, is provided in Table 2.1.

Table 2.1 Summary of Survey Dates for the Georges River Cross Lines during Longwall 38

Extraction Plan Commitments	Date	Monitoring Line						Proposed Future Monitoring
		G & H	I, J & K	L	M	N, O & P	R	
Initial survey of cross lines G to R at start of LW38. Survey L to R Lines monthly for first 1500m. Survey G to L Lines monthly after 1500m. Final survey after the completion of LW38.	23-Feb-15			Initial	Initial	Initial	Initial	None as no future mining currently proposed in Area 5 at West Cliff Colliery.
	3-Mar-15			✓	✓	✓	✓	
	31-Mar-15			✓	✓	✓	✓	
	30-Apr-15			✓	✓	✓	✓	
	1-Jun-15			✓	✓	✓	✓	
	30-Jun-15			✓	✓	✓		
	15-Jul-15	Initial	Initial					
	27-Jul-15		✓	✓	✓			
	3-Aug-15		✓	✓	✓			
	10-Aug-15		✓	✓	✓			
	18-Aug-15		✓	✓	✓			
	24-Aug-15		✓	✓	✓			
	31-Aug-15		✓	✓	✓			
	7-Sep-15		✓	✓	✓			
	14-Sep-15		✓	✓	✓			
	21-Sep-15		✓	✓	✓			
	28-Sep-15		✓	✓	✓			
	6-Oct-15		✓	✓	✓			
	12-Oct-15		✓	✓	✓			
	19-Oct-15		✓	✓	✓			
	26-Oct-15		✓	✓	✓			
	2-Nov-15		✓	✓	✓			
	9-Nov-15	✓	✓	✓	✓			
	16-Nov-15	✓	✓	✓				
	23-Nov-15	✓	✓	✓				
	1-Dec-15	✓	✓	✓				
	7-Dec-15	✓	✓					
	12-Jan-16	✓	✓					
	13-Apr-16	✓	✓	✓	✓	✓	✓	

The predicted subsidence, upsidence and closure movements at the Georges River, resulting from the extraction of Longwalls 37 and 38, were provided in Report No. MSEC533. These predictions for the Georges River cross lines are slightly lower than those provided in Report No. MSEC326, because of the setbacks of longwalls on the western side of the Georges River.

The predicted profiles of incremental and total upsidence, net vertical movement and closure along the centreline of the river, after the extraction of Longwall 38, have been reproduced in Figs. A.01 and A.02, respectively, in Appendix A. The predicted and observed movements for each cross line have been indicated as blue and red circles, respectively, in these figures. The observed net vertical movement for each monitoring line has been taken at the survey mark nearest the centreline of the river, so as to match the location of the predicted net vertical movement.

The observed profile of total net vertical movement and the development of the observed total upsidence and closure for each of the Georges River cross lines, during the extraction of Longwall 38, are provided in Figs. A.03 to A.13, in Appendix A.

The actual upsidence and closure movements at the Georges River cross lines could be greater than those measured, as the monitoring lines do not extend to the tops of the valley sides. It can be seen from the figures, however, that the net vertical movements and compressive strains are generally concentrated near the valley base and, therefore, it is likely that the majority of these movements have been recorded.

A summary of the predicted and observed incremental and total upsidence and closure movements for each of the Georges River cross lines, after the completion of Longwall 38, is provided in Table 2.2. The incremental upsidence and closure are the additional movements due to Longwall 38 only. The total upsidence and closure are the accumulated movements due to Longwalls 29 to 38.

Table 2.2 Summary of the Predicted and Observed Upsidence and Closure Movements at the Georges River Cross Lines after the Completion of Longwall 38

Location	Parameter	Incremental Movements Resulting from the Extraction of Longwall 38		Total Movements Resulting after the extraction of Longwall 38	
		Predicted (mm)	Observed (mm)	Predicted (mm)	Observed (mm)
G-Line	Upsidence	< -20	-18	-125	-155
	Closure	< 20	12	150	169
H-Line	Upsidence	< -20	0	-150	-29
	Closure	< 20	29	125	161
I-Line	Upsidence	< -20	-4	-125	-31
	Closure	30	3	150	25
J-Line	Upsidence	-30	-15	-100	-63
	Closure	70	21	150	92
K-Line	Upsidence	-40	-7	-150	-95
	Closure	80	8	175	105
L-Line	Upsidence	-50	-65	-100	-279
	Closure	125	60	200	236
M-Line	Upsidence	-20	-26	-125	-432
	Closure	30	11	225	245
N-Line	Upsidence	< -20	-9	-150	-190
	Closure	< 20	9	225	251
O-Line	Upsidence	< -20	-1	-200	-23
	Closure	< 20	2	200	8
P-Line	Upsidence	-20	0	-100	-3
	Closure	30	1	150	6
R-Line	Upsidence	-20	-1	-60	-1
	Closure	20	4	60	5

The accuracies of the measured relative horizontal and vertical positions along the Georges River cross lines are in the order ±5 mm. The accuracies of the measured absolute horizontal and vertical positions are in the order of ±20 mm and ±30 mm, respectively.

The observed incremental upsidence for the L-Line and M-Line of 65 mm and 26 mm were slightly greater than the predicted incremental upsidence of 50 mm and 20 mm, respectively. The observed incremental closure along the H-Line of 29 mm was also slightly greater than the predicted incremental closure of less than 20 mm. These three exceedances were small (i.e. 6 to 15 mm) and within the order of accuracy of the prediction method. The observed incremental upsidence and closure for the remaining monitoring lines were all less than the incremental predictions.

The observed total upsidence and closure exceeded the predictions at the G-Line, H-Line (closure only) L-Line, M-Line and N-Line. In each of these cases, the observed movements had exceeded the predictions prior to the extraction of Longwall 38.

As discussed in Report No. MSEC533, "*Upsidence is the measure of micro valley movements in the base of the valley, which can vary significantly between adjacent cross-sections due to variations in near surface geology, whether failure of the bedrock occurs and the nature of bedrock failure. As a result, there is greater scatter in the observed upsidence movement data…… the predicted closure movements are considered to be more reliable than the predicted upsidence movements".*

The observed total closures exceeded the predictions by 9 % to 18 % for the G-Line, L-Line, M-Line and N-Line and by 29 % for the H-Line. There is more uncertainty in the prediction of valley related movements when compared with the prediction of vertical subsidence. The accuracy of empirical prediction methods are generally in the order of ±15 % to ±25 % for maximum vertical subsidence. The exceedances for the valley related closure along the Georges River are similar to the order of accuracy normally considered acceptable for empirical methods.

The observed total closure for the remaining monitoring lines were between 4 % and 61 % of the predicted total closure (i.e. observed less than predicted). The average ratio of the observed to predicted total closure for all the Georges River cross lines was 67 %.

2.3. Exley Road Monitoring Line

Exley Road crosses Longwall 38 near the commencing end of this longwall. The mine subsidence movements were measured along this road by IC using 2D and 3D monitoring techniques. The location of the Exley Road monitoring line is shown in Drawing No. MSEC807-01, in Appendix B.

A summary of the survey dates for the Exley Road monitoring line for Longwall 38 is provided in Table 2.3.

Table 2.3 Summary of Survey Dates for the Exley Road Monitoring Line for Longwall 38

Extraction Plan Commitments	Monitoring Dates	Proposed Future Monitoring
Initial survey prior to LW38. Subsequent survey monthly from 100m prior to undermining until 400m past mining. Final survey after the completion of Longwall 38	Initial survey on the 30th January 2015 prior to commencement of Longwall 38. Subsequent surveys during mining on the 11th February, 11th March, 8th April, 15th April, 23rd April and 27th May 2015. Final survey after the completion of Longwall 38 on the 10th March 2016.	None as no future mining currently proposed in Area 5 at West Cliff Colliery

The observed profiles of incremental subsidence, tilt and strain along the Exley Road monitoring line due to the mining of Longwall 38 are shown in Fig. A.14, in Appendix A. A comparison of the observed and predicted subsidence parameters for this monitoring line is provided in Table 2.4. The values in this table are the maxima at any time during or after the mining of Longwall 38.

Table 2.4 Maximum Observed and Predicted Incremental Subsidence, Tilt and Strains for the Exley Road Monitoring Line due to the Mining of Longwall 38

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	922	7.9	0.5	2.7
Predicted	360	2.5	*- Refer to discussions below -*	

The accuracies of the measured relative vertical and horizontal positions for the monitoring line are in the order of ±5 mm. The accuracies of the measured absolute vertical and horizontal positions are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum observed subsidence of 922 mm was greater than the maximum predicted value of 360 mm. The exceedance is partly due to the proximity of the monitoring line to the longwall commencing end, with the end effects reducing the predicted subsidence. If the end effects are excluded, then the maximum predicted subsidence for the monitoring line would be 560 mm.

The maximum observed subsidence therefore exceeded the maximum predicted by a factor of 2.5 when the longwall end effects are included and by a factor of 1.6 when the longwall end effects are excluded. The maximum observed tilt of 7.9 mm/m was greater than the maximum predicted value of 2.5 mm/m based on the modified commencing end position and 3.5 mm/m when the longwall end effects are excluded.

The vertical subsidence and tilt along this monitoring line could have exceeded the predictions due to the presence of both O'Hares Fault and the Georges River valley. The proximities of these features could have made this longwall subside more like a series panel rather than a single isolated longwall. Further discussions have been provided in Section 2.8.

The maximum observed strains were 0.5 mm/m tensile and 2.7 mm/m compressive. The maximum predicted strains based on regular (i.e. conventional) ground movements were 1.2 mm/m tensile and 1.8 mm/m compressive. The maximum predicted strains including the potential for irregular movements were: 0.9 mm/m tensile and 1.6 mm/m compressive based on the 95 % confidence level; and 1.6 mm/m tensile and 3.2 mm/m compressive based on the 99 % confidence level.

The tensile strains therefore were within the range of those predicted based on regular ground movements. The maximum observed compressive strain of 2.8 mm/m appears to be a localised irregular movement, with its magnitude less than that predicted based on the 99 % confidence level. Elsewhere, the compressive strains were 1.5 mm/m or less and, therefore, within the range of those predicted based on regular ground movements.

2.4. Blackburn Road Monitoring Line

Blackburn Road crosses Longwall 38 near the middle of this longwall. The mine subsidence movements were measured along this road by IC using 2D monitoring techniques. The location of the Blackburn Road monitoring line is shown in Drawing No. MSEC807-01, in Appendix B.

A summary of the survey dates for the Blackburn Road monitoring line for Longwall 38 is provided in Table 2.5.

Table 2.5 Summary of Survey Dates for the Blackburn Road Monitoring Line for Longwall 38

Extraction Plan Commitments	Monitoring Dates	Proposed Future Monitoring
Initial survey prior to LW38. Subsequent survey monthly from 100m prior to undermining until 400m past mining. Final survey after the completion of Longwall 38	Initial survey on the 3rd February 2015 at the commencement of Longwall 38. Subsequent surveys during mining on the 15th May, 11th June, 18th June, 23rd June,1st July, 7th July, 14th July, 21st July and 28th July 2015. Final survey after the completion of Longwall 38 on the 11th March 2016.	None as no future mining currently proposed in Area 5 at West Cliff Colliery

The observed profiles of incremental subsidence, tilt and strain along the Blackburn Road monitoring line due to the mining of Longwall 38 are shown in Fig. A.15, in Appendix A. A comparison of the observed and predicted subsidence parameters for this monitoring line is provided in Table 2.6. The values in this table are the maxima at any time during or after the mining of Longwall 38.

Table 2.6 Maximum Observed and Predicted Incremental Subsidence, Tilt and Strains for the Blackburn Road Monitoring Line due to the Mining of Longwall 38

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	840	8.4	0.5	1.9
Predicted	540	3.5	*- Refer to discussions below -*	

The accuracies of the measured relative vertical and horizontal positions for the monitoring line are in the order of ±5 mm. The accuracies of the measured absolute vertical and horizontal positions are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum observed subsidence of 840 mm was greater than the maximum predicted value of 540 mm, representing an exceedance of 1.6 times. The maximum observed tilt of 8.4 mm/m was greater than the maximum predicted value of 3.5 mm/m, representing an exceedance of 2.4 times.

The vertical subsidence and tilt along this monitoring line could have exceeded the predictions due to the presence of both O'Hares Fault and the Georges River valley. The proximities of these features could have made this longwall subside more like a series panel rather than a single isolated longwall. Further discussions have been provided in Section 2.8.

The maximum observed strains were 0.5 mm/m tensile and 1.9 mm/m compressive. The maximum predicted strains based on regular (i.e. conventional) ground movements were 1.2 mm/m tensile and 1.8 mm/m compressive. The strains measured along the Blackburn Road monitoring line therefore were similar to the range predicted based on regular ground movements.

2.5. Wedderburn Airfield Monitoring Line

The Wedderburn Airfield is located outside and to the east of Longwall 38. The mine subsidence movements were measured in this location by IC using 3D monitoring techniques. The location of the Wedderburn Airfield monitoring line is shown in Drawing No. MSEC807-01, in Appendix B.

A summary of the survey dates for the Wedderburn Airfield monitoring line for Longwall 38 is provided in Table 2.7.

Table 2.7 Summary of Survey Dates for the Wedderburn Airfield Monitoring Line for Longwall 38

Extraction Plan Commitments	Monitoring Dates	Proposed Future Monitoring
Initial survey prior to LW38. Subsequent survey monthly after 600m extraction, then weekly for the last 350m extraction. Final survey after the completion of Longwall 38	Initial survey on the 13th August 2015 when Longwall 38 had 1,070 metres of extraction remaining. Subsequent surveys during mining on the 19th October, 16th November, 30th November, 7th December, 14th December, 24th December, 30th December 2015, 12th January 2016 and 18th January 2016. Final survey after the completion of Longwall 38 on the 15th March 2016.	None as no future mining currently proposed in Area 5 at West Cliff Colliery

The observed profiles of incremental subsidence, tilt and strain along the Wedderburn Airfield monitoring line due to the mining of Longwall 38 are shown in Fig. A.16, in Appendix A. The comparison of the observed and predicted subsidence parameters for this monitoring line is provided in Table 2.8. The values in this table are the maxima at any time during or after the mining of Longwall 38.

Table 2.8 Maximum Predicted Incremental Subsidence, Tilt and Strains for the Wedderburn Airfield Monitoring Line due to the Mining of Longwall 38

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	37	0.8	0.3	0.5
Predicted	< 50	< 0.5	*- Refer to discussions below -*	

The accuracies of the measured relative vertical and horizontal positions for the monitoring line are in the order of ±5 mm. The accuracies of the measured absolute vertical and horizontal positions are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum observed subsidence of 37 mm was similar to the maximum predicted subsidence of less than 50 mm. The maximum observed tilt of 0.8 mm/m was slightly greater than the maximum predicted tilt of less than 0.5 mm/m. However, the maximum tilt appears to be the result of a disturbed survey mark (AF25) due to the locally higher subsidence in this location. Elsewhere, the observed tilts were up to 0.4 mm/m and therefore were less than the maximum predicted tilt.

The maximum observed strains were 0.3 mm/m tensile and 0.5 mm/m compressive. The maximum predicted strains based on regular (i.e. conventional) ground movements outside of the longwall were less than 0.5 mm/m tensile and compressive. The strains measured along the Wedderburn Airfield monitoring line were therefore within the range of those predicted based on regular ground movements.

2.6. Harland's Dam Monitoring Points

Harland's Dam is located directly above Longwall 38 on the southern side of Blackburn Road. The dam wall was monitored by IC using 3D monitoring points. The location of the Harland's Dam monitoring points are shown in Drawing No. MSEC807-01, in Appendix B.

A summary of the survey dates for the Harland's Dam monitoring points for Longwall 38 is provided in Table 2.9.

Table 2.9 Summary of Survey Dates for the Harland's Dam Monitoring Points for Longwall 38

Extraction Plan Commitments	Monitoring Dates	Proposed Future Monitoring
Initial survey prior to LW38. Subsequent survey monthly between 600m and 800m extraction, then weekly from 800m to 1300m extraction. Final survey after the completion of Longwall 38.	Initial survey on the 29th April 2015 when Longwall 38 had 1,900 metres of extraction remaining. Subsequent surveys during mining on the 15th May, 11th June, 18th June, 23rd June, 1st July, 7th July, 14th July, 21st July, 28th July and 4th August 2015. Final survey after the completion of Longwall 38 on the 11th Mar 2016.	None as no future mining currently proposed in Area 5 at West Cliff Colliery

A comparison of the observed and predicted subsidence parameters for this monitoring line is provided in Table 2.10. The values in this table are the maxima at any time during or after the mining of Longwall 38.

Table 2.10 Maximum Predicted Incremental Subsidence, Tilt and Strains for the Harland's Dam Monitoring Points due to the Mining of Longwall 38

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	267	4.1	1.8	1.2
Predicted	430	3.5	*- Refer to discussions below -*	

The accuracies of the measured relative vertical and horizontal positions for the monitoring points are in the order of ±5 mm. The accuracies of the measured absolute vertical and horizontal positions are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum observed subsidence of 267 mm was less than the maximum predicted value of 430 mm. Harland's Dam is located midway between the longwall centreline and goaf edge and away from the location of maximum subsidence for the longwall. Hence, the magnitudes of the observed subsidence for these monitoring points were less than predicted, whereas the observed subsidence exceeded those predicted along the other monitoring lines that were located directly above the longwall.

The maximum observed tilt of 4.1 mm/m was similar to but slightly greater than the maximum predicted value of 3.5 mm/m. The exceedance represents around 17 % which is within the range considered acceptable for subsidence prediction methodologies of ±15 % to ±25 % for maximum tilt.

The maximum observed strains were 1.8 mm/m tensile and 1.2 mm/m compressive. The maximum predicted strains based on regular (i.e. conventional) ground movements were 1.2 mm/m tensile and 1.8 mm/m compressive. The maximum observed tensile strain is greater than the prediction based on regular movements. The strain in this location reduced to 1.2 mm/m tensile in the final survey and, therefore, was similar to that predicted based on regular movements. The observed compressive strains were within the range of those predicted based on regular ground movements.

The vectors of horizontal movement for the Harland's Dam monitoring points are illustrated in Fig. 2.1.

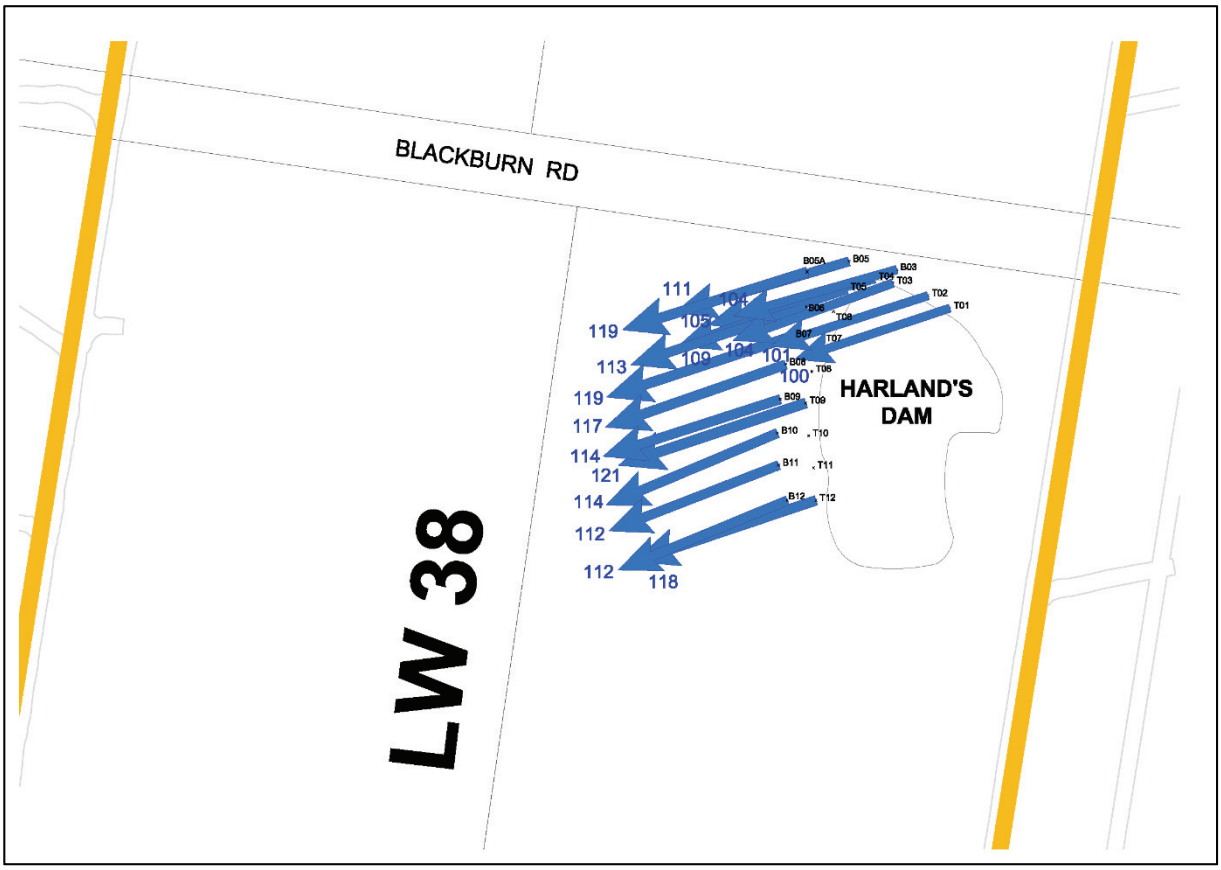

Fig. 2.1 Observed Vectors of Incremental Horizontal Movements at the Harland's Dam Monitoring Points due to the Mining of Longwall 38

The horizontal movements at the survey marks were all orientated towards the centreline of Longwall 38. The magnitudes of these movements varied between 100 mm and 121 mm. The maximum predicted horizontal movement based on applying a factor of 15 to the predicted tilt of 4 mm/m is 60 mm. The maximum predicted horizontal movement based on applying this factor to the maximum observed tilt of 8 mm/m is 120 mm.

2.7. WaterNSW Infrastructure

WaterNSW (formally the Sydney Catchment Authority) owns infrastructure on the western side of Area 5 at West Cliff Colliery. The infrastructure is shown in Drawing No. MSEC807-03 and includes the Upper Canal, Devines Tunnels, wrought iron and concrete aqueducts and other associated structures.

The WaterNSW infrastructure is located more than 3.8 kilometres from Longwall 38. At this distance, it is unlikely that the infrastructure would have experienced any measurable movements due to mining this longwall.

The last 200 metres of Appin Longwall 705 and the full length of Appin Longwall 706 were extracted at the same time as West Cliff Longwall 38. The longwalls at Appin Colliery are located around 1 kilometre from the WaterNSW infrastructure at their closest point.

Any movements at the WaterNSW infrastructure measured during the mining of Longwall 38 therefore are expected to be due to the concurrent mining of the longwalls at Appin Colliery. A review of the ground monitoring data for the WaterNSW infrastructure has been provided in the End of Panel report for Appin Longwall 706 rather than in this report.

2.8. Discussions on the Exceedance of Vertical Subsidence and Tilt

The vertical subsidence and tilt exceeded the predictions along the Exley Road and Blackburn Road monitoring lines. The maximum observed subsidence were 1.6 times the maximum predicted for these monitoring lines, when the end effects were excluded at the longwall commencing end. The reasons for these exceedances could be attributed to the presence of O'Hares Fault, the Georges River, or a combination of these two features.

O'Hares Fault is located to the north of the commencing end of Longwall 38. The throw of this normal fault varies between around 15 metres and 76 metres and the dip is around 75 degrees to 80 degrees, based on the seismic surveys and investigations in the nearby first workings. A long-section through the commencing end of Longwall 38 and O'Hares Fault is provided in Fig. 2.2.

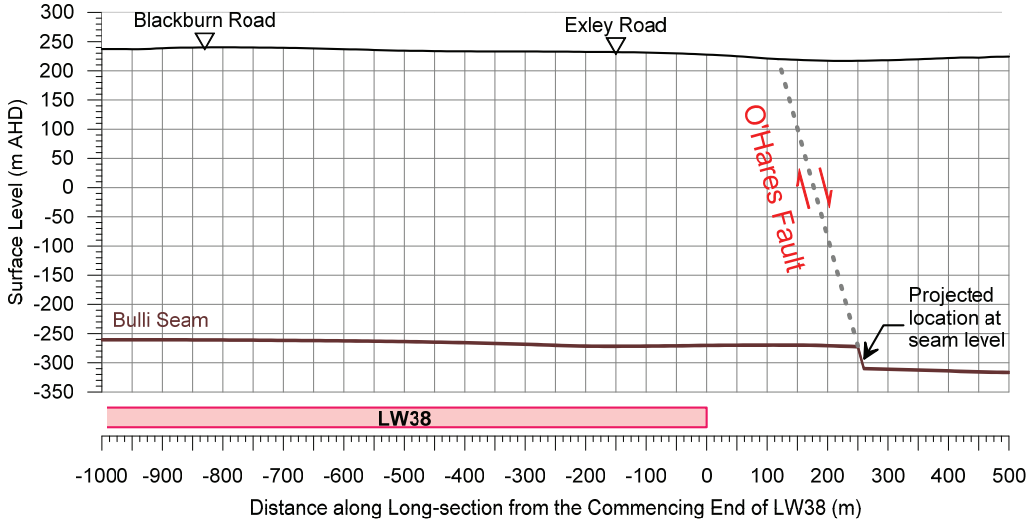

Fig. 2.2 Long-section through the Commencing End of Longwall 38 and O'Hares Fault

Exley and Blackburn Roads are located at distances of 270 metres and 950 metres, respectively, south of the projected surface expression of the fault. This surface expression has not been identified on site.

The Georges River is located to the west of Longwall 38. A cross-section through the longwall and the river is provided in Fig. 2.3. The cross-section has been taken where the Georges River is located closest to Longwall 38, to the south of Blackburn Road.

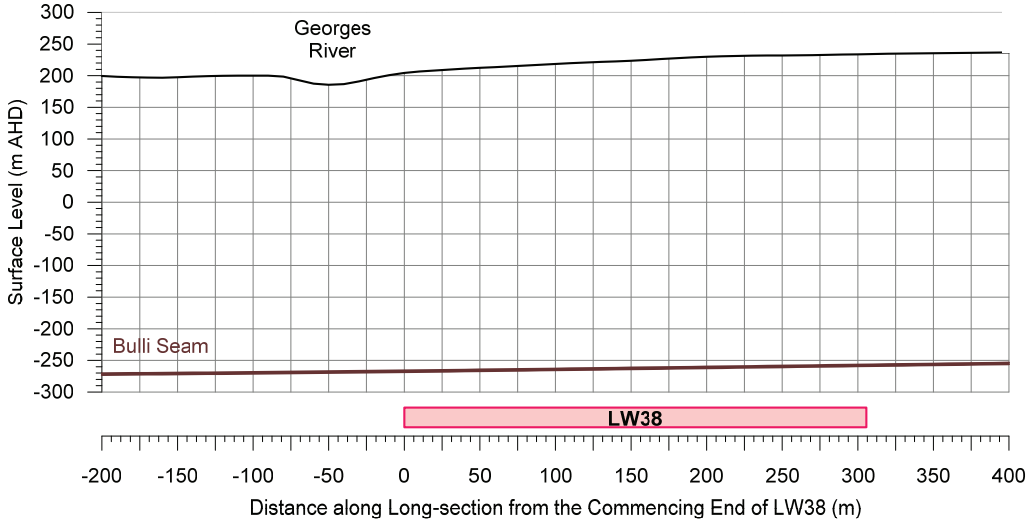

Fig. 2.3 Cross-section through Longwall 38 and the Georges River

The valley height of the Georges River in the vicinity of Longwall 38 is around 40 metres. The surface incision is small when compared with the overall depth of cover which is around 500 metres.

Longwalls have been extracted in the vicinity of major faults in the Southern Coalfield without increased subsidence being observed. This includes Longwall 37 at West Cliff Colliery which was extracted at a distance of around 1 kilometre south of O'Hares fault, i.e. a similar distance as the Blackburn Road monitoring line from this fault.

Similarly, longwalls have been extracted adjacent to and beneath large river valleys in the Southern Coalfield without increased subsidence being observed. This includes mining directly beneath the Nepean, Cataract and Georges Rivers at Appin and West Cliff Collieries.

Increased subsidence with similar levels of exceedance has only been observed in one other location within the Southern Coalfield, at the eastern ends of Longwalls 24 to 27 at Tahmoor Colliery. The observed subsidence in that location was up to twice that observed elsewhere at the colliery. The Bargo River and the Nepean Fault zone are located in the vicinity of the area of increased subsidence.

The increased subsidence at Tahmoor Colliery was investigated by Strata Control Technology who concluded that it was "*consistent with localised weathering of joint and bedding planes above a depressed water table adjacent to an incised gorge. The study has shown that other factors such as variation in stress field, joint zones, variation in rock strength and topographic factors did not sufficiently impact to induce the abnormal subsidence*" (SCT, 2011).

The increased subsidence above Longwall 38 at West Cliff Colliery could be due to the combination of both the nearby O'Hare's Fault and the Georges River valley. The maximum observed subsidence along the Exley Road and Blackburn Road monitoring lines of 800 to 900 mm are similar to the maximum observed incremental subsidence due to the extraction of Longwalls 32 to 37 at the colliery. It is possible that the combination of the fault and the river has resulted in Longwall 38 acting more like a series panel rather than a single isolated longwall.

The comparisons between observed and predicted subsidence profiles along the Exley Road and Blackburn Road monitoring lines, assuming that the longwall is a series panel, are provided in Fig. 2.4 and Fig. 2.5, respectively. The predicted vertical subsidence has been based on Longwall 38 being a second panel within a series of longwalls.

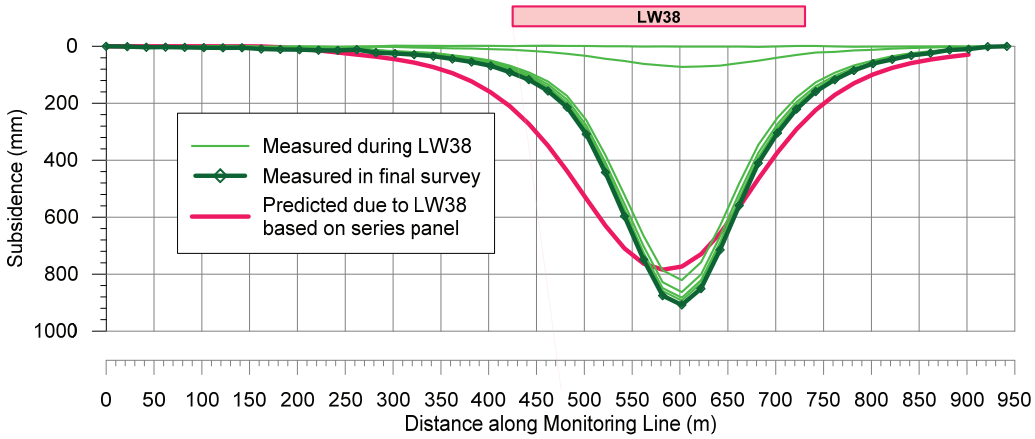

Fig. 2.4 Observed and Predicted Subsidence for the Exley Road Monitoring Line based on Longwall 38 being Equivalent to a Second Panel in a Series

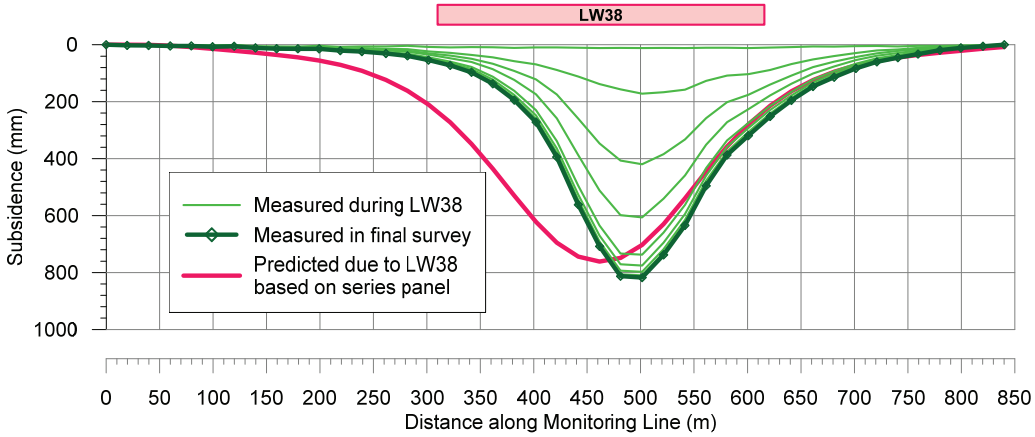

Fig. 2.5 Observed and Predicted Subsidence for the Blackburn Road Monitoring Line based on Longwall 38 being Equivalent to a Second Panel in a Series

The profiles of the observed vertical subsidence are more similar to those predicted along the Exley and Blackburn Road monitoring lines when Longwall 38 is assumed to be equivalent to a second panel in a series. However, the observed subsidence profiles are slightly steeper than the predicted profiles, i.e. the observed tilts are greater than predicted. There is also a lateral shift between the observed and predicted profiles along the Blackburn Road monitoring line and, to a lesser extent, the Exley Road monitoring line.

The increased subsidence and steeper profiles are consistent with weakened joints and bedding planes in the overburden strata. It is possible that the presence of both the O'Hares Fault and the Georges River valley have resulted in increased weathering of the discontinuities, similar to that suggested to have occurred at Tahmoor Colliery (SCT, 2011).

The maximum observed subsidence for Longwall 38 is similar to the maximum incremental subsidence above Longwalls 32 to 37 at West Cliff Colliery. The presence of O'Hares Fault and the Georges River valley appear to have resulted in the vertical subsidence developing closer to a second panel in the series, rather than as a single isolated longwall.

3.1. Natural Features

The natural features in the vicinity of Longwall 38 are shown in Drawing No. MSEC807-02, in Appendix B. These features include the following:-

- The Georges River;
- Tributaries to the Georges River;
- Cliff GR-CF01 and rock outcrops;
- Steep slopes;
- Endangered Ecological Communities; and
- Archaeological Sites.

The impact assessments for the natural features due to the mining of Longwall 38 were provided by MSEC in Report Nos. MSEC533 and MSEC718. 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 due to the mining of Longwall 38 are provided in Table 3.1.

Table 3.1 Summary of the Observed and the MSEC Assessed Impacts for the Natural Features due to the Mining of Longwall 38

Natural Feature	MSEC Assessed Impacts	Observed Impacts
The Georges River	Increased levels of **ponding**, **flooding**, **scouring** and **desiccation** are unlikely to be significant	No reported impacts
	Minor fracturing in the bed of the river, with isolated fracturing up to 400 metres from the extracted longwalls	Fracturing identified at Rockbar 49, with the largest fracture 10 metres long and 0.04 metres wide. Refer to the IC landscape report for further details
	Low potential for **surface water flow diversions**	Flow diversion identified upstream of Rockbar 49. Refer to the IC landscape report for further details
	Possible mining-induced **springs** or **iron staining**	Iron staining along a 20 metre section of the river downstream of Pool 49. Refer to the IC landscape report for further details
	Possible **gas emissions**	No reported impacts
	Water quality – Refer to the water quality report **Terrestrial ecology** – Refer to the report by IC Environmental Field Team **Aquatic ecology** – Refer to the aquatic ecology report	
Tributaries	Localised increased levels of **ponding**, **flooding** and **scouring**	No reported impacts
	Some **fracturing** in the bedrock beneath the watercourses which are directly mined beneath	Fracturing and associated uplift observed in tributaries GR104, GR108 and GR110. Refer to the IC landscape report for further details
	Some **surface water flow diversions** into the dilated strata beneath the watercourses which are directly mined beneath	Surface water flow diversions observed in tributaries GR108 and GR110. Refer to the IC landscape report for further details
	Possible mining-induced **springs** or **iron staining**	Minor iron staining in tributary GR108. Refer to the IC landscape report for further details
	Possible **gas emissions**	No reported impacts
Cliff and Rock Outcrops	Possible **rockfalls** along the exposed rockfaces	Zone of fracturing to a rock outcrop adjacent to tributary GR110, 2.1 metres long and 0.03 metres wide. Refer to the IC landscape report for further details
Steep Slopes	Potential for **soil slippage**	No reported impacts.

Natural Feature	MSEC Assessed Impacts	Observed Impacts
Endangered Ecological Communities	Refer to the report by IC Environmental Field Team	
Archaeological Sites	Possible fracturing in the sandstone bed of the Georges River within 400 metres of the proposed longwalls	No reported impacts. Refer to the archaeological report for further details

It can be seen from Table 3.1 that the observed impacts on the natural features, resulting from the extraction of Longwall 38, were consistent with the MSEC assessments. Further assessments of natural features have been provided by other consultants, which are described in the relevant reports attached to the *End of Panel Report*.

3.2. Built Features

The built features in the vicinity of Longwall 38 are shown in Drawing No. MSEC807-03, in Appendix B. These features include the following:-

- Exley, Blackburn and Lysaght Roads;
- Unsealed tracks;
- Low voltage aerial powerlines;
- Copper telecommunications cables;
- Farm dams;
- Rural building structures;
- Tanks;
- Houses;
- Private swimming pools;
- Wedderburn Airfield and associated infrastructure; and
- Survey control marks

The impact assessments for the built features due to mining Longwall 38 were provided in Report Nos. MSEC533 and MSEC718. Comparisons between the observed and assessed impacts for the built features due to the mining of Longwall 38 are provided in Table 3.2.

Table 3.2 Summary of the Observed and Assessed Impacts for the Built Features due to the Mining of Longwall 38

Built Feature	Assessed Impacts	Observed Impacts
Public Roads and tracks	Minor impacts that could be managed using normal road maintenance techniques	Soil cracking in two access tracks to Georges River, up to 3 metres long and 0.01 metres wide.
Low voltage powerlines	Minor impacts possible requiring adjustment of cable catenaries, pole tilts or consumer cables	No reported impacts
Copper telecommunications cables	Impacts unlikely	No reported impacts
Farm dams	Potential for cracking or leakage in farm dams	Leaking in one dam reported
Rural Building Structures	Minor impacts that could be remediated using normal building techniques. Structures would remain safe and serviceable.	One impact reported where the concrete slab in a shed had dropped
Tanks	Impacts unlikely	No reported impacts
Houses	94% of Category R0 to R2 Impacts 3 % of Category R3 and R4 impacts 3 % of Category R5 impacts Generally slight to minor impacts anticipated, but possible major impacts due to irregular movements	Cracking to one house (not directly mined beneath) reported
Pools	Tilt could be visible along waterline and inground pools could be more susceptible to strain impacts	Cracking in one pool reported

Built Feature	Assessed Impacts	Observed Impacts
Fences	Possible some fences could experience impacts	No reported impacts
Wedderburn Airfield	Impacts unlikely	No reported impacts
Survey control marks	Small far-field horizontal movements which could require re-establishment	Small far-field horizontal movements observed.

It can be seen from Table 3.2, that the observed impacts on the surface infrastructure, after the extraction of Longwall 38, were similar to or less than the assessed (i.e. predicted) impacts.

APPENDIX A. FIGURES

West Cliff Colliery - Longwall 38
Predicted and Observed Incremental Subsidence, Upsidence and Closure along the Centreline of the Georges River

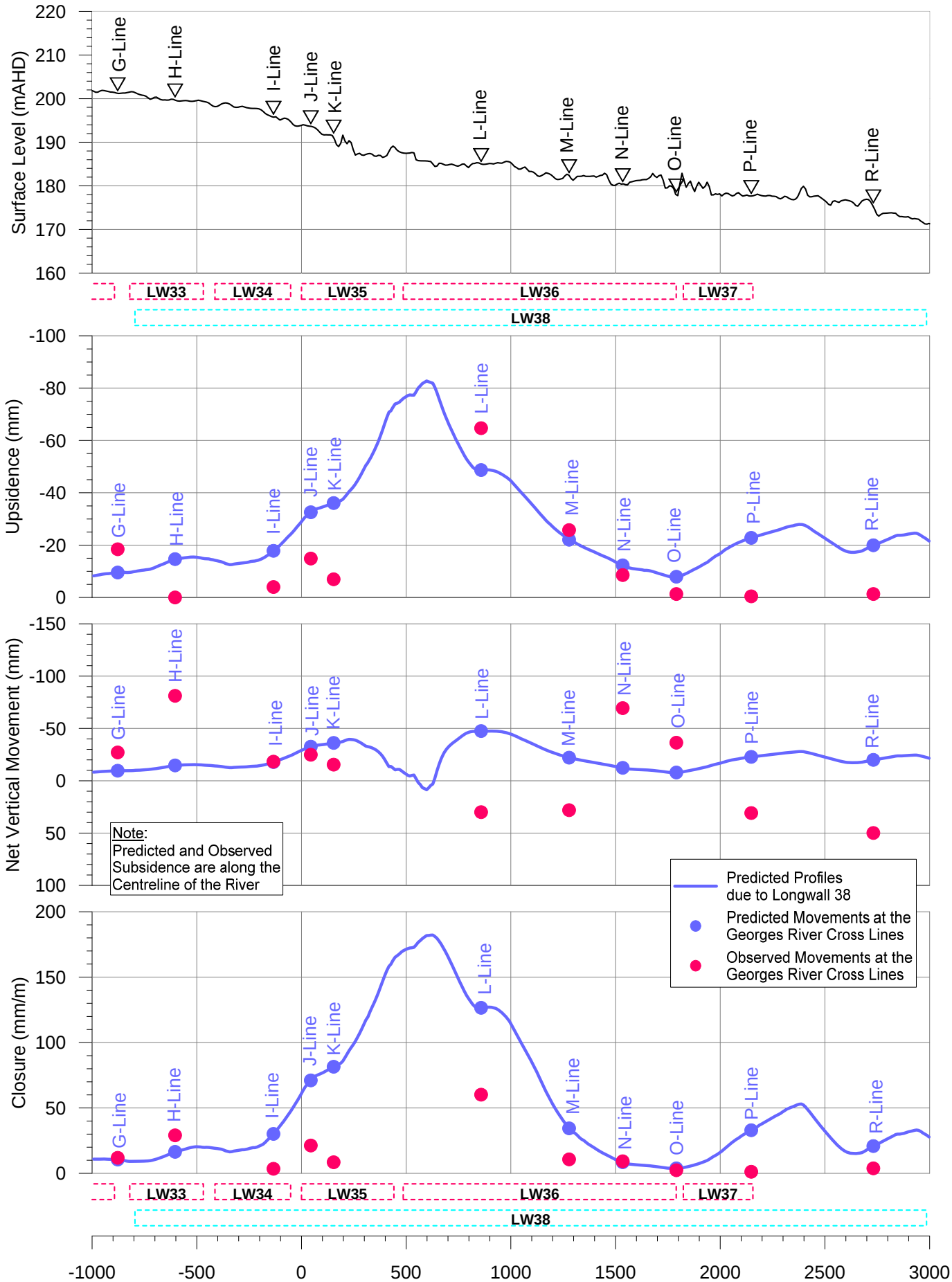

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Fig. A.01

West Cliff Colliery - Longwall 38
Predicted and Observed Total Subsidence, Upsidence and Closure along the Centreline of the Georges River

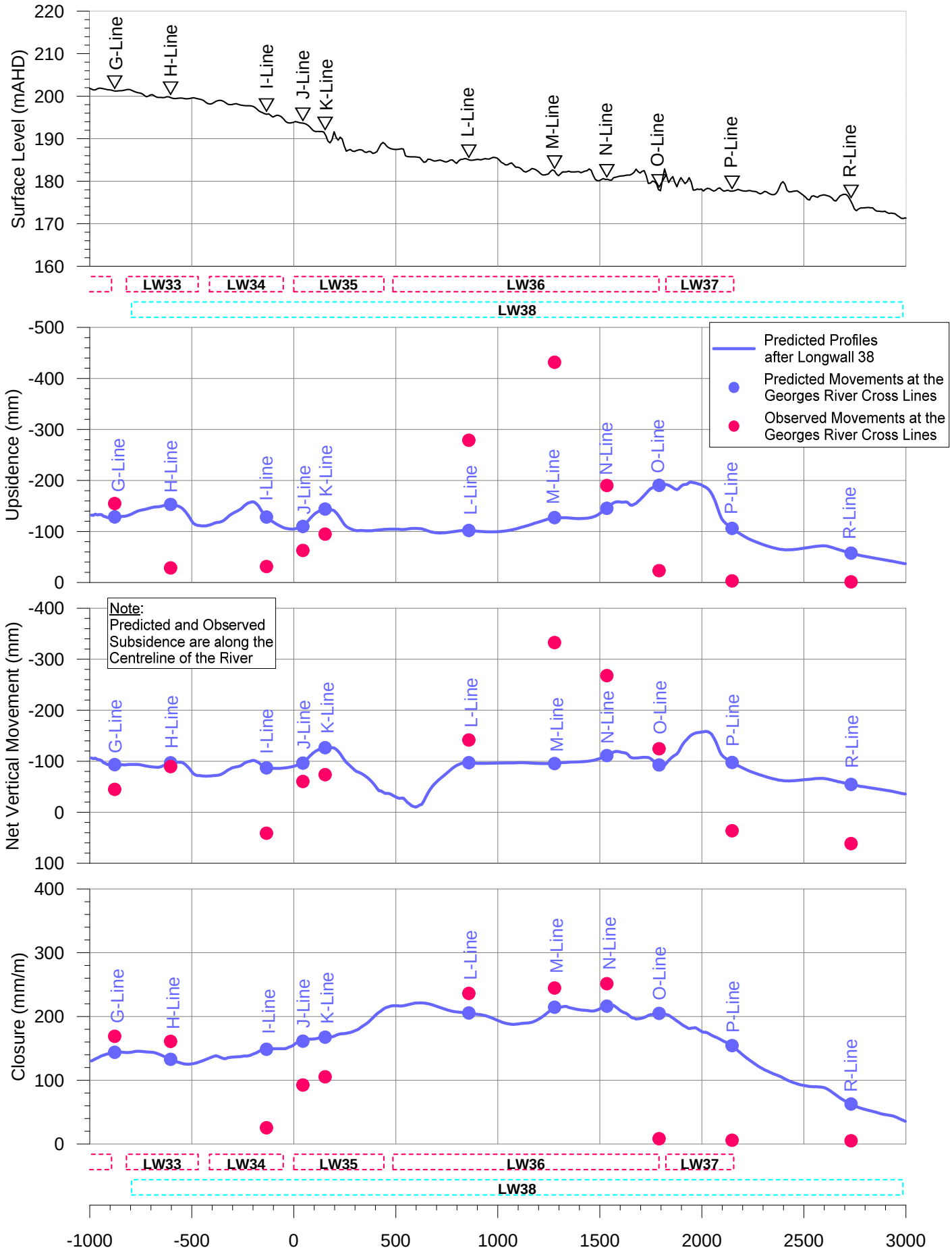

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Fig. A.02

West Cliff Colliery - Longwall 38 - Georges River G-Line
Total Subsidence, Strain, Upsidence and Closure Profiles

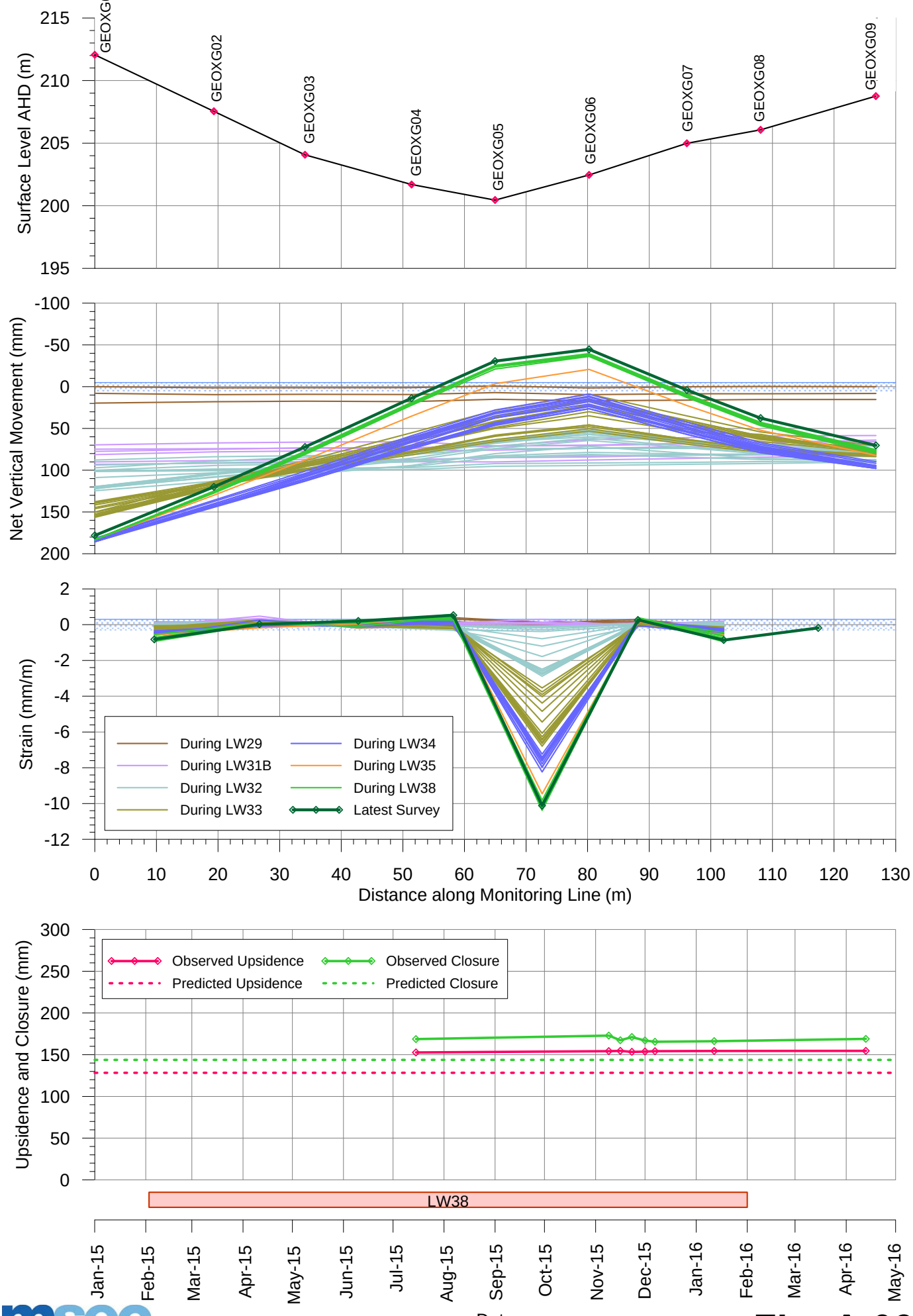

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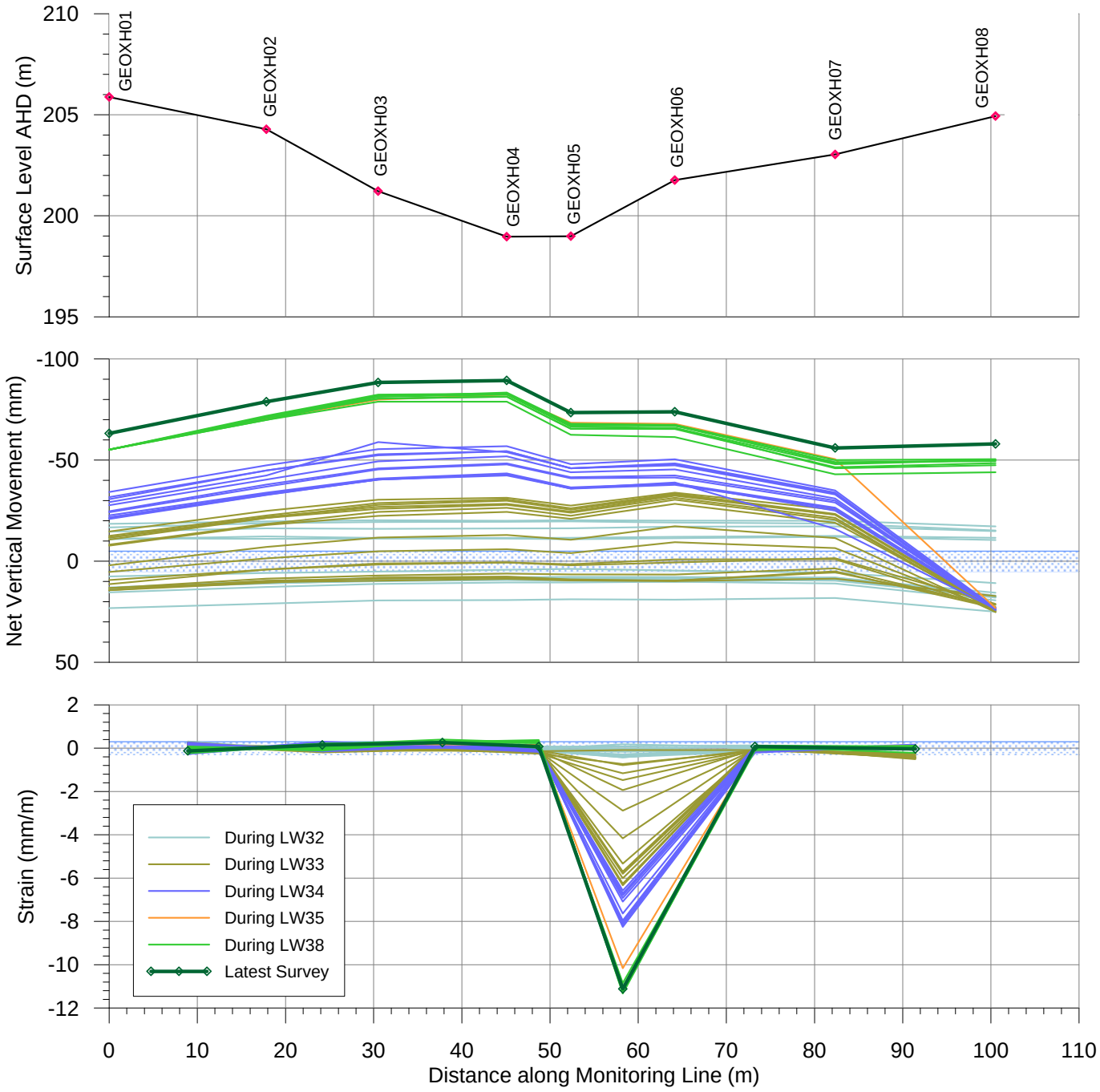
Fig. A.03

West Cliff Colliery - Longwall 38 - Georges River H-Line
Total Subsidence, Strain, Upsidence and Closure Profiles



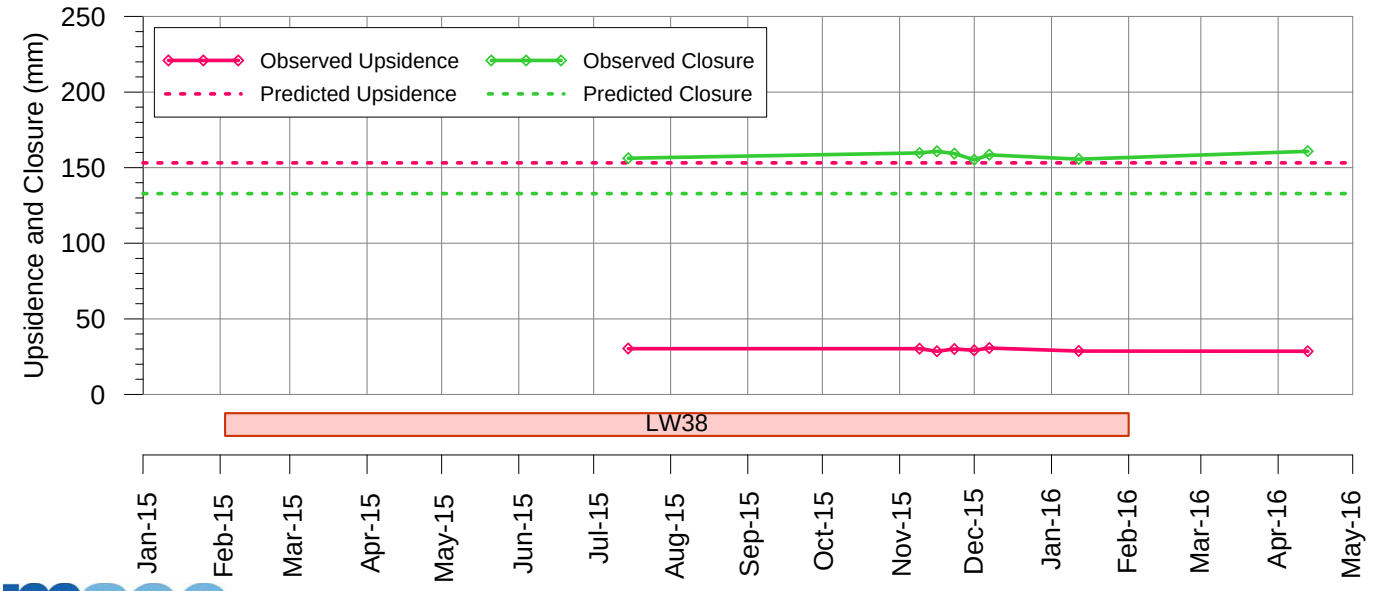


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Fig. A.04

West Cliff Colliery - Longwall 38 - Georges River I-Line
Total Subsidence, Strain, Upsidence and Closure Profiles

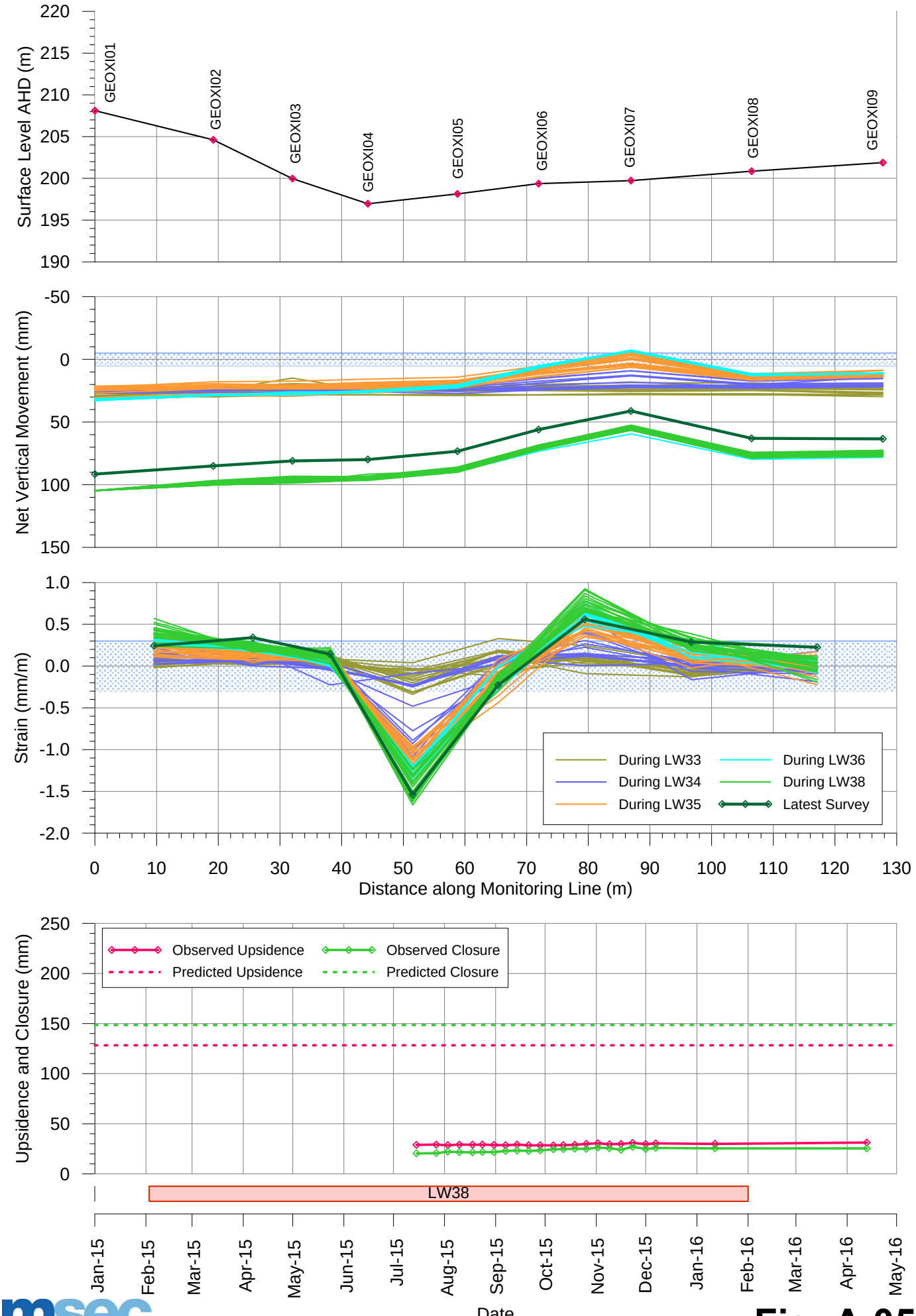

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Fig. A.05

West Cliff Colliery - Longwall 38 - Georges River J-Line
Total Subsidence, Strain, Upsidence and Closure Profiles

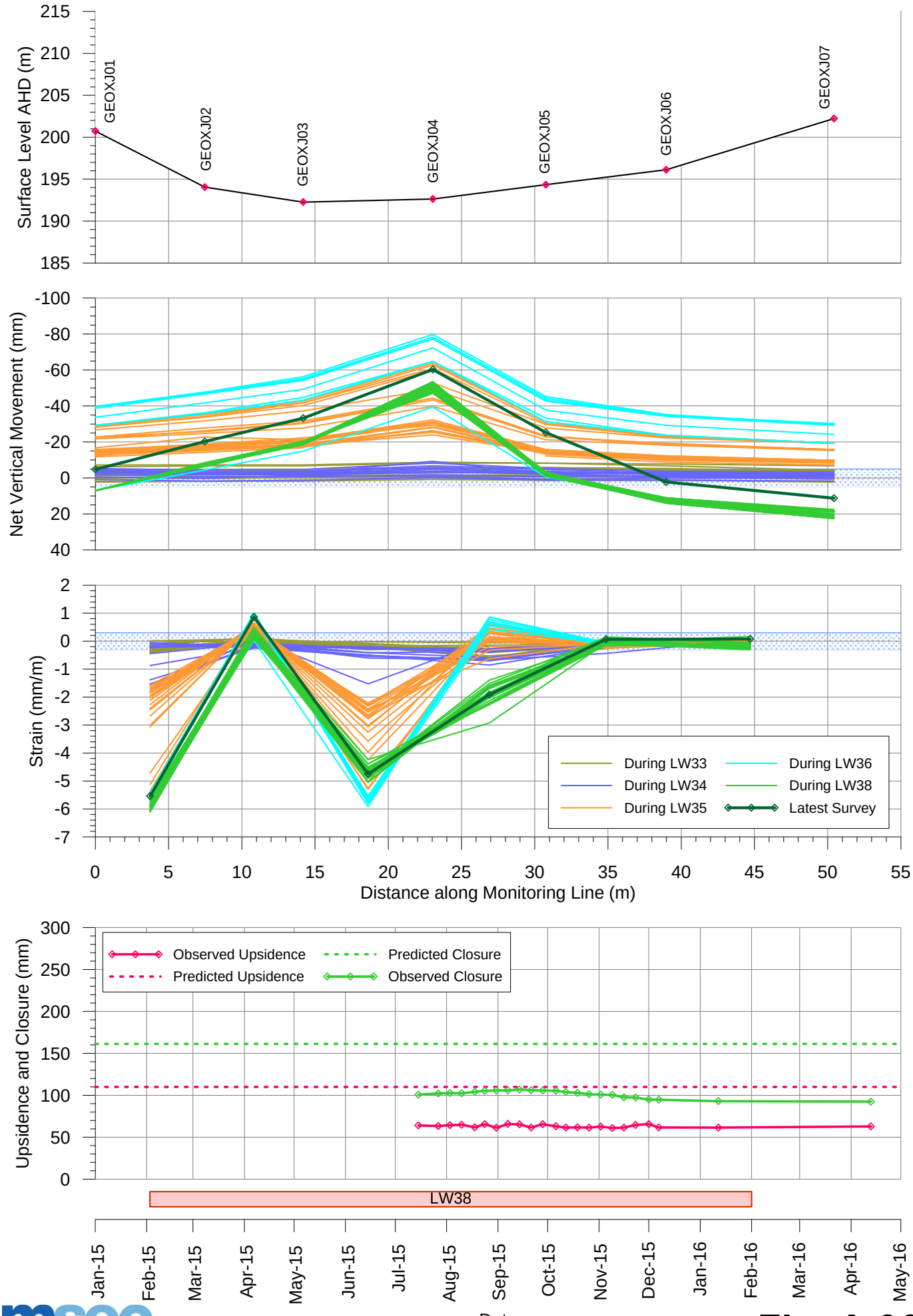

Fig. A.06

West Cliff Colliery - Longwall 38 - Georges River K-Line
Total Subsidence, Strain, Upsidence and Closure Profiles

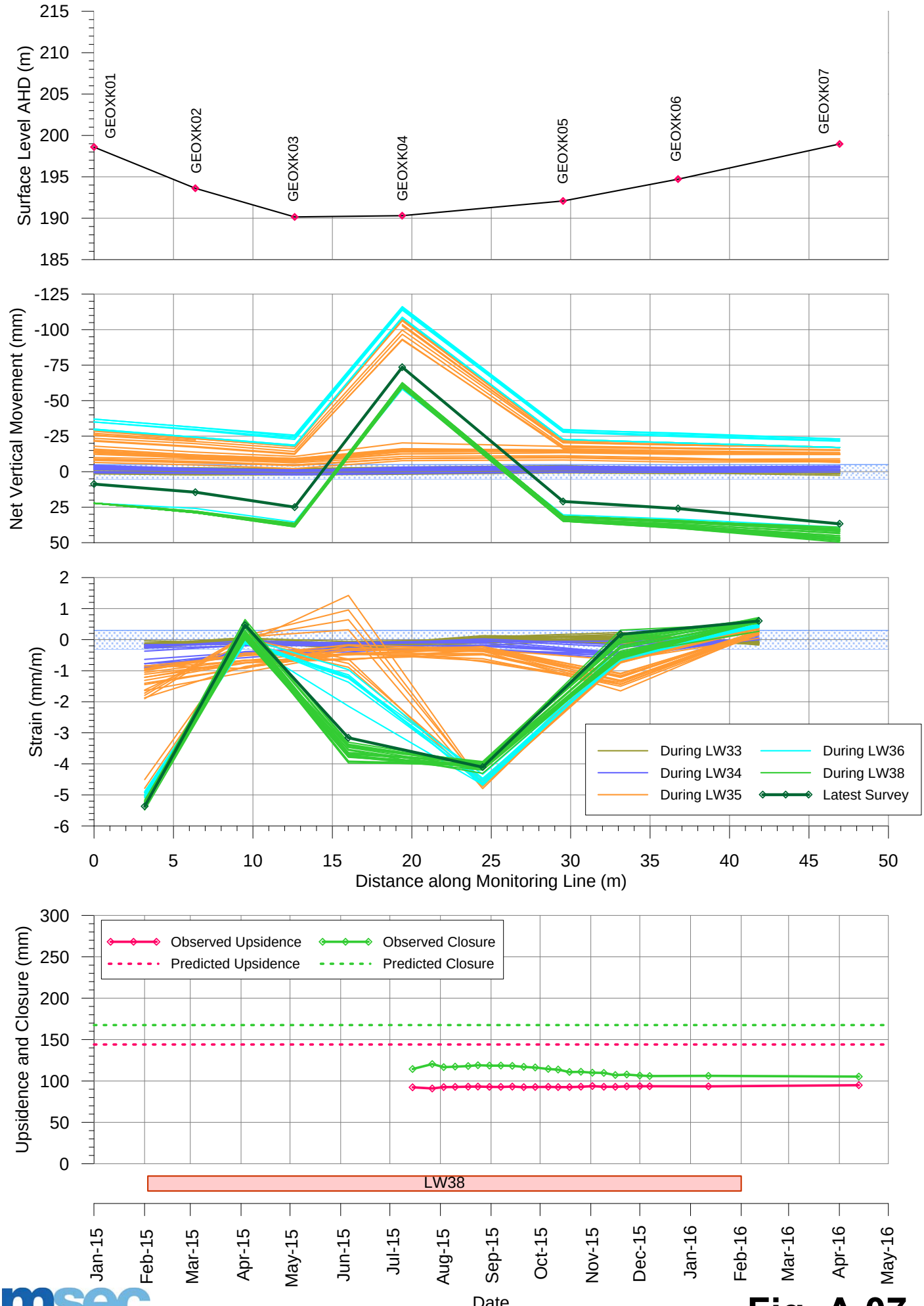

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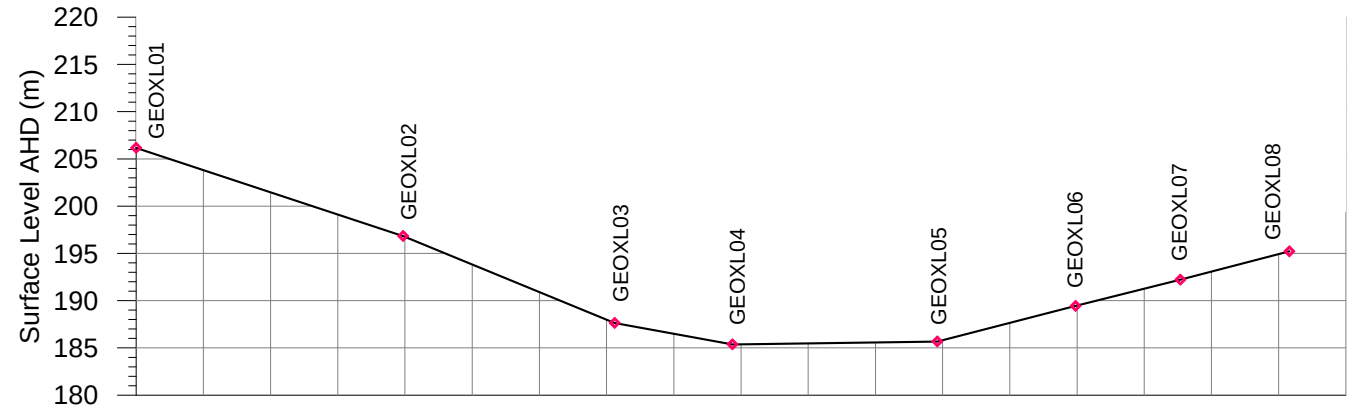
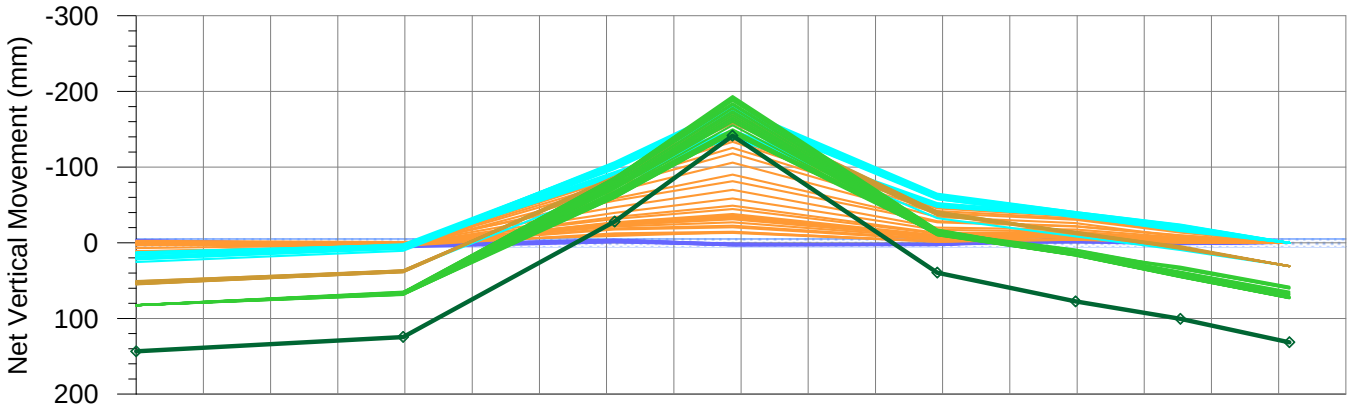
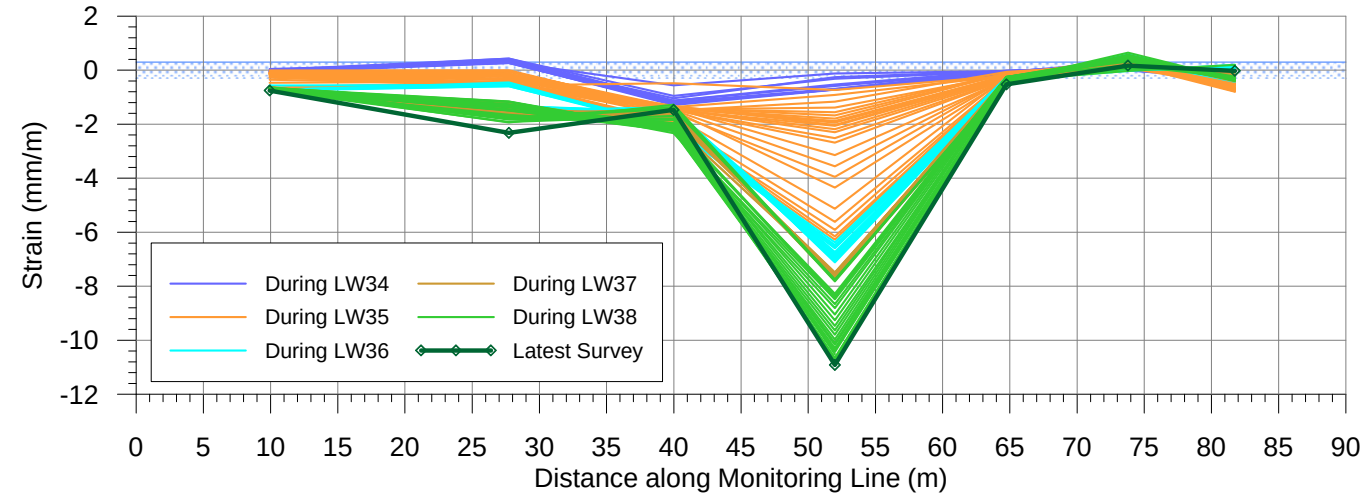
Fig. A.07

West Cliff Colliery - Longwall 38 - Georges River L-Line
Total Subsidence, Strain, Upsidence and Closure Profiles







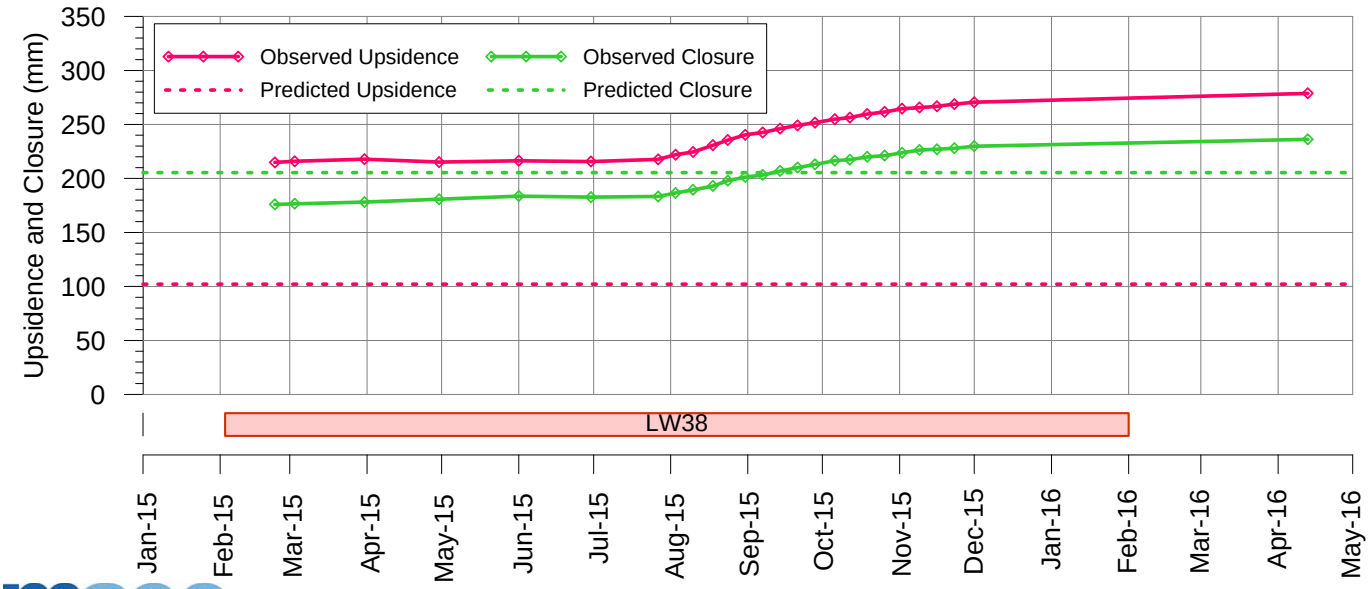


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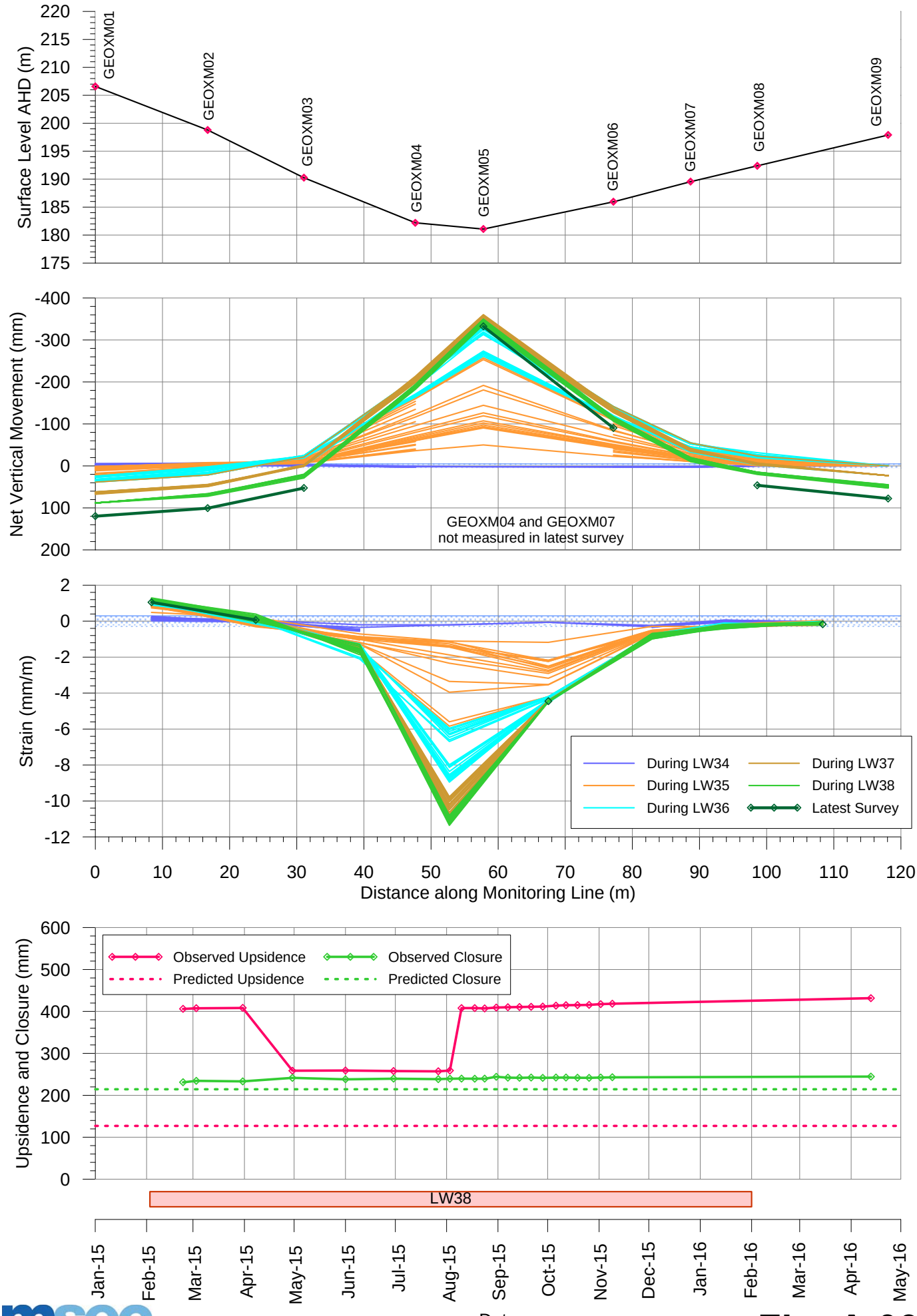
Fig. A.08

West Cliff Colliery - Longwall 38 - Georges River M-Line
Total Subsidence, Strain, Upsidence and Closure Profiles



msec

Fig. A.09

West Cliff Colliery - Longwall 38 - Georges River N-Line
Total Subsidence, Strain, Upsidence and Closure Profiles

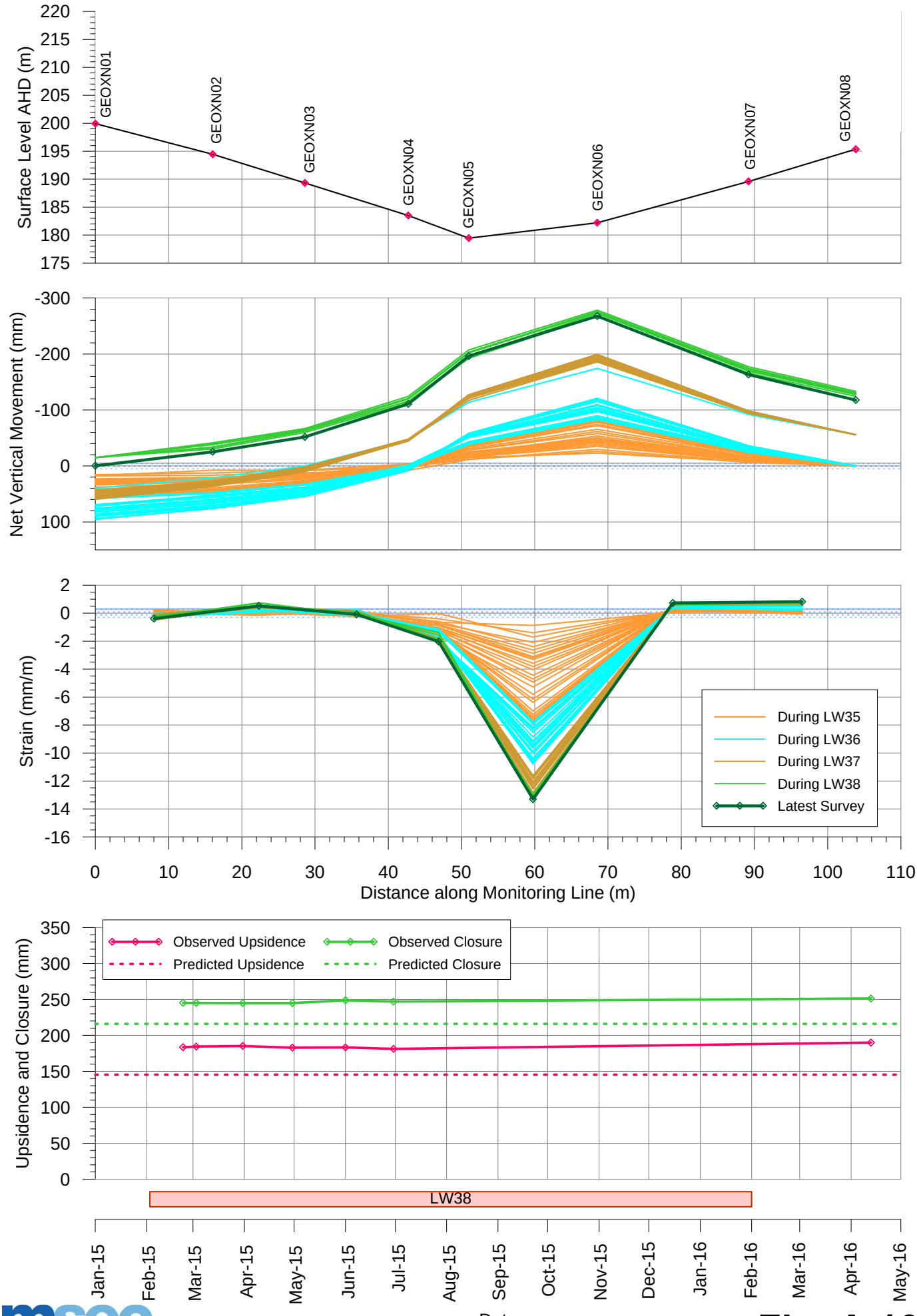


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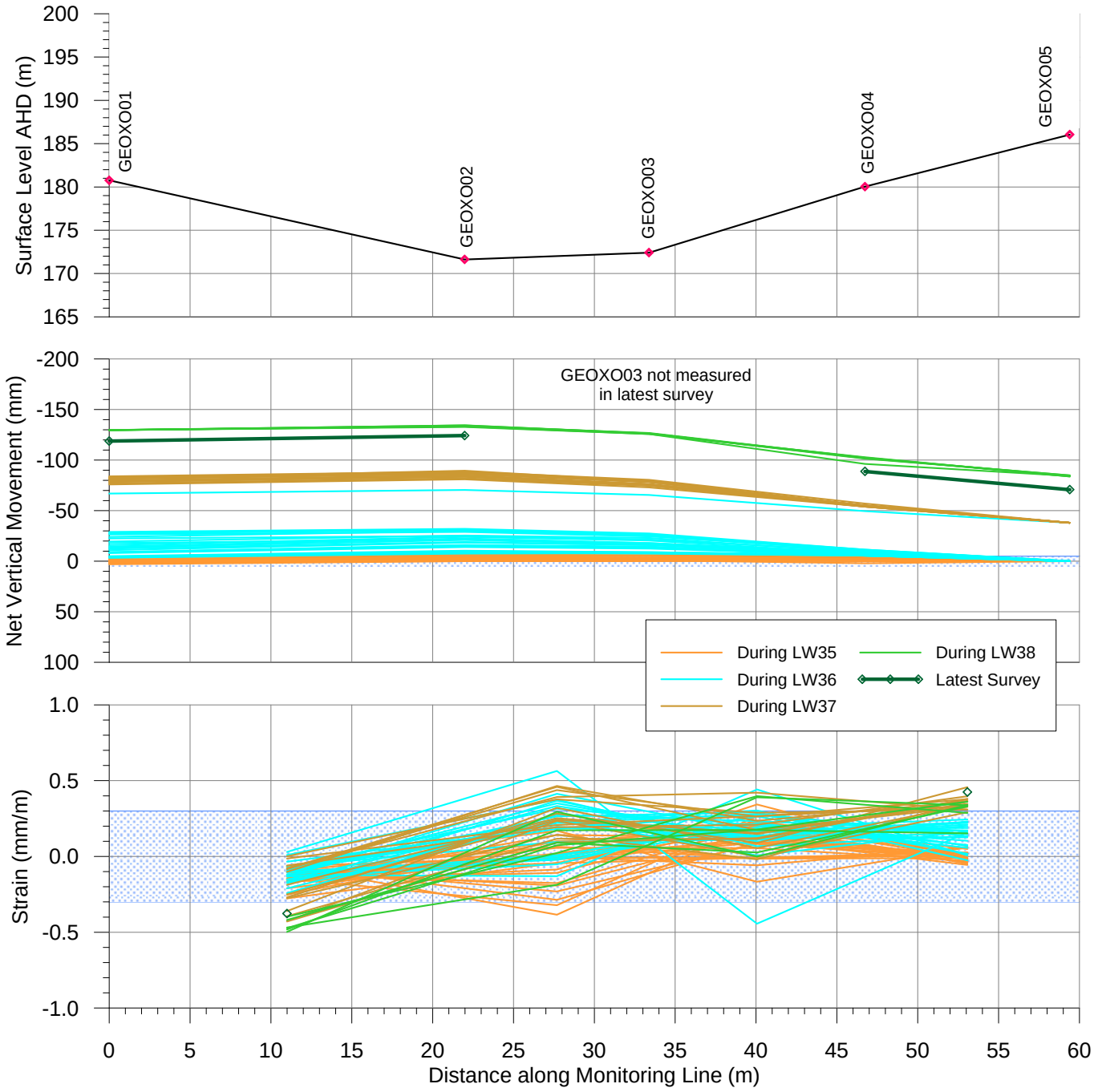
Fig. A.10

West Cliff Colliery - Longwall 38 - Georges River O-Line
Total Subsidence, Strain, Upsidence and Closure Profiles



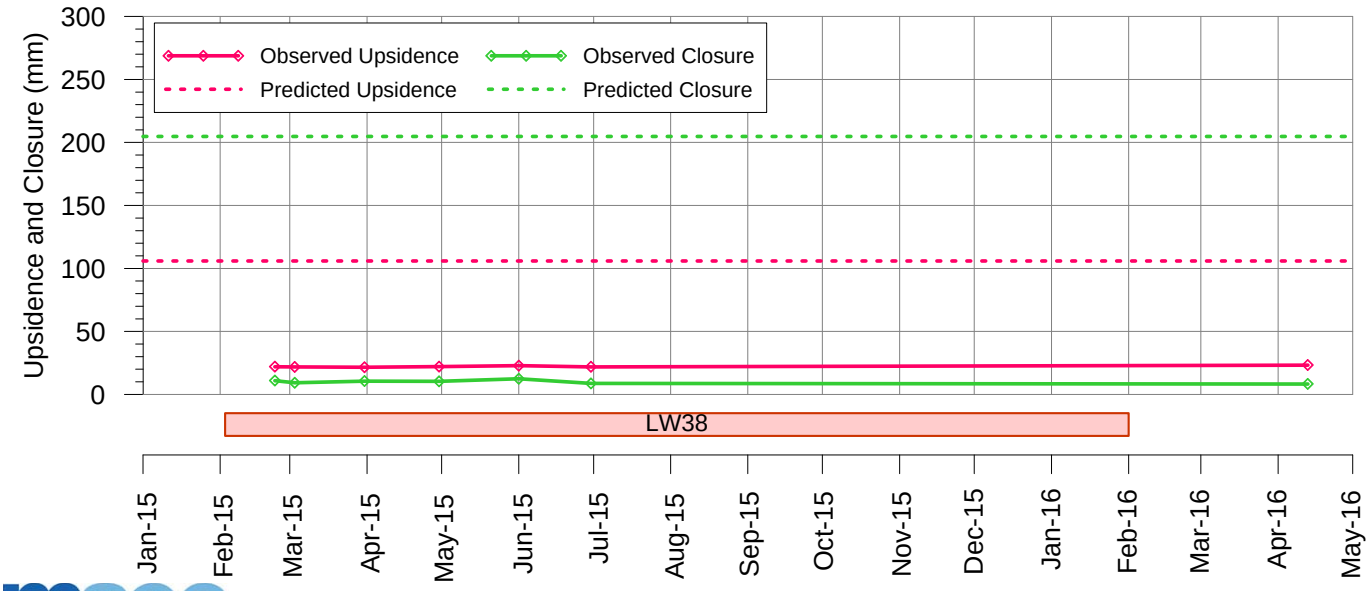


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Fig. A.11

West Cliff Colliery - Longwall 38 - Georges River P-Line
Total Subsidence, Strain, Upsidence and Closure Profiles

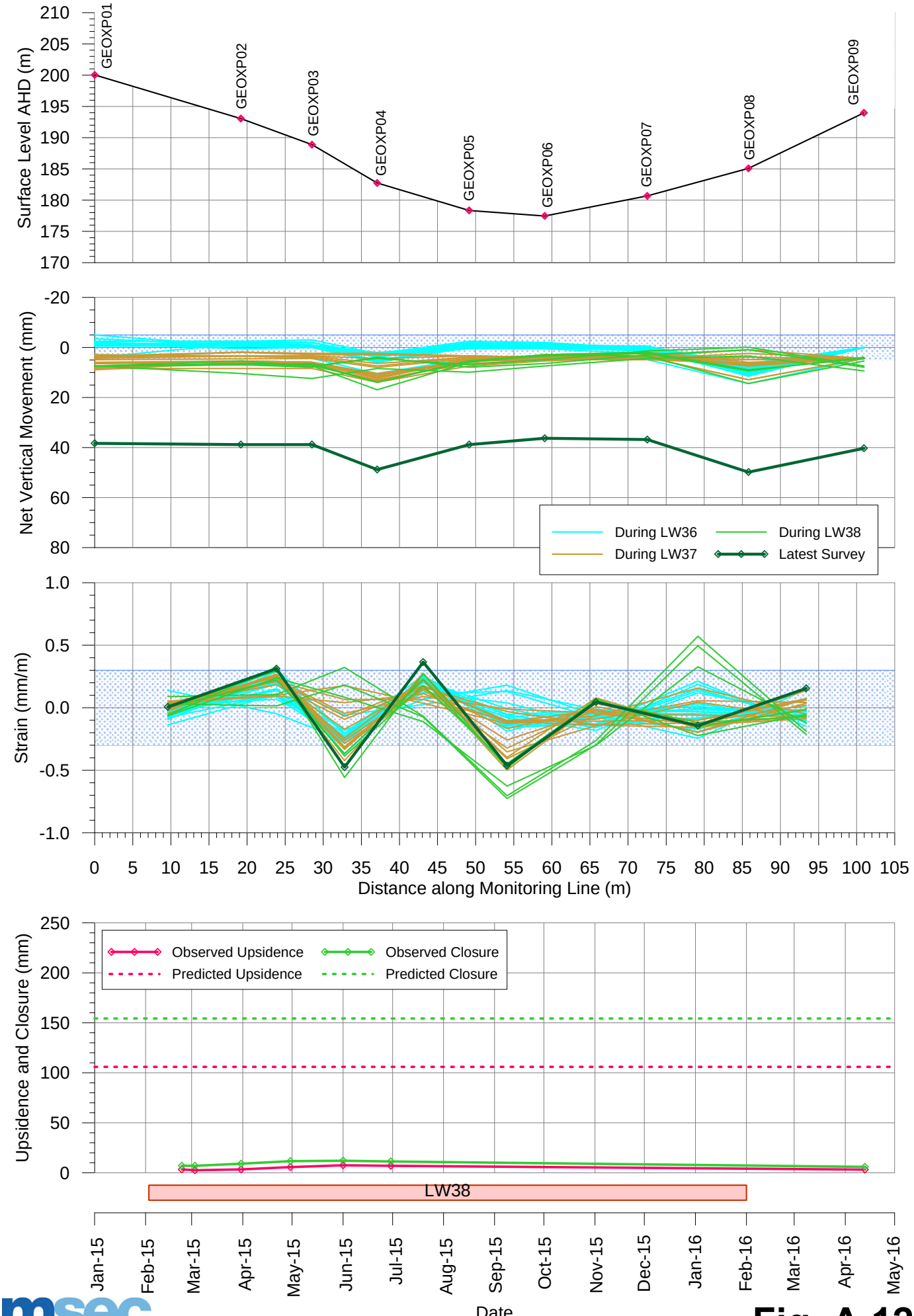

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Fig. A.12

West Cliff Colliery - Longwall 38 - Georges River R-Line
Total Subsidence, Strain, Upsidence and Closure Profiles

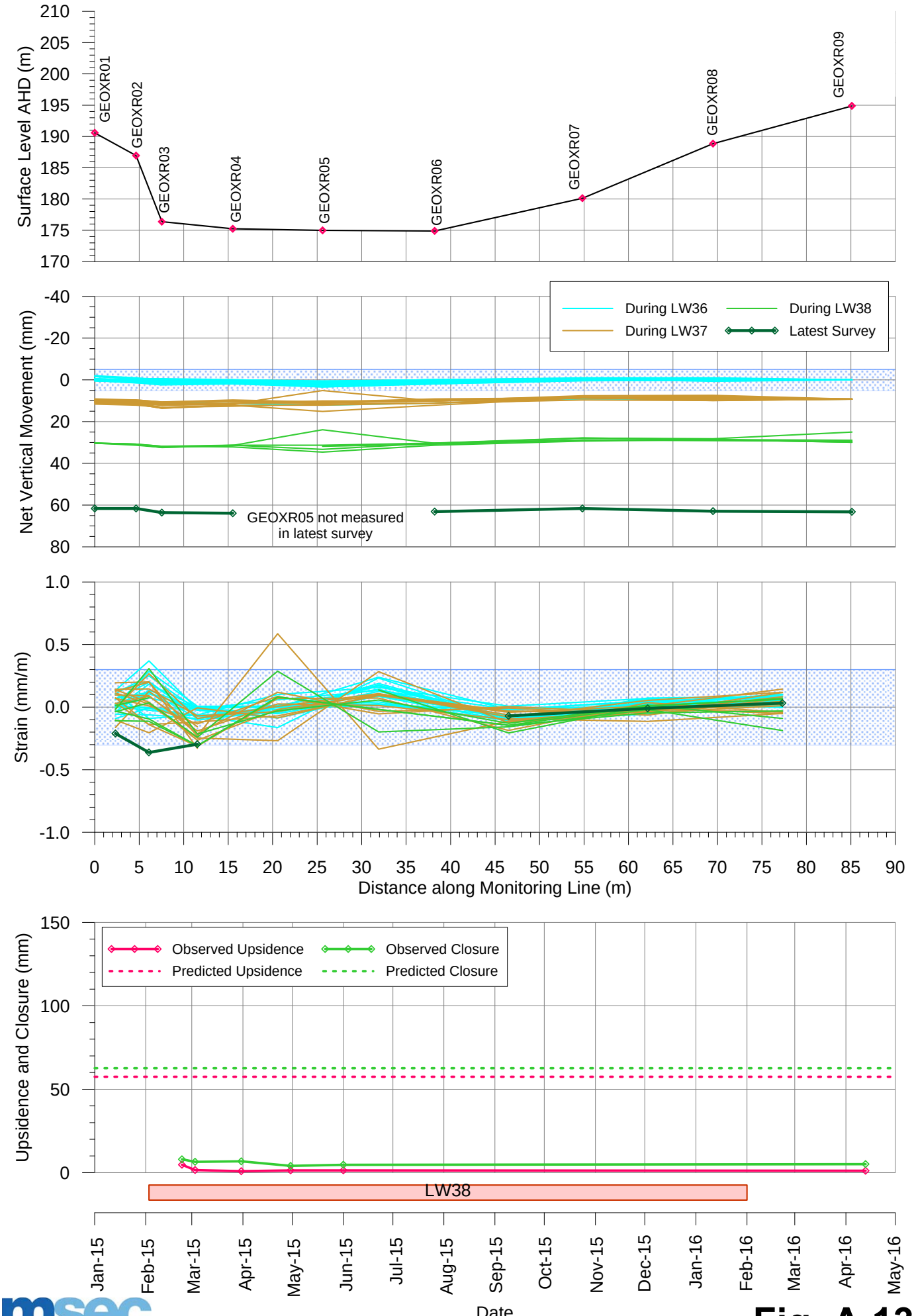

Fig. A.13

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the Exley Road Line during the Extraction of West Cliff LW38

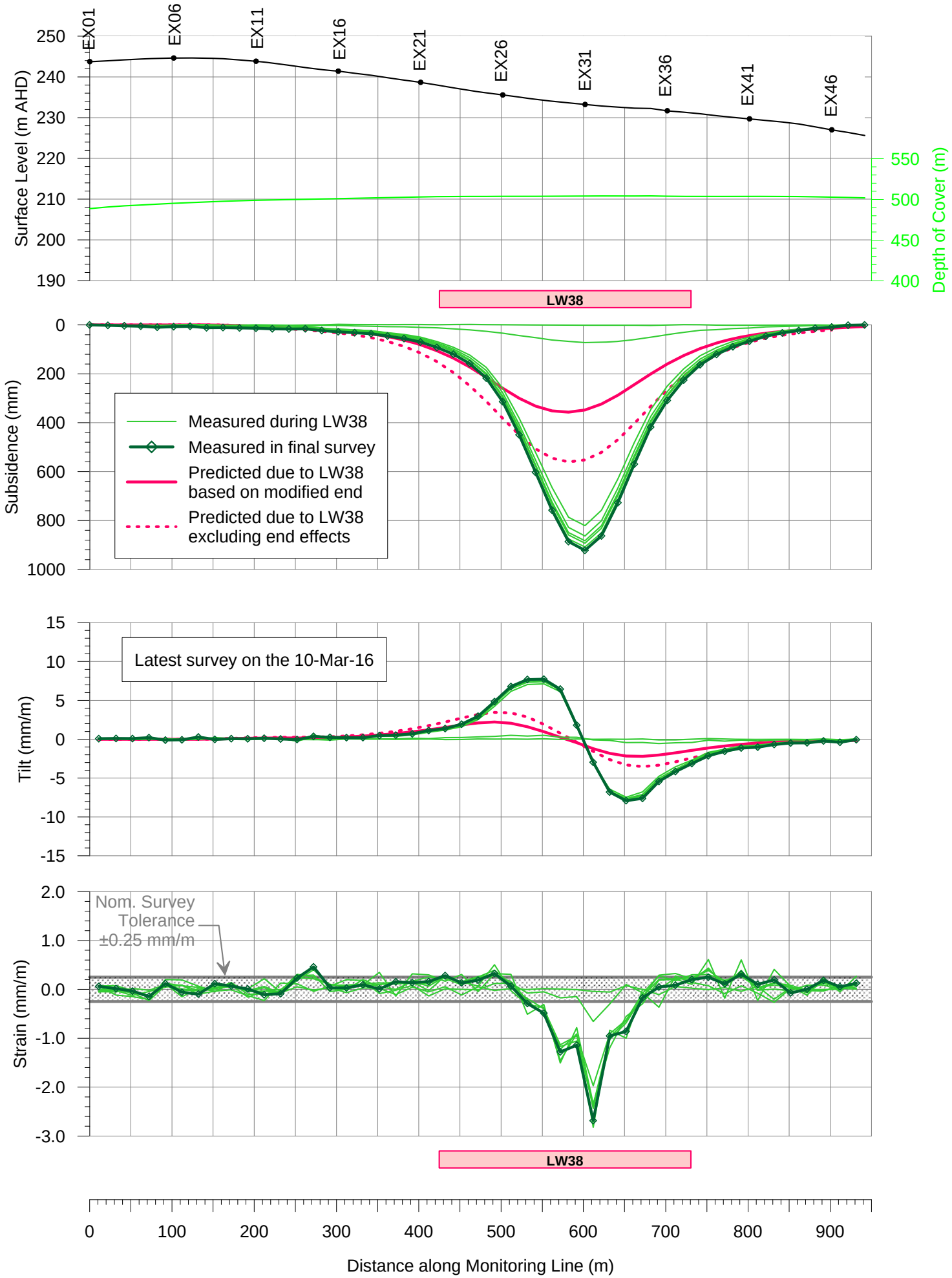

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Fig. A.14

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the Blackburn Road Line during the Extraction of West Cliff LW38

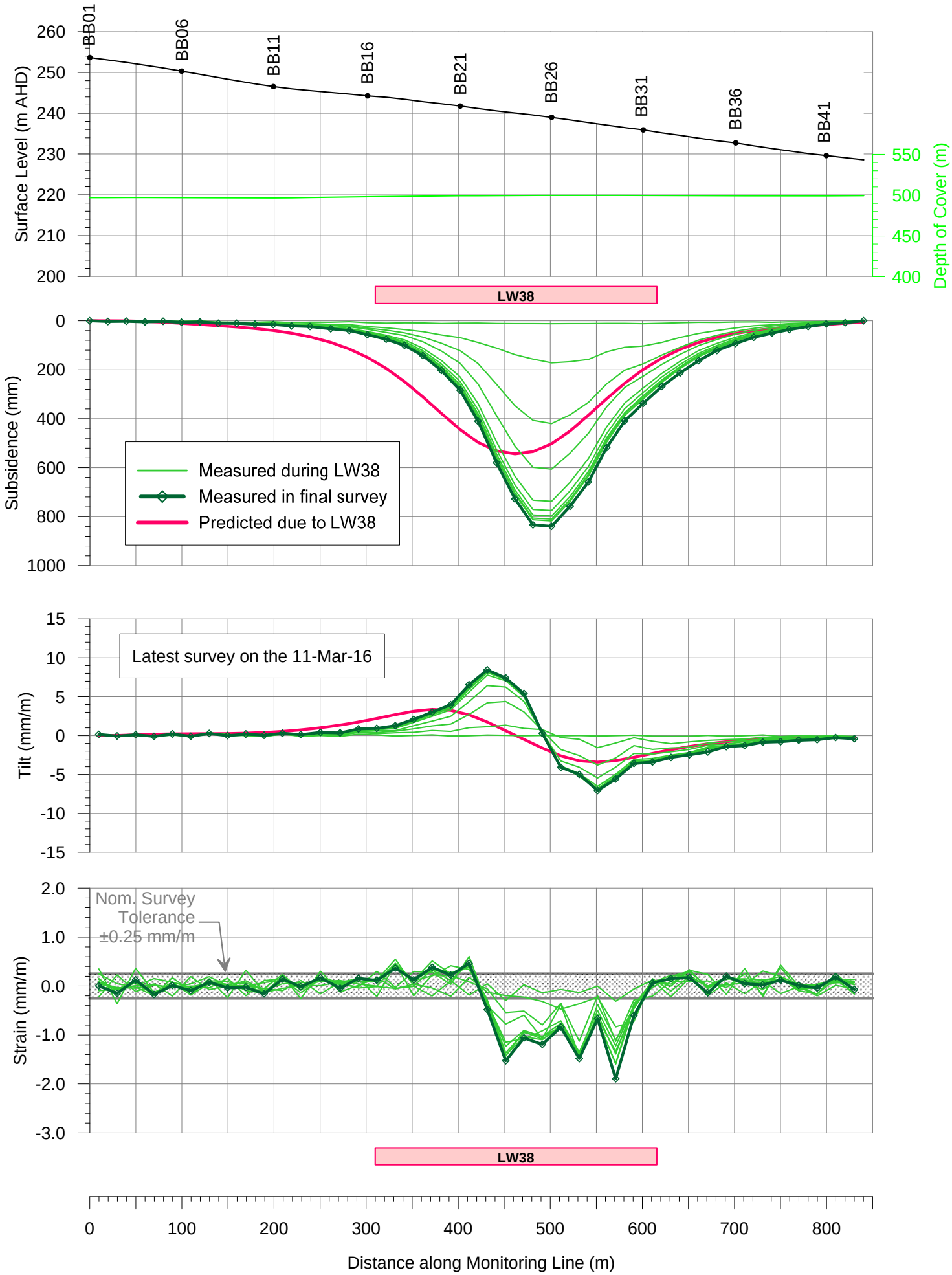

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Fig. A.15

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the Wedderburn Airfield Line during the Extraction of West Cliff LW38

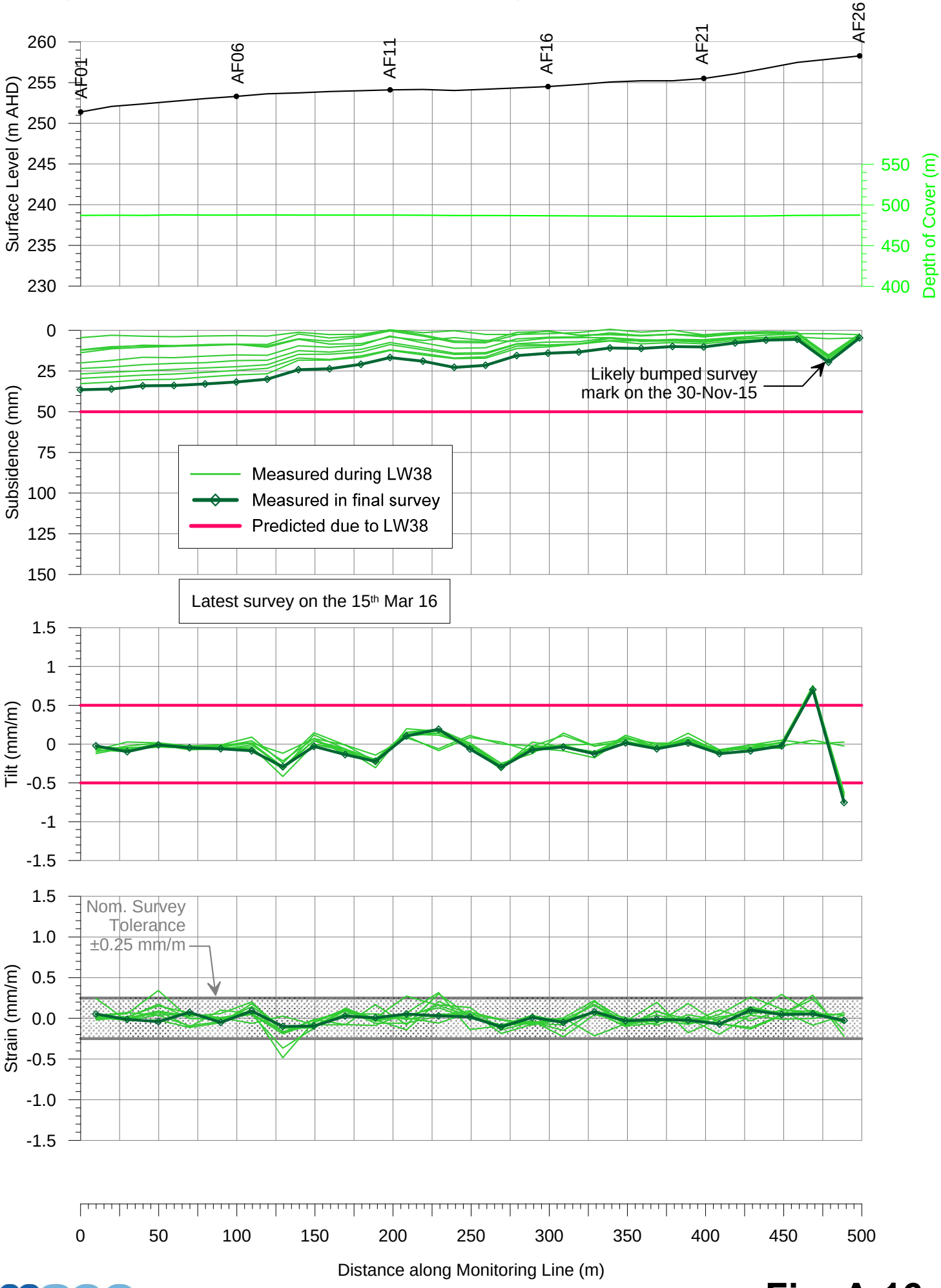

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Fig. A.16

APPENDIX B. DRAWINGS

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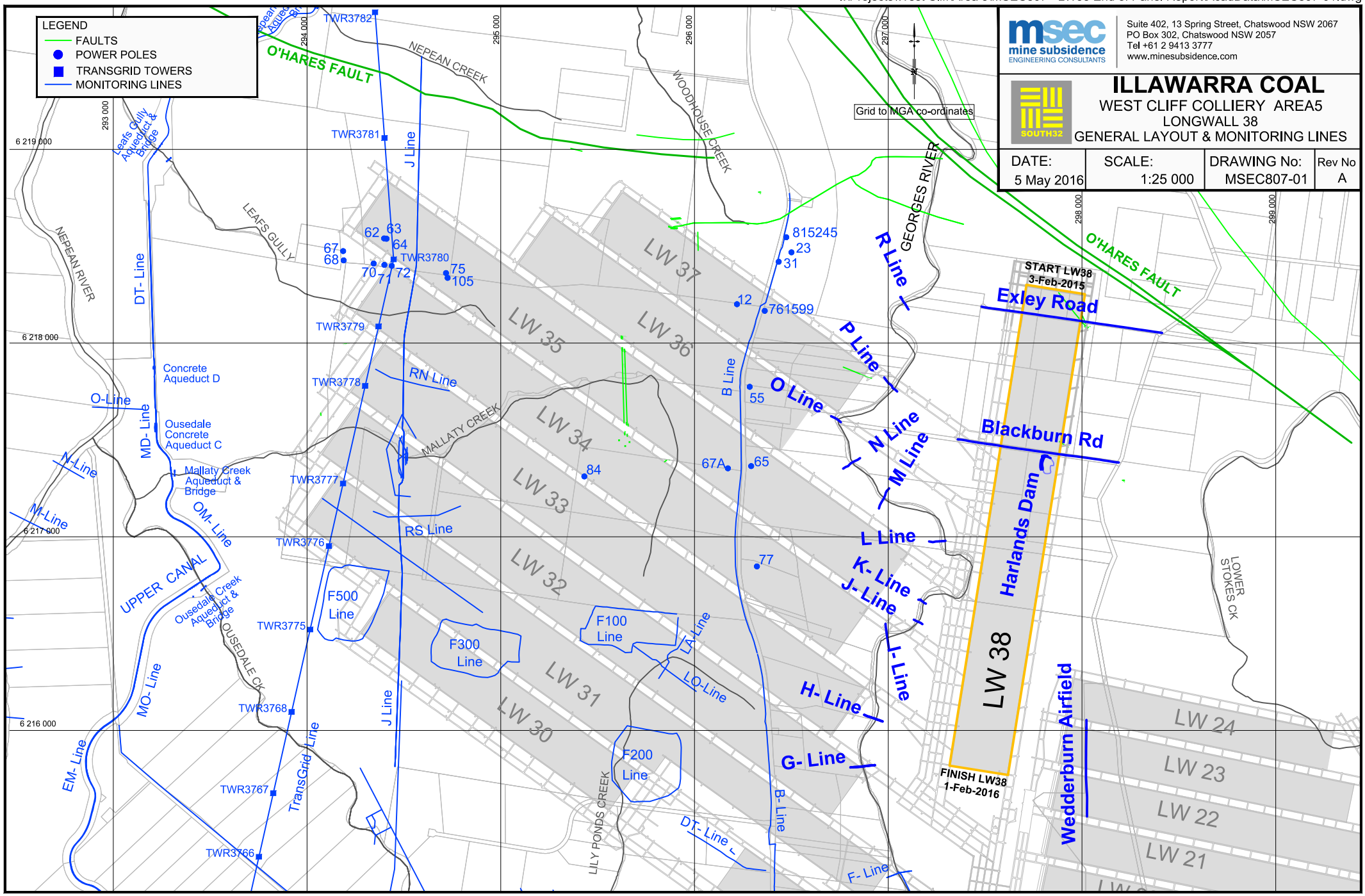

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SOUTH32

ILLAWARRA COAL

WEST CLIFF COLLIERY AREA5
LONGWALL 38
GENERAL LAYOUT & MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
5 May 2016	1:25 000	MSEC807-01	A

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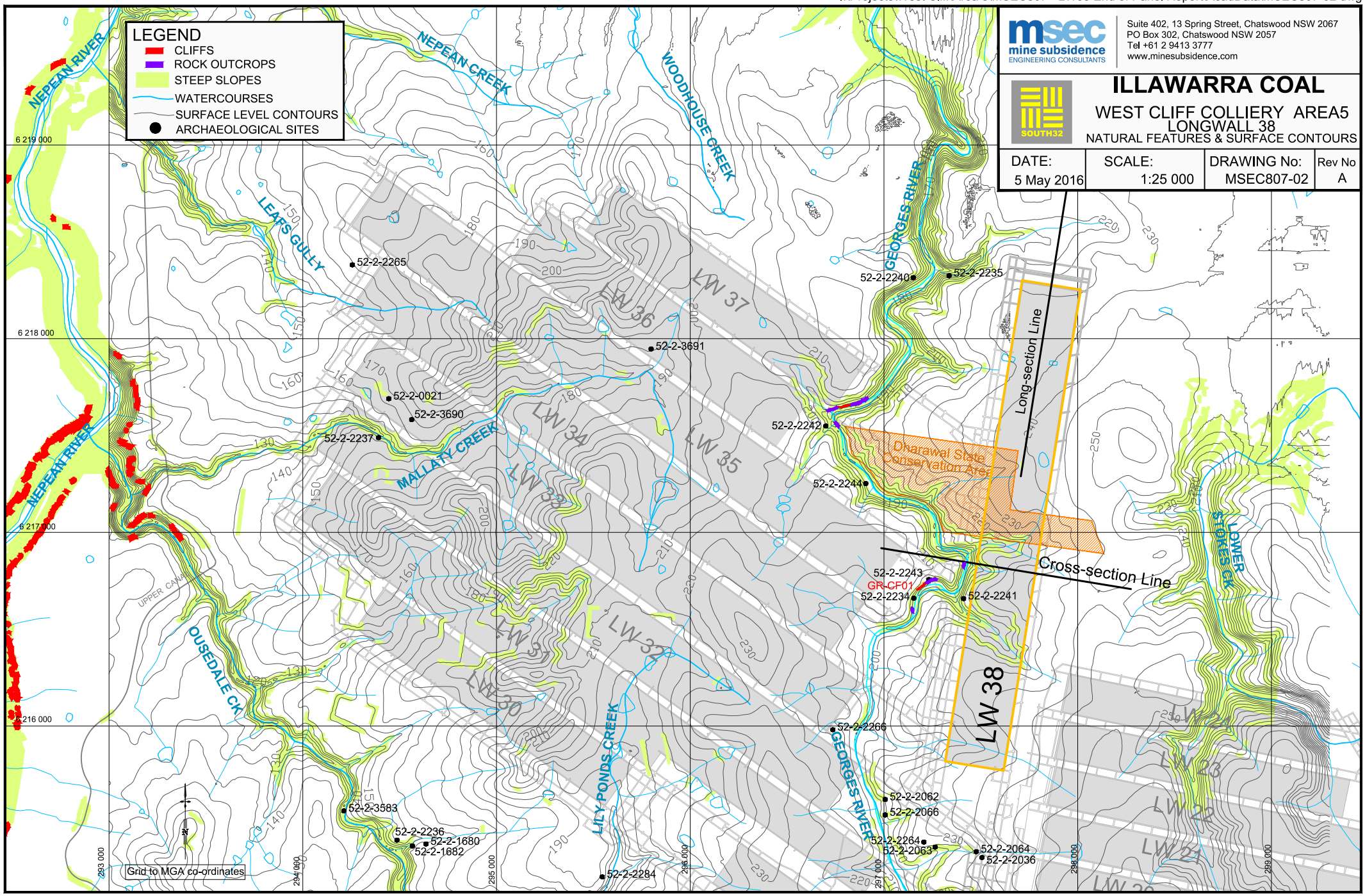

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WEST CLIFF COLLIERY AREA5
LONGWALL 38
NATURAL FEATURES & SURFACE CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
5 May 2016	1:25 000	MSEC807-02	A

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