Strata Control Technology

REPORT TO:

ASHTON UNDERGROUND MINE

Ashton Multi-Seam Subsidence Predictions
3D Extrapolation

ASH3852

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REPORT TO	Phil Fletcher Technical Services Manager Ashton Underground Mine PO Box 699 SINGLETON NSW 2330
SUBJECT	Ashton Multi-Seam Subsidence Predictions – 3D Extrapolation
REPORT NO	ASH3852
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EXECUTIVE SUMMARY

This report provides a three dimensional (3D) subsidence extrapolation of subsidence predictions for the Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seams at the Ashton Underground Mine. The subsidence predictions are an extrapolation based on two dimensional (2D) subsidence profiles developed in numerical caving models conducted by SCT Operations. The subsidence consists of single seam and multi-seam extraction.

The purpose of the subsidence extrapolation is to provide an estimation of the maximum subsidence and the pillar subsidence based on the numerical modelling results. The actual shape of the subsidence may vary from the modelled profiles.

The quantitative model outputs include:

- Differential subsidence contour plots for each seam,
- Cumulative subsidence contour plots for each seam in extraction order, and
- Surface topography after subsidence.

The primary outcomes of this study are as follows:

- The cumulative maximum subsidence for each seam of the multi-seam extraction is as follows:
    - The Pikes Gully Seam generally ranges from 0.6m to 1.6m depending on seam thickness and panel width,
    - The combined Pikes Gully and Upper Liddell Seams ranges from 2.2m to 3m,
    - The Upper Lower Liddell Seam combined with the Pikes Gully and Upper Liddell seams has maximum subsidence ranging from 3.6m to 4.3m, and
    - The Lower Barrett Seam further increases the cumulative maximum subsidence range for all four seams to 5m to 6.2m.

- The cumulative chain pillar subsidence for each seam of the multi-seam extraction is as follows:
  - The Pikes Gully Seam generally ranges from 0.05m to 0.2m,
  - The Upper Liddell Seam increases the cumulative chain pillar subsidence range to 0.5m to 0.6m,
  - The Upper Lower Liddell Seam increases the cumulative chain pillar subsidence ranges to 0.7m to 0.9m, and
  - The total chain pillar subsidence for the four seams including the Lower Barrett Seam ranges 1.6m to 1.7m.

SCT's deliverables from the subsidence extrapolation include:

- Differential and cumulative subsidence contour plots for Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seams,
- Topographic surface plots with subsidence for the cumulative subsidence of each seam,
- DXF of subsidence (differential and cumulative) for each seam, and
- DXF of surface topography post subsidence, cumulative after extraction of each seam.

Ongoing subsidence monitoring is recommended during multi-seam mining to provide the means for validating the approach used for subsidence predictions in this study. In addition to the current scope of subsidence monitoring, it is recommended to extend XL5 subsidence line west of Longwall 7 to investigate the angle of draw. The XL5 line is stopped by Bowmans Creek, however there is a "far field' line beyond Bowmans Creek which should capture this information. It is also recommended to extend the XL5 line to the eastern side of Glennies Creek to investigate movement across the creek. This could be a couple of pegs on the eastern side of the creek to provide a reference point for the XL5 line.

The Longwall 8 narrow longwall was not modelled for multi-seam subsidence as the FLAC modelling was based on panels 1-4. It is therefore recommended to locate a subsidence crossline across Longwall 8 to monitor and validate the subsidence predictions. There is a planned XL13 line that should capture the Longwall 8 subsidence.

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1. INTRODUCTION

This report provides a 3D subsidence extrapolation of subsidence predictions for the Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seams. The subsidence predictions are an extrapolation based on 2D subsidence profiles developed in numerical caving models conducted by SCT Operations. The subsidence consists of single seam and multi-seam extraction.

This subsidence extrapolation is to provide an estimation of the maximum subsidence and the pillar subsidence based on the numerical modelling results. The actual shape of the subsidence may vary from the modelled profiles.

This report consists of an extrapolation of FLAC 2D subsidence profiles only and does not include an assessment of tilt or strain. An assessment on these subsidence characteristics would be broad, as the actual shape of the profiles may vary, and is not included so as not to be misleading.

A validation of the predicted subsidence profiles for the Pikes Gully Seam has been conducted by comparison with extrapolated model subsidence and Longwall 1-7 subsidence data.

Ashton consists of eight nor-northeast orientated panels in each of the four target seams. The Upper Liddell Seam is offset from the Pikes Gully Seam to the west. The Upper Lower Liddell Seam is stacked with the Pikes Gully Seam while the Lower Barrett Seam is stacked with the Upper Liddell Seam. The mine plans for Ashton are presented in Figure 1.

2. METHODOLOGY

The 2D subsidence profiles were produced from numerical caving modelling of longwall extraction in FLAC 2D. The 2D profiles were then extrapolated to encompass the mine area creating the 3D subsidence surface. In-house code was developed to extrapolate the 2D subsidence profiles to 3D. The model consists of a grid with 10x10m elements encompassing the mine area. Subsidence was determined at each grid point and superimposed onto the topography.

Surfer 10 was used for manipulating the grid files and modelling the subsidence surfaces. Surfer 10 is a contouring and 3D surface mapping software package that facilitates the manipulation and presentation of 3D surfaces.

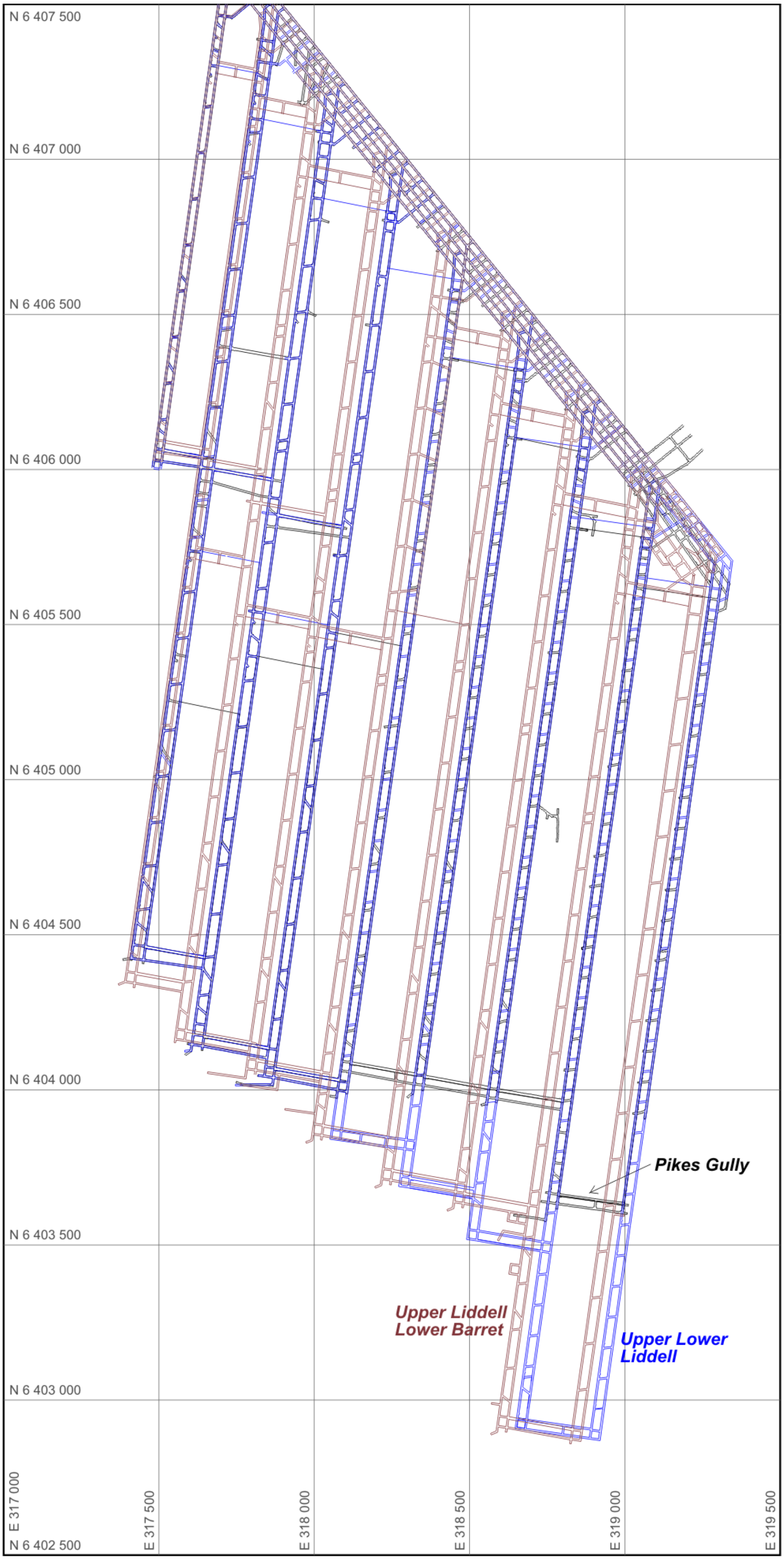


Figure 1: Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett mine plans.

2.1 Mine Data

Mine data (with file names) supplied by Ashton and used for the subsidence predictions included:

- Pikes Gully Mine Plan – "Ashton-Standard 110928.dwg"
- Upper Liddell/Lower Barrett Mine Plan – "Ashton_ULD_110614.dwg"
- Upper Lower Liddell Mine Plan – "ULLD_BAR.dxf"
- Pikes Gully RLs – "PGFLOOR.XYZ"
- Pikes Gully Seam Thickness – "PGTHICK.XYZ"
- Upper Liddell RLs – "ULDFLOOR.XYZ"
- Upper Liddell Seam Thickness – "ULDTHICK.XYZ"
- Upper Lower Liddell RLs – "ULLDFLOOR.XYZ"
- Upper Lower Liddell Seam Thickness – "ULLDTHICK.XYZ"
- Lower Barrett RL – "LBFLOOR.XYZ"
- Lower Barrett Seam Thickness – "LBTHICK.XYZ"
- Topography RLs – "TOPOGRAPHY.XYZ"

The seam extraction heights as outlined by Ashton personnel include a maximum extraction height of 3.0m and a minimum extraction height of 2.2m. Where the seam thickness is between this maximum and minimum, the seam thickness was adopted as the extraction height.

2.2 Geological Characterisation

The four target seams dip at approximately 5 degrees to the west over the mine area. The overburden depth is a combination of surface topography and seam dip, with seam dip comprising the majority of overburden depth variation. There is approximately 50m of natural topographic variation over the mine area.

The overburden depth range for the Pikes Gully Seam over the mine area is approximately 40-180m. For the Upper Liddell Seam the overburden depth ranges approximately 80-220m. The Upper Lower Liddell and Lower Barrett Seams have overburden depths approximately ranging 100-260m and 150-290m, respectively.

The relationship between the surface topography and the seam RLs is presented in Figure 2.

The Pikes Gully seam thickness is generally within the maximum 3m and minimum 2.2m extraction heights, except for the far north and southern extents of the mine plan where the seam thickness is less than the minimum 2.2m extraction height. The Pikes Gully Seam extraction height contours for the seam are presented in Figure 3.

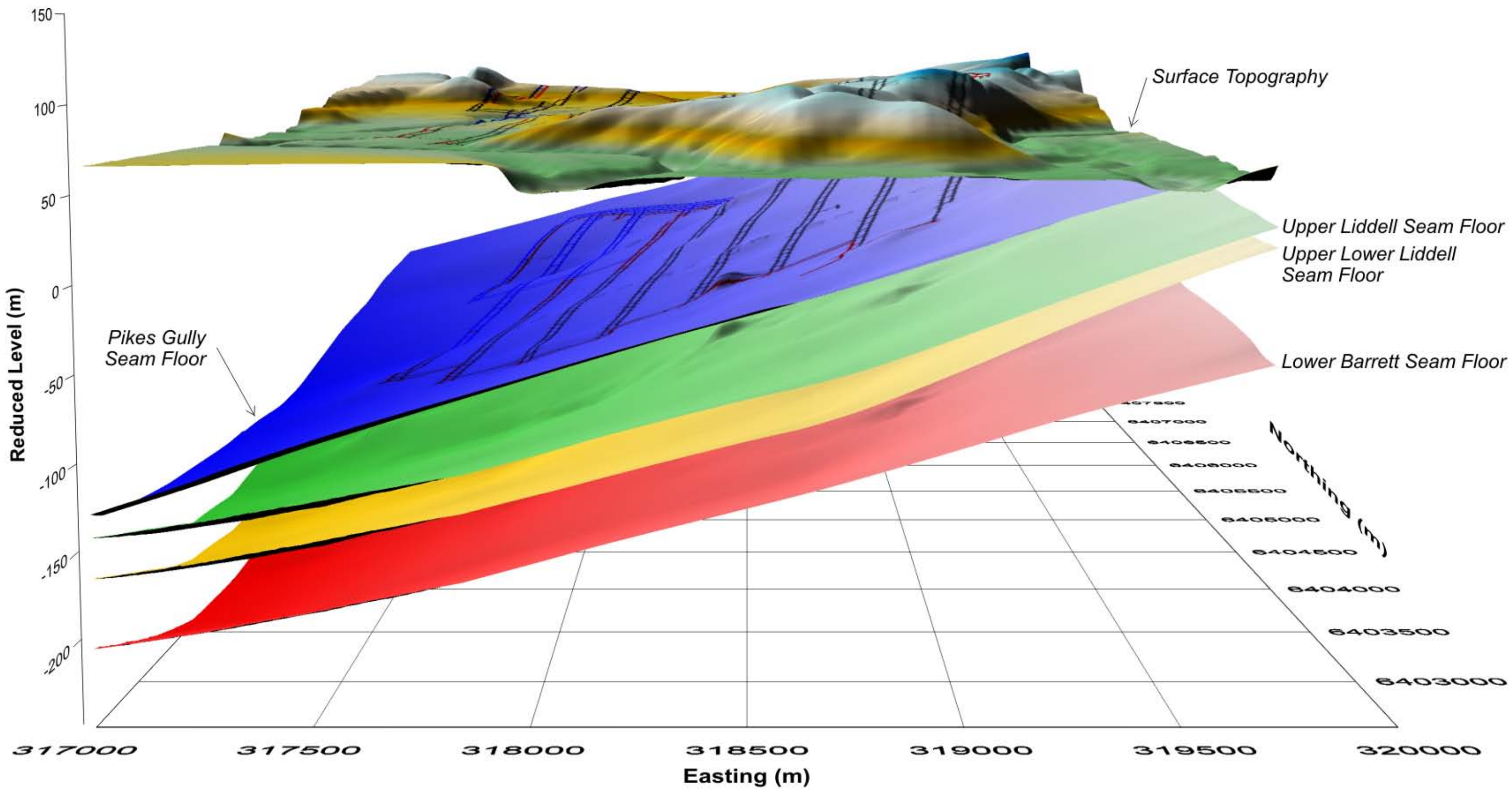


Figure 2: Relationship between surface topography and seam RL *(vertical exaggeration x 4).*

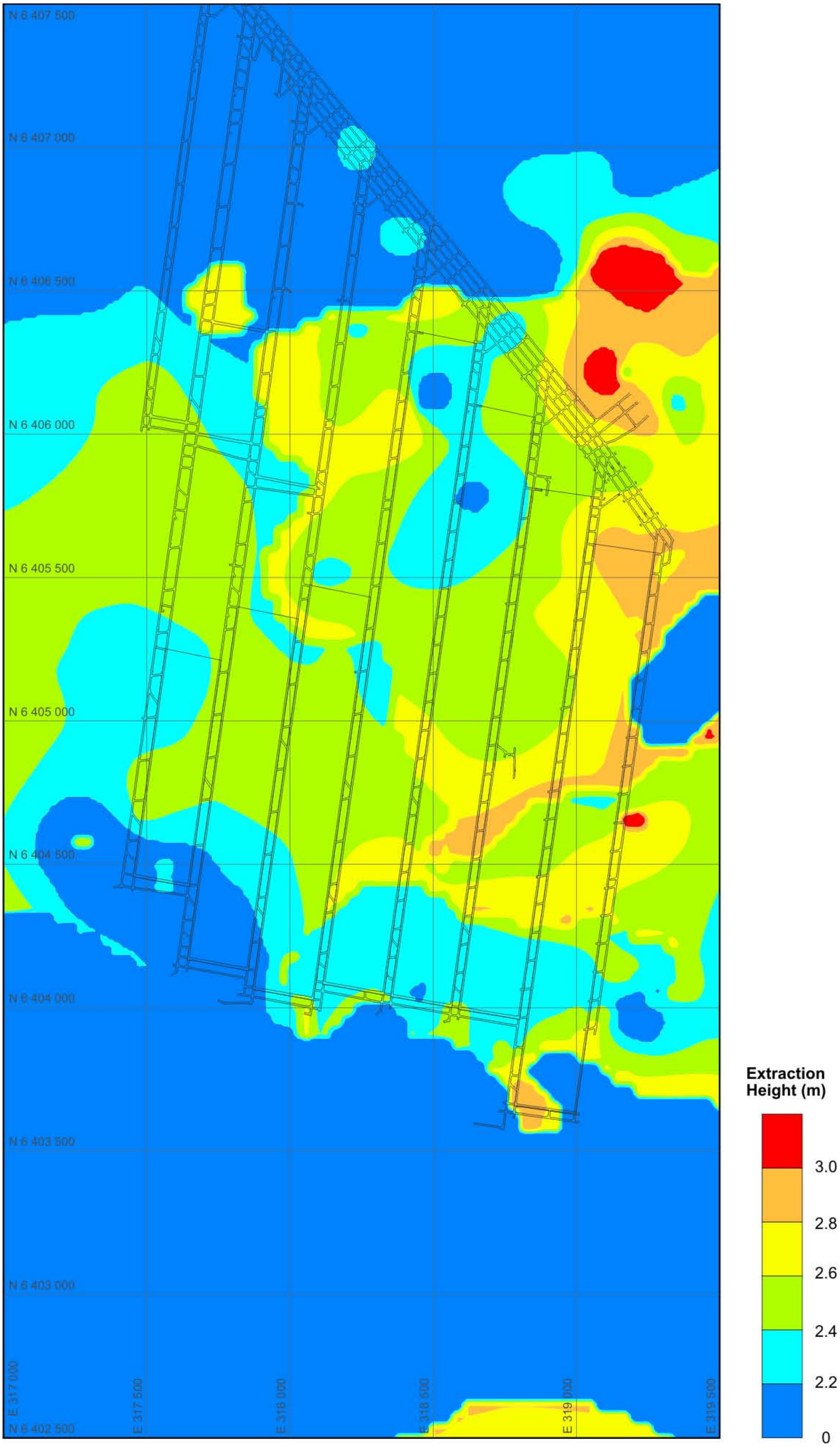


Figure 3: Pikes Gully Seam extraction height.

The Upper Liddell Seam has a large area of seam height below the 2.2m minimum extraction height. The seam thickens to the southeast and to the northwest, where it reaches beyond maximum extraction height of 3m. The Upper Liddell Seam extraction height contours are presented in Figure 4.

The Upper Lower Liddell Seam height is generally less than the 2.2m minimum extraction height. There is a small area above the minimum height throughout the centre of the mining area. The Upper Liddell Seam extraction height contours are presented in Figure 5.

The Lower Barrett Seam thickness is mostly greater than the 2.2m minimum extraction height with a large proportion in the northern half above the 3m maximum extraction height. The Lower Barrett Seam extraction heights are presented in Figure 6.

The geological sections that the numerical caving models are based on are from Boreholes WML007 and WML009 as the available data from these holes was considered representative of the mine area at the time of the FLAC 2D numerical modelling study. The model layers from the numerical caving model are presented in Figure 7.

2.3 Subsidence Profiles

The subsidence profiles were developed from numerical caving models of the multi-seam extraction of the Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seams. The model approach and results are outlined in SCT Report (ASH3560a_Final). The numerical caving model provided the cumulative subsidence for each seam extracted. The FLAC 2D results are presented in Figure 8. The previous subsidence was subtracted to provide the additional subsidence for each seam as presented in Figure 9.

Subsidence was determined for each seam individually and then combined to create the cumulative subsidence from the extraction of each additional seam. Longwall panels were identified as single or multi-seam extraction panels and subsidence applied accordingly. For single seam subsidence, a maximum and minimum depth range is required for the subsidence to be distributed proportionally over the depth range.

Where multi-seam subsidence exists, one subsidence profile fits all overburden depths as the depth range to the overlying seam is consistent and supercritical. There is some variation in the incremental subsidence profiles, namely Lower Barrett Seam in Figure 9c, however this variation occurs both naturally and in the model as observed when compared with the adjacent longwall panels. The adjacent panels have the same geometry and geology in the model making it difficult to predict. For this reason, the variation is not included in the extrapolation.

The Pikes Gully Seam consists of single seam subsidence only. The Upper Liddell Seam consists primarily of multi-seam extraction with areas of single seam extraction. The Upper Lower Liddell and Lower Barrett Seams consist entirely of multi-seam extraction.

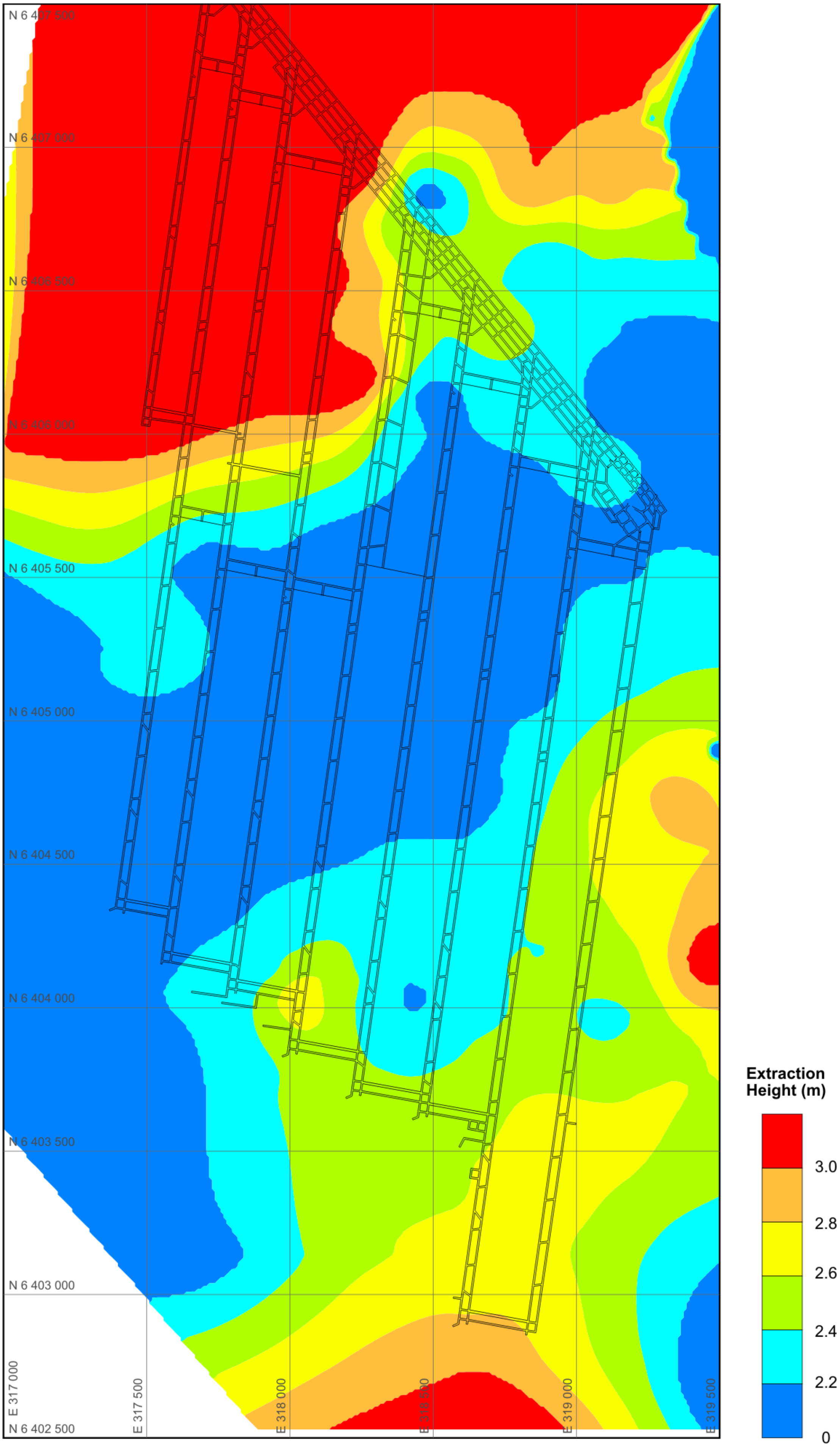


Figure 4: Upper Liddell Seam extraction height.

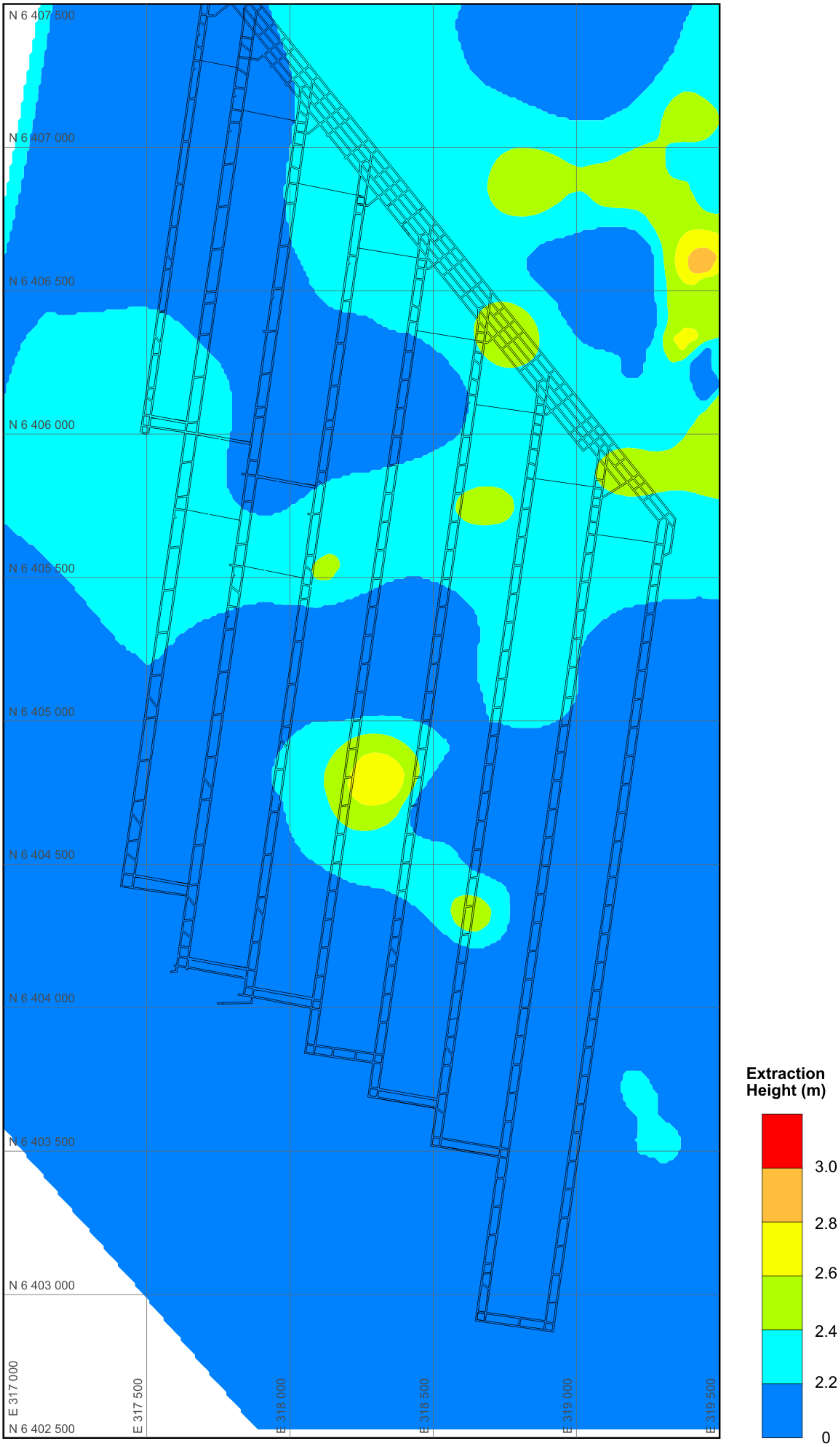


Figure 5: Upper Lower Liddell Seam extraction height.

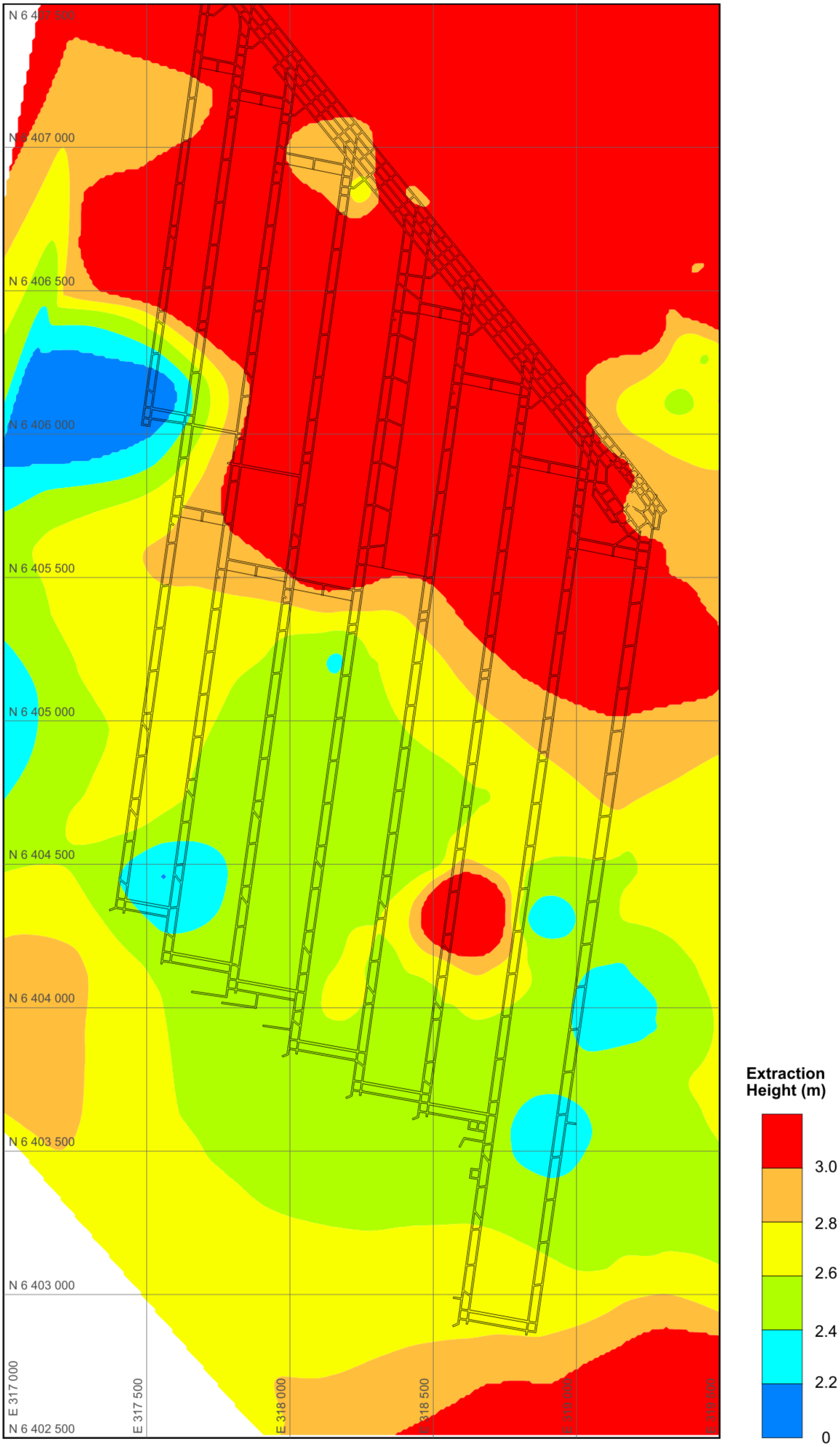


Figure 6: Lower Barrett Seam extraction height

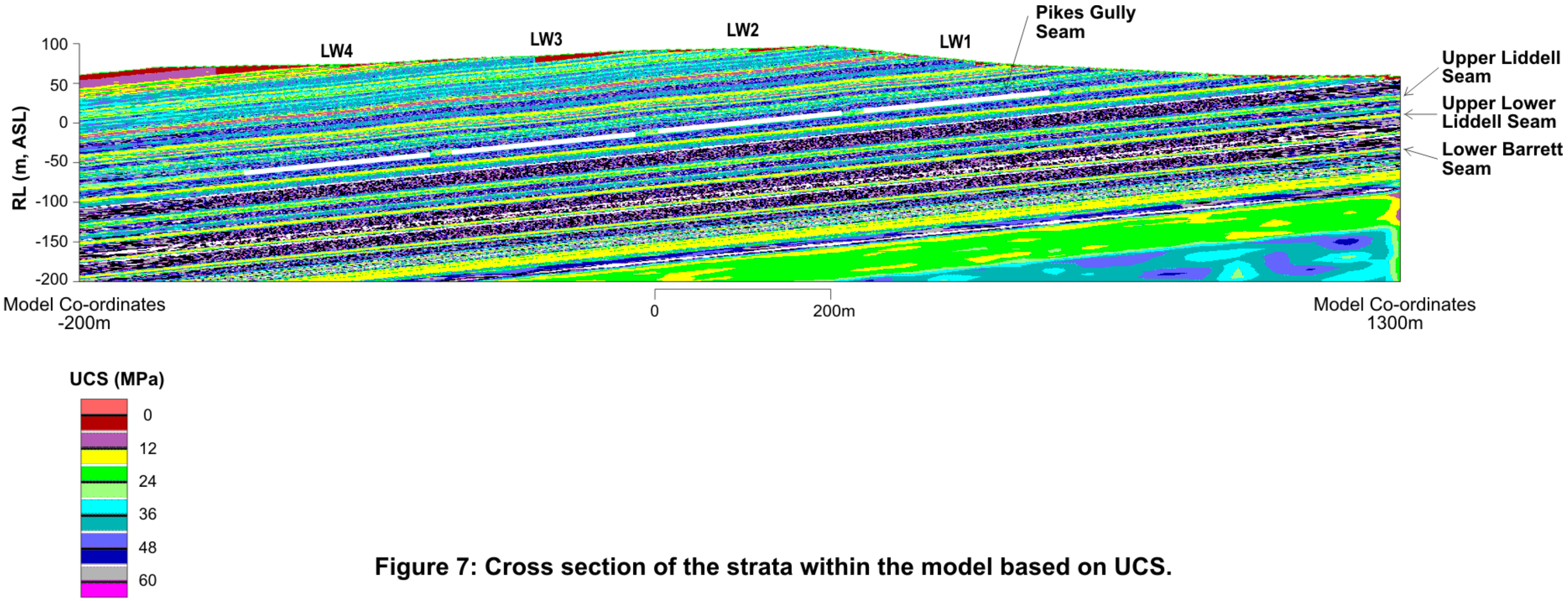


Figure 7: Cross section of the strata within the model based on UCS.

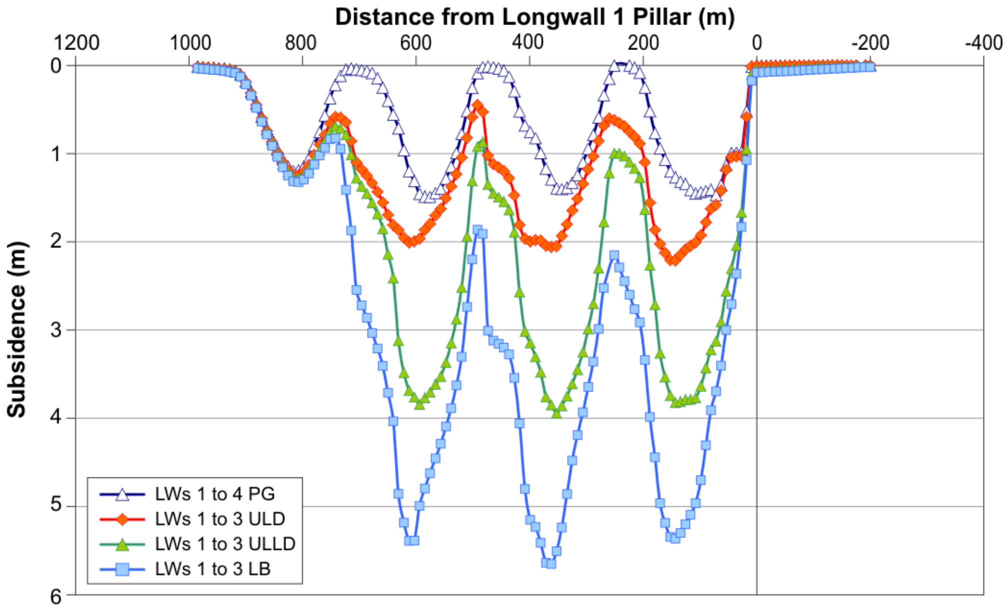
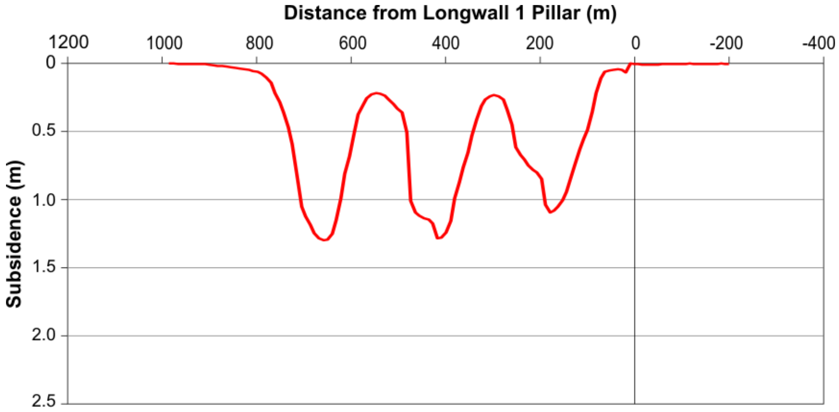
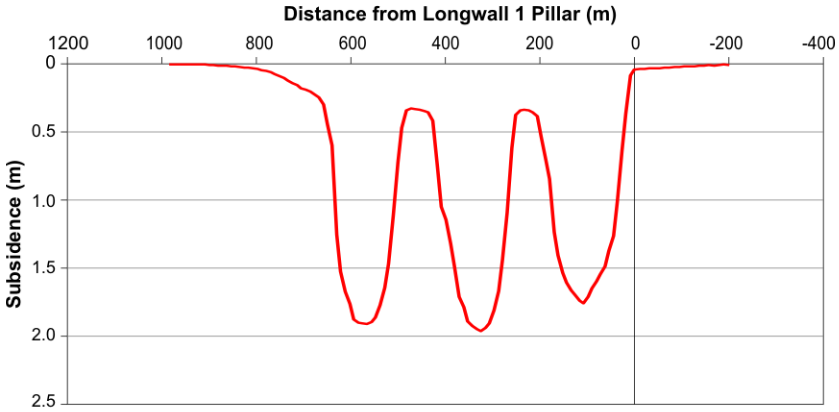


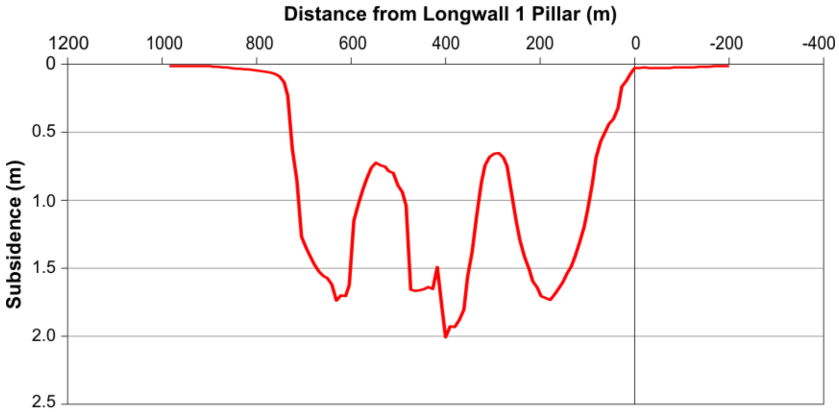
Figure 8: Cumulative subsidence from FLAC 2D caving model.



a) Upper Liddell Seam.



b) Upper Lower Liddell Seam.



c) Lower Barrett Seam.

Figure 9: Incremental subsidence for each seam.

Each seam has specific subsidence profiles outlined in the following sections.

2.3.1 Pikes Gully Seam

Each longwall width and seam height for the Pikes Gully Seam has two subsidence profiles representing two overburden depths. The Longwall 1 to 6 profiles are at 40m and 190m overburden depths for both 2.2m and 3.0m extraction heights.

The profiles are based on the Longwall 1-6 Pikes Gully observed subsidence data, including maximum subsidence, pillar subsidence and angle of draw, and use the shape of the FLAC 2D model profile.

The maximum subsidence to "panel width to depth" relationship used in this study is presented in Figure 10. The upper range of maximum subsidence was adopted so as not to underestimate the subsidence. Current Ashton data does not reach lower panel width to depth ratios, so a typical relationship was used and is illustrated on Figure 10.

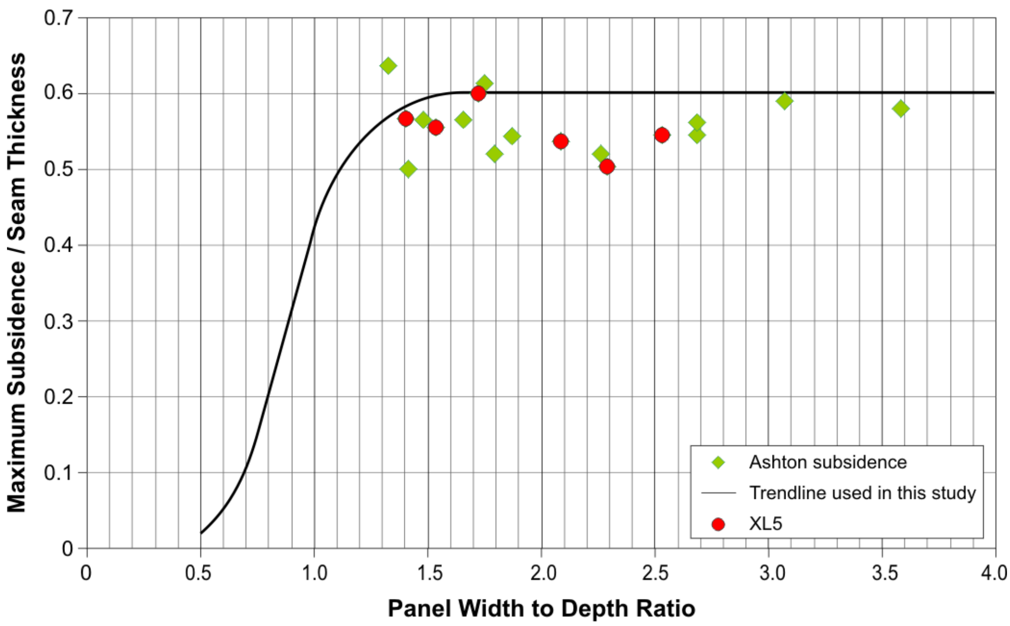


Figure 10: Maximum subsidence for Longwalls 1-7.

Chain pillar subsidence across the XL5 subsidence line is presented in Figure 11. Two trends are depicted from the data to best represent the trend for shallow and deep overburden depths. The linear trend is used for shallower depths while the polynomial trend is used for greater depths. This trend is used to determine the chain pillar subsidence for the "shallow" and "deep" subsidence profiles. The nature of the 3D extrapolation generates a linear trend between these two points, which can overestimate the chain pillar subsidence by up to 60mm between the two profiles.

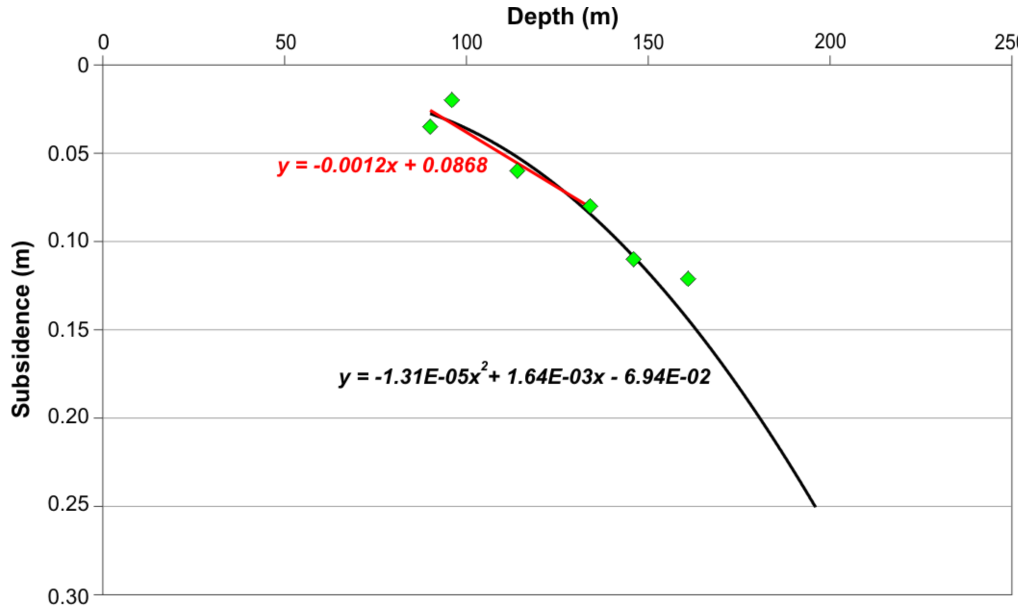


Figure 11: Chain pillar subsidence for XL5 subsidence line.

Angle of draw data from Ashton shows an increasing trend with increasing depth as presented in Figure 12. A linear trend through this dataset is used to determine angle of draw for the Pikes Gully Seam.

Subsidence profiles based on the above characteristics for Longwalls 1 to 6, Longwall 7 and Longwall 8 narrow longwall are presented in Figure 13, Figure 14 and Figure 15, respectively. The Longwall 8 narrow longwall pillar subsidence is based on the results in SCT's Report on Ashton mini walls (ASH3536).

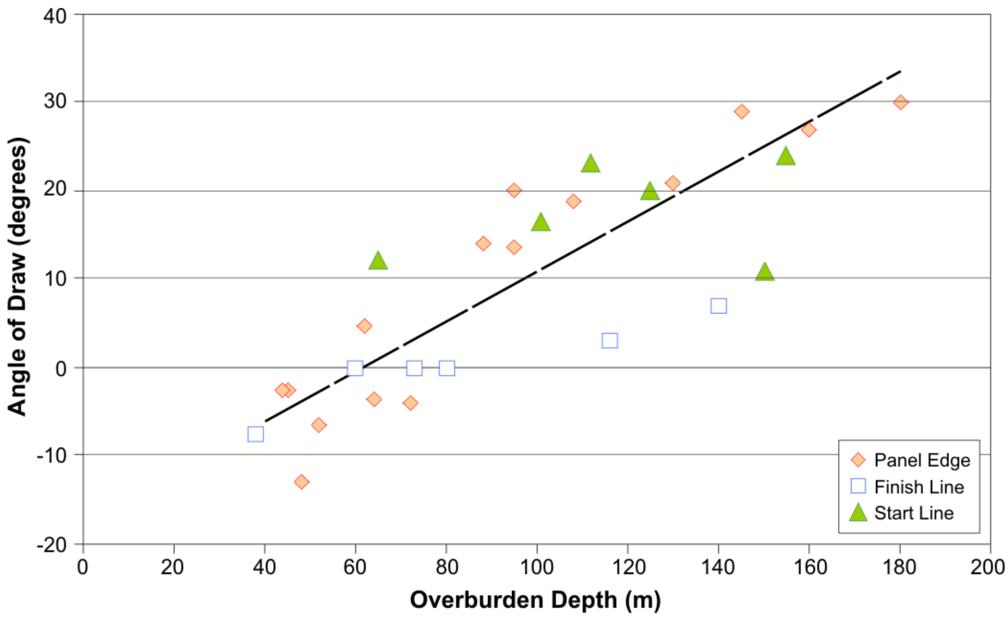
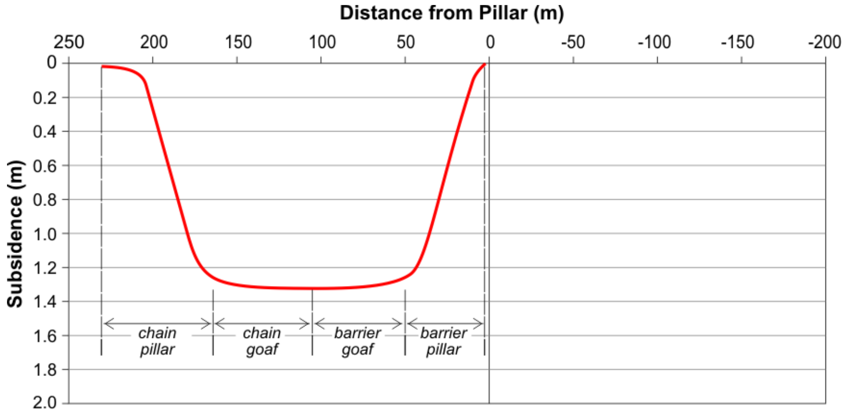
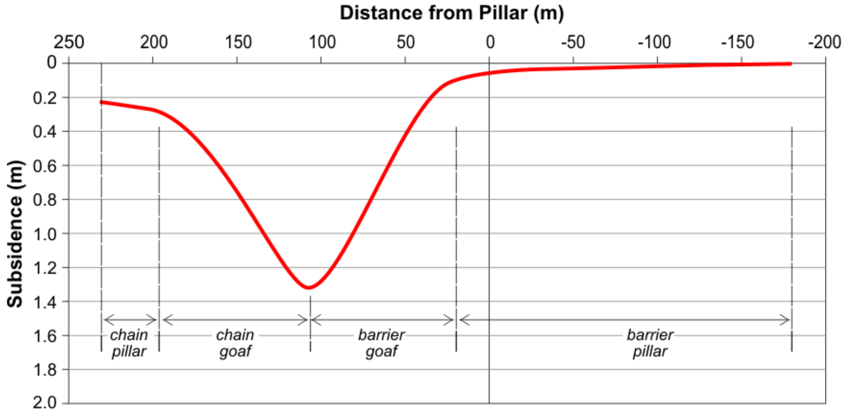


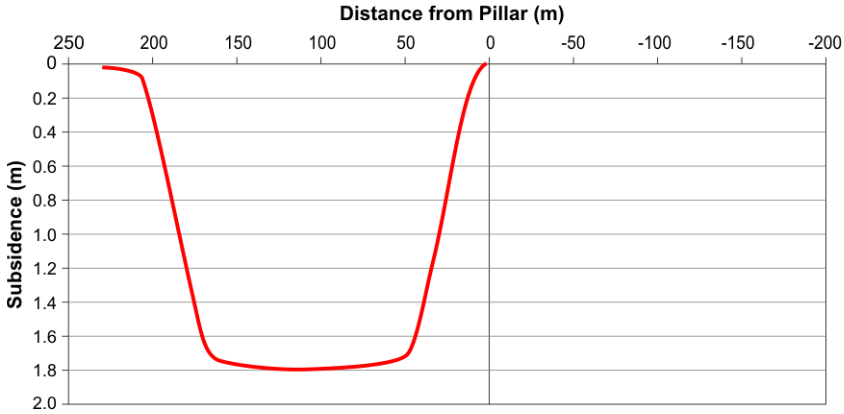
Figure 12: Relationship between angle of draw measured at Ashton and overburden depth.



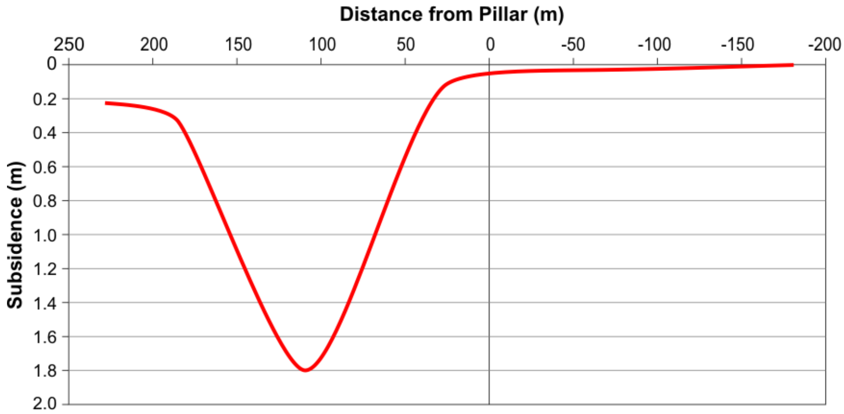
a) 2.2m seam, 40m overburden depth.



b) 2.2m seam, 190m overburden depth.

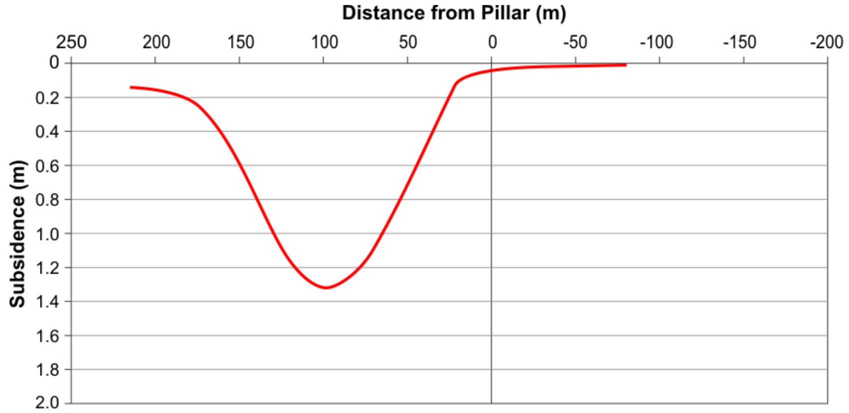


c) 3.0m seam, 40m overburden depth.

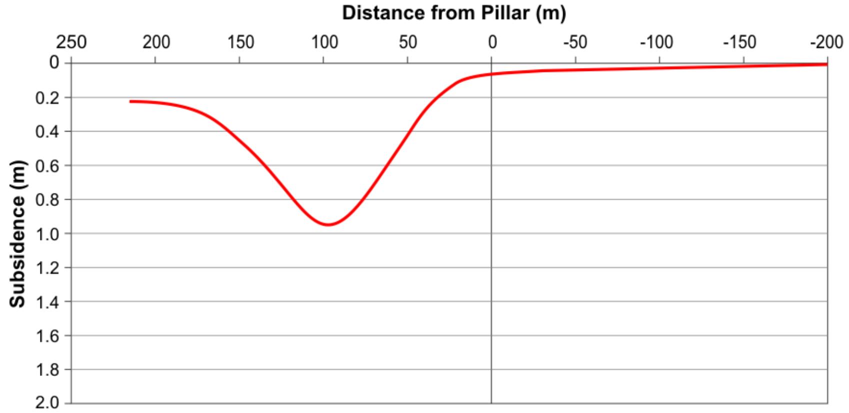


d) 3.0m seam, 190m overburden depth.

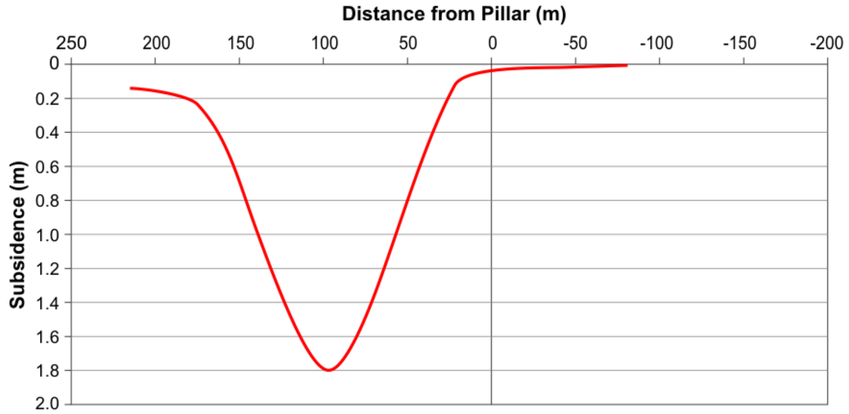
Figure 13: Subsidence for Pikes Gully Seam for Longwalls 1 - 6.



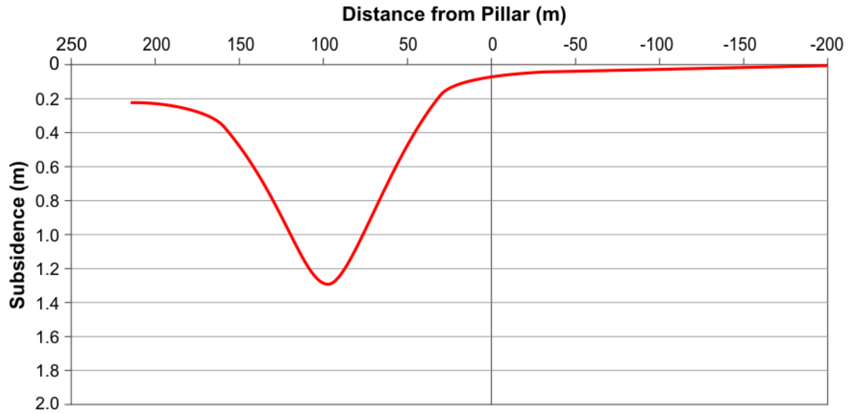
a) 2.2m seam, 130m overburden depth.



b) 2.2m seam, 190m overburden depth.

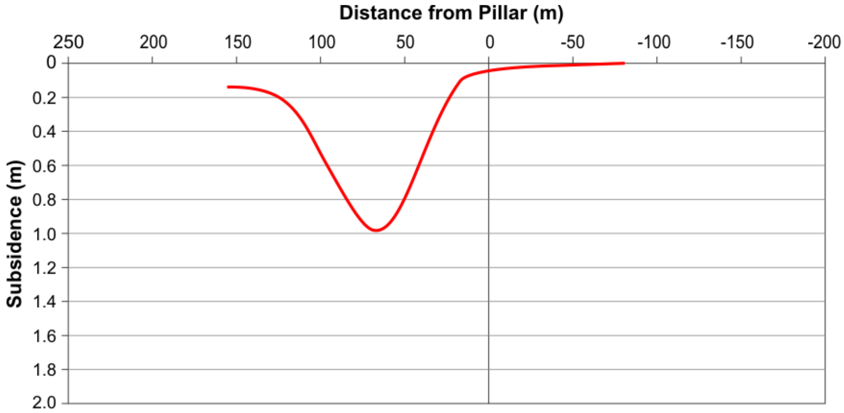


c) 3.0m seam, 130m overburden depth.

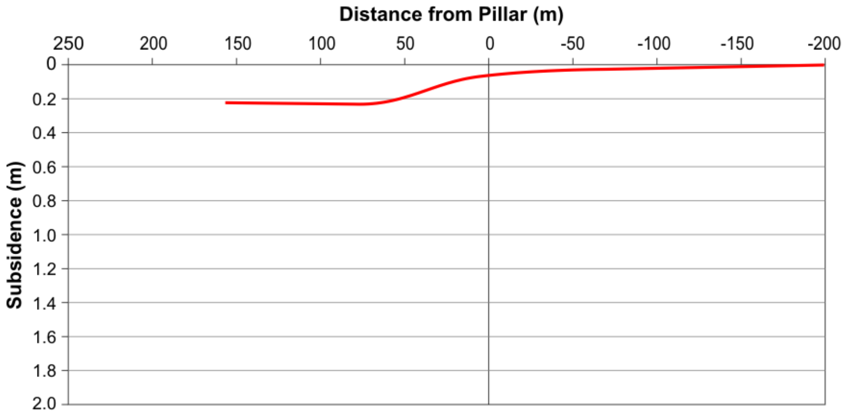


d) 3.0m seam, 190m overburden depth.

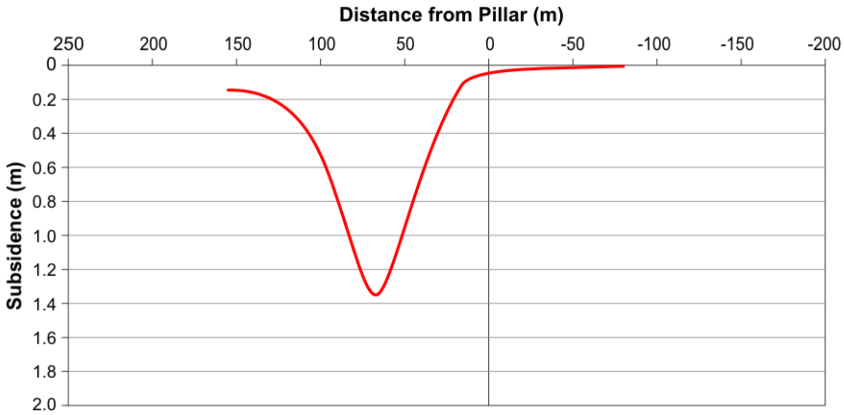
Figure 14: Subsidence for Pikes Gully Seam for Longwall 7.



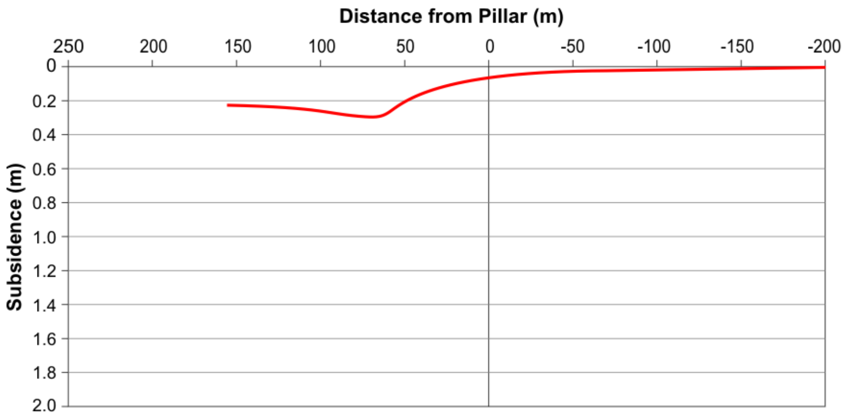
a) 2.2m seam, 130m overburden depth.



b) 2.2m seam, 190m overburden depth.



c) 3.0m seam, 130m overburden depth.



d) 3.0m seam, 190m overburden depth.

Figure 15: Subsidence for Pikes Gully Seam for Longwall 8.

Longwalls were assessed in separate groups characterised by their panel width. Longwalls 1-6 were assessed together while Longwall 7 and Longwall 8 were assessed separately.

For Longwalls 1-6 the subsidence is supercritical and the maximum subsidence is 1.3m for the 2.2m seam thickness, while for the 3.0m seam thickness the maximum subsidence is 1.8m. The subsidence over the barrier pillars for 40m overburden depth is zero as the angle of draw is negative, while the subsidence over the chain pillar for 40m depth is <0.1m. The subsidence over the pillars for 190m overburden depth is 0.2m for the chain pillars and <0.1m for the barrier pillars.

For Longwall 7 the subsidence ranges from critical to subcritical. For a 2.2m thick seam, the maximum subsidence is 1.3m for 130m depth and 1m for 190m overburden depth. For a 3.0m thick seam the maximum subsidence ranges from 1.8m for 130m depth to 1.3m for 190m depth. The chain pillar subsidence for Longwall 7 is approximately 0.2m while the barrier pillar subsidence is <0.1m.

For Longwall 8 the subsidence is subcritical with maximum subsidence for a 2.2m thick seam ranging from 1m at 130m overburden depth to 0.2m for 190m. For a 3.0m seam, the subsidence ranges from 1.4m for 130m depth to 0.5m for 190m depth. Chain pillar subsidence is about 0.2m while barrier pillar subsidence is <0.1m.

Polynomial equations were fitted to the 2D subsidence profiles for the purpose of 3D extrapolation. Equations were established covering the variation in longwall width, seam height, overburden depth and pillar type. The profiles were characterised by two equations to formulate the best profile fit. The two equations namely cover the pillar and goaf sections of the subsidence profile for both chain and barrier pillars as illustrated in Figures 13a and 13b. The depicted regions indentify the equation limits, not the actual pillar and goaf locations.

The following 6 order polynomial equation was used for the Pikes Gully Seam profiles:

$$y = ax^6 + bx^5 + cx^4 + dx^3 + ex^2 + fx + g$$

where a, b, c, d, e, f and g coefficients are tabulated in Table A1.1 in Appendix 1 and x is the distance into the goaf from the pillar edge. The maximum and minimum x values (distances into goaf) for each equation are also outlined in Table A1.1 in Appendix 1.

2.3.2 Upper Liddell Seam

The Upper Liddell Seam consists of single seam and multi-seam extraction panels. The profiles for the Upper Liddell Seam multi-seam extraction are based on the FLAC 2D modelling of the 2.2m seam. For single seam extraction of Longwalls 1-6, 80m and 220m depth profiles were created. For single seam extraction of Longwall 7, a 180m depth profile was used.

The characteristics for single seam extraction were based on the Ashton subsidence dataset as outlined previously in Section 2.3.1.

For the multi-seam subsidence, profiles were created for the different panel widths, however the maximum subsidence and profile shape remains the same and is depicted from the FLAC 2D modelling. The subsidence profiles for the Upper Liddell Seam Longwalls 1-6 are presented in Figure 16, while Longwalls 4b, 7 and 8 are presented in Figure 17.

The maximum incremental subsidence for the Upper Liddell multi-seam extraction is consistent at 1.3m. The maximum subsidence is also 1.3m for the supercritical panels of the single seam extraction for Longwalls 1-6 at 80m and 220m overburden depth. The maximum subsidence for single seam extraction of Longwalls 4b and 7 is 0.7m at 180m depth. The barrier pillar subsidence is equal to or less than 0.1m for all profiles while the chain pillar subsidence is 0.2m for multi seam extraction and for single seam extraction is <0.1m for 80m depth, 0.4m for 220m depth and 0.3m for 180m depth.

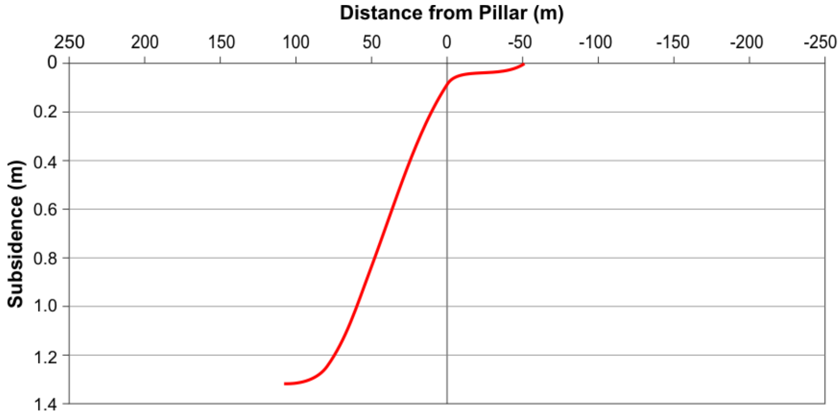
For 3.0m seam thickness, the subsidence inside the panels was multiplied by 1.36, leaving the pillar subsidence the same. This gives a maximum subsidence of 1.8m for Longwalls 1-6. The 3m extraction height subsidence is proportional to the 2.2m extraction height subsidence as subsidence is directly proportional to seam thickness and incremental subsidence is internationally recognised as subsidence/extraction height (Whittaker and Reddish, 1989).

Polynomial equations were fitted to the 2.2m subsidence profiles for the purposes of 3D extrapolation. Equations were established for each profile covering the variation in longwall width, seam height, singe/multi-seam extraction, overburden depth and pillar type. The profiles were characterised by two equations to formulate the best profile fit. The two equations namely cover the pillar and goaf sections of the subsidence profile for both chain and barrier pillars, similar to the Pikes Gully Seam examples in Figures 13a and 13b.

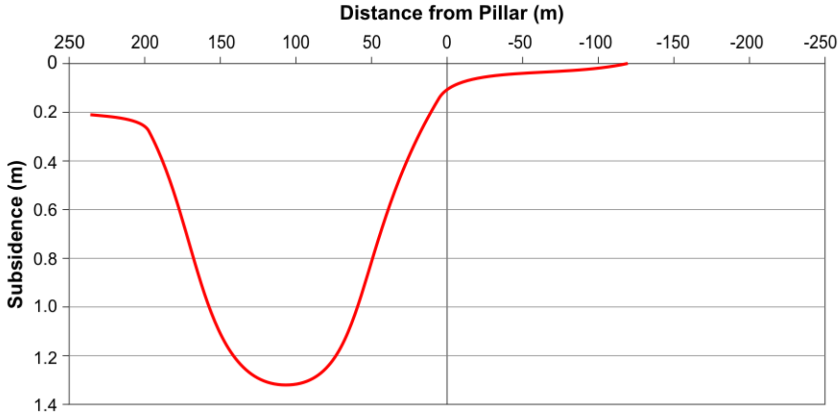
The following 5 order polynomial equation was used for the Upper Liddell Seam profiles:

$$y = ax^5 + bx^4 + cx^3 + dx^2 + ex + f$$

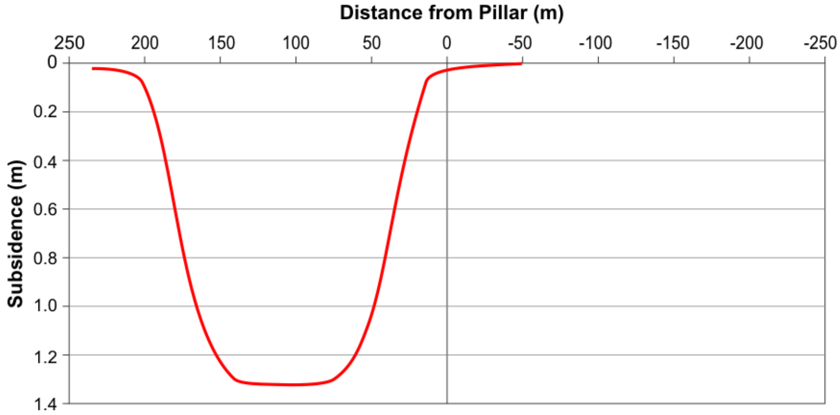
where a, b, c, d, e and f coefficients are tabulated in Table A1.2 in Appendix 1 and x is the distance into the goaf from the pillar edge. The maximum and minimum x values (distances into goaf) for each equation are also outlined in Table A1.2 in Appendix 1.



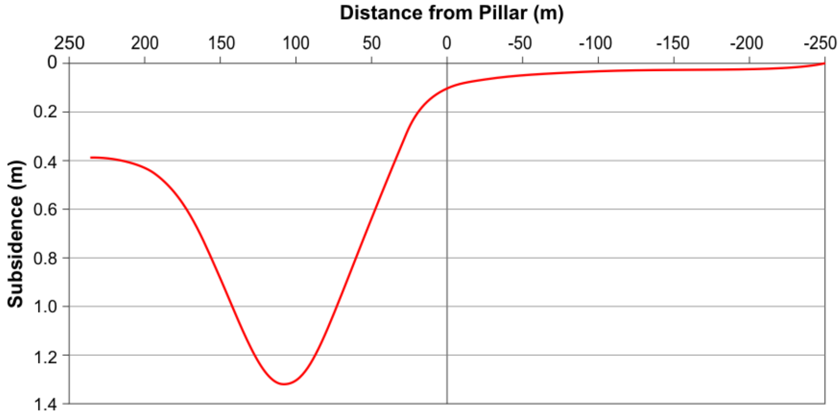
a) Tailgate 1 - multiseam subsidence.



b) Multiseam subsidence.

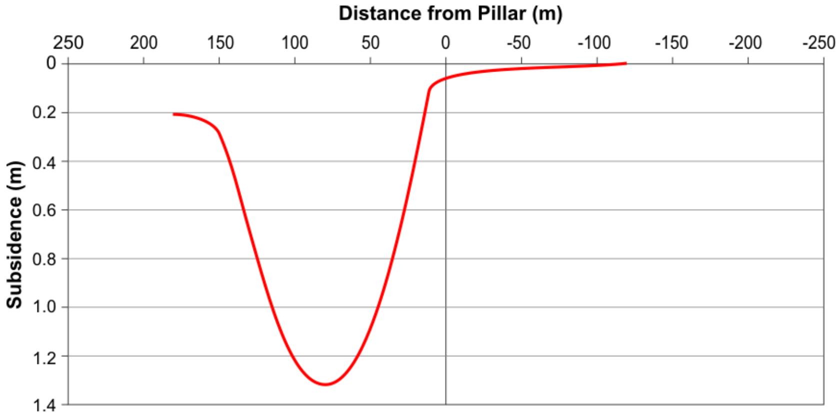


c) 80m overburden depth - single seam subsidence.

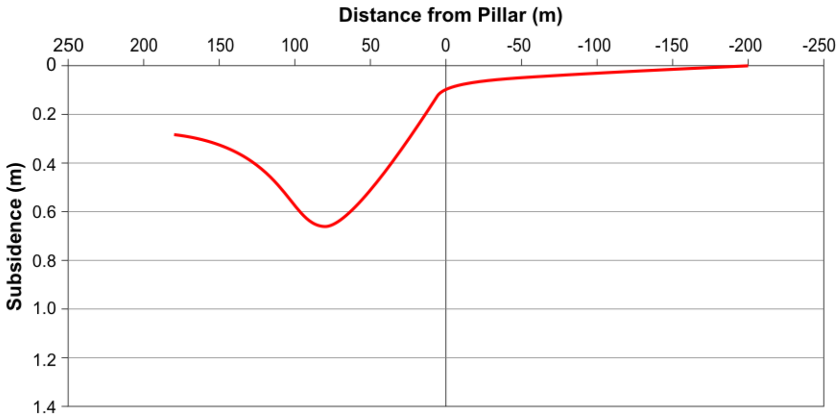


d) 220m overburden depth - single seam subsidence.

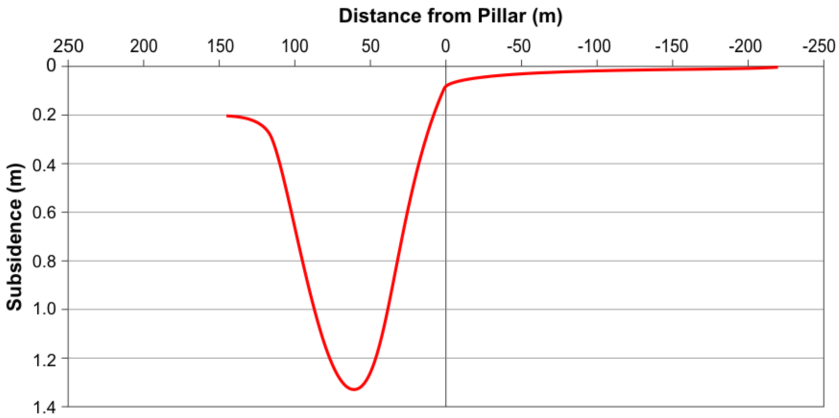
Figure 16: Subsidence for Upper Liddell Seam for Longwalls 1-6 - 2.2m seam thickness.



a) Longwalls 4b and 7 - multiseam subsidence.



b) Longwall 7 - single seam subsidence - 180m overburden depth.



c) Longwall 8 - multiseam subsidence,

Figure 17: Subsidence for Upper Liddell Seam for Longwalls 7 and 8 - 2.2m seam thickness.

2.3.3 Upper Lower Liddell Seam

The Upper Lower Liddell Seam consists of multi-seam extraction only. There are three profiles covering the different panel widths. The subsidence profiles are based on the FLAC 2D modelling of the 3m seam. The FLAC model is based on a borehole that was considered representative of the deposit at the time of modelling and 3m was the best representation of seam thickness at this location.

Profiles were created for the different panel widths of multi-seam extraction, however the maximum subsidence and profile shape remains the same and is depicted from the FLAC 2D modelling. The subsidence profiles for the Upper Lower Liddell are presented in Figure 18.

The maximum predicted subsidence for all panels is 2m for the 3m extraction height. The chain pillar subsidence is estimated at 0.3m while the barrier pillar subsidence is <0.1m. These characteristics are consistent throughout due to the super critical nature of multi-seam extraction.

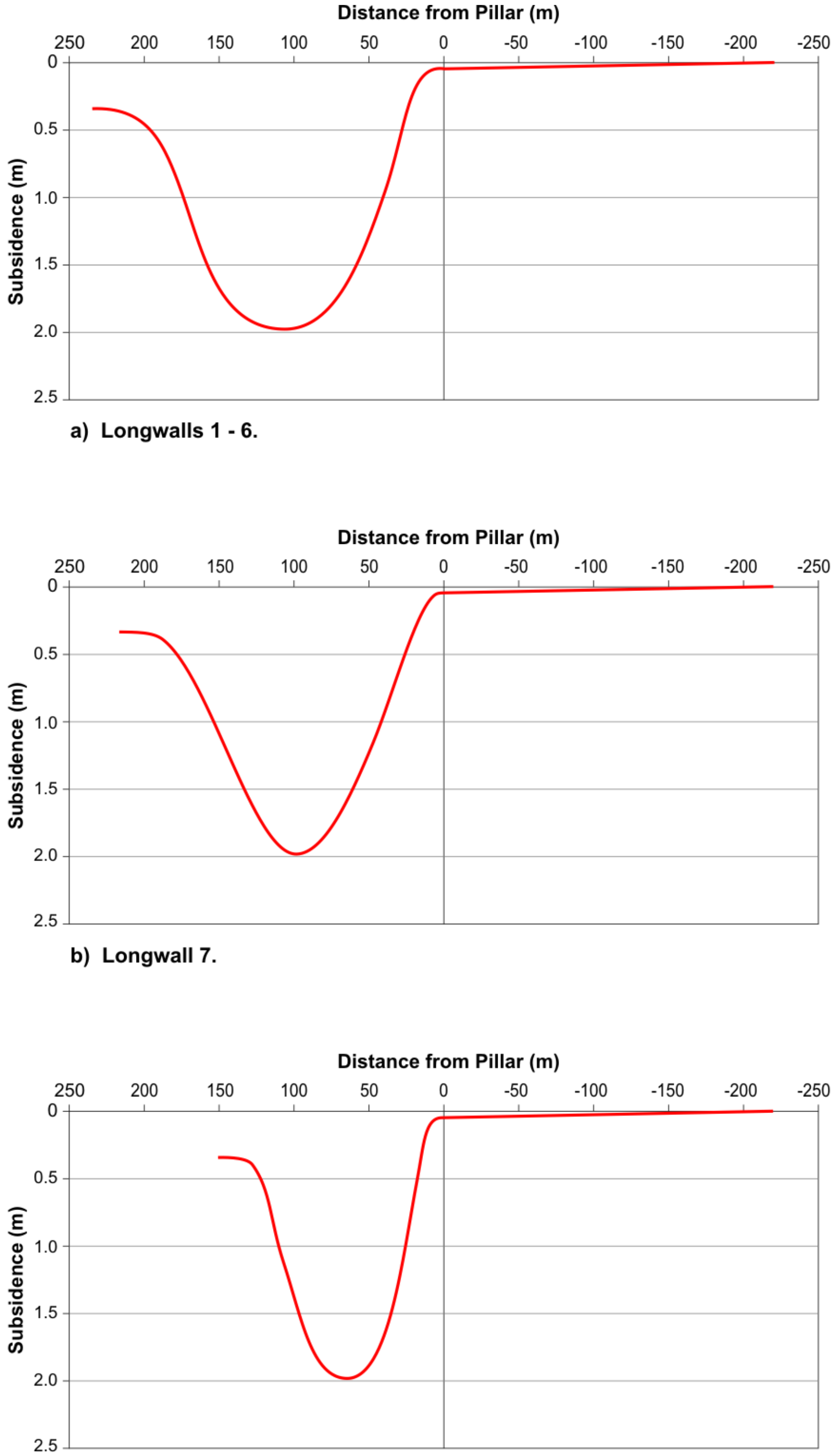
For the 2.2m seam thickness, the subsidence inside the panels is multiplied by 0.73 (2.2m/3m seam height), leaving the pillar subsidence the same. This gives a maximum subsidence of 1.5m for 2.2m seam thickness. The 2.2m extraction height subsidence is proportional to the 3m extraction height subsidence as previously described in Section 2.3.2 of this report.

Polynomial equations were fitted to the 3m 2D subsidence profiles for the purposes of 3D extrapolation. Equations were established for each profile covering the variation in longwall width and pillar type for the multi-seam extraction. The profiles were characterised by two equations to formulate the best profile fit. The two equations namely cover the pillar and goaf sections of the subsidence profile for both chain and barrier pillars, similarly to the Pikes Gully Seam examples in Figures 13a and 13b.

The following 6 order polynomial equation was used for the Upper Lower Liddell Seam profiles:

$$y = ax^6 + bx^5 + cx^4 + dx^3 + ex^2 + fx + g$$

where a, b, c, d, e, f and g coefficients are tabulated in Table A1.3 in Appendix 1 and x is the distance into the goaf from the pillar edge. The maximum and minimum x values (distances into goaf) for each equation are also outlined in Table A1.3.



a) Longwalls 1 - 6.

b) Longwall 7.

c) Longwall 8.

Figure 18: Subsidence for Upper Lower Liddell Seam - 3m seam thickness.

2.3.4 Lower Barrett Seam

The Lower Barrett Seam consists of multi-seam extraction only. There are three profiles covering the different panel widths. The subsidence profiles are based on the FLAC 2D modelling of the 3m thick seam. A 3m seam was used for the FLAC modelling as it was considered the best estimate of seam thickness. The FLAC model is based on a borehole that was considered representative of the deposit at the time of modelling.

Subsidence profiles were created for the different panel widths, however the maximum subsidence and profile shape remains the same for multi-seam extraction and is depicted from the FLAC 2D modelling. The subsidence profiles for the Lower Barrett Seam are presented in Figure 19.

The maximum predicted subsidence for all panels is 2m for the 3m extraction height. The chain pillar subsidence is estimated at 0.7m while the barrier pillar subsidence is <0.1m. These characteristics are consistent throughout due to the super critical nature of multi-seam extraction.

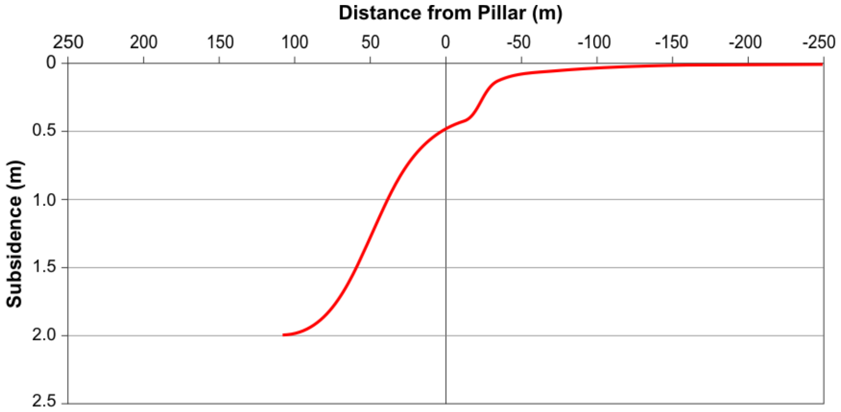
For the 2.2m seam thickness, the subsidence inside the panels is multiplied by 0.73 (2.2m/3m seam height), leaving the pillar subsidence the same. This gives a maximum subsidence of 1.5m for 2.2m seam thickness. The 2.2m extraction height subsidence is proportional to the 3m extraction height subsidence as previously described in Section 2.3.2 of this report.

Polynomial equations were fitted to the 3m 2D subsidence profiles for the purposes of 3D extrapolation. Equations were established for each profile covering the variation in longwall width and pillar type for the multi-seam extraction. The profiles were characterised by two equations to formulate the best profile fit. The two equations namely cover the pillar and goaf sections of the subsidence profile for both chain and barrier pillars, similarly to the Pikes Gully Seam examples in Figures 13a and 13b.

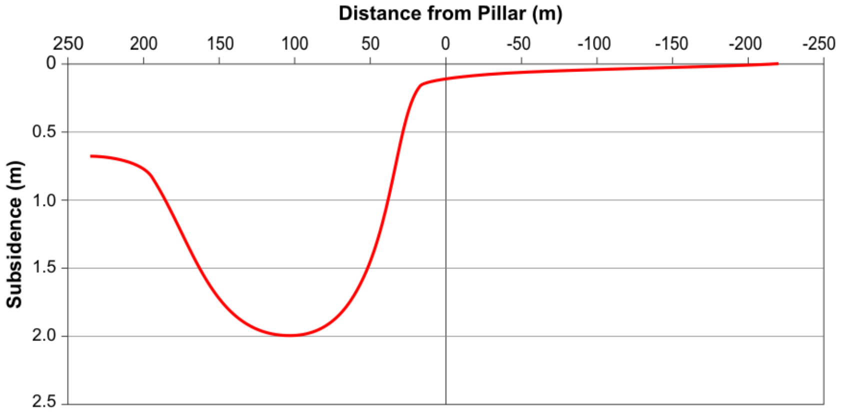
The following 5 order polynomial equation was used for the Lower Barrett Seam profiles:

$$y = ax^5 + bx^4 + cx^3 + dx^2 + ex + f$$

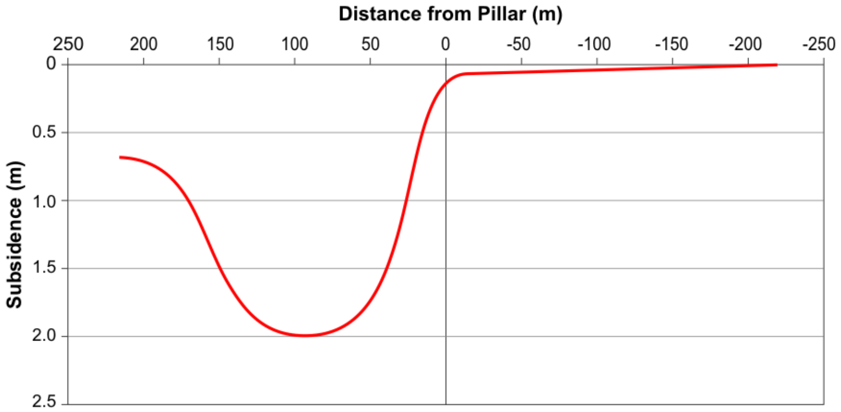
where a, b, c, d, e and f coefficients are tabulated in Table A1.4 in Appendix 1 and x is the distance into goaf from pillar edge. The maximum and minimum x values (distances into goaf) for each equation are also outlined in Table A1.4.



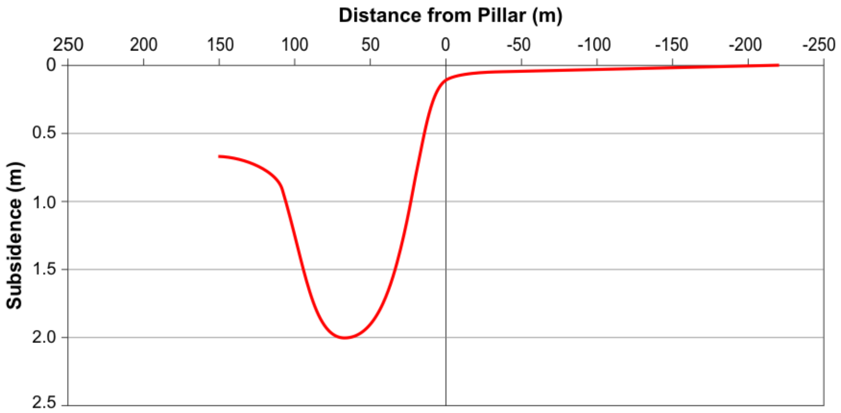
a) Tailgate 1.



b) Longwalls 1-6.



c) Longwall 7 and 4b.



c) Longwall 8.

Figure 19: Subsidence for Lower Barrett Seam - 3m seam thickness.

2.4 Node Subsidence

In house code was developed in Visual Basics for MS Excel and is used to create, determine and assign the following information to each node of the 10x10m grid:

- Coordinates
- Distance from pillar edge
- Closest pillar
- Pillar type – chain or barrier
- Shallow subsidence for single seam extraction at 2.2m seam height (where required)
- Deep subsidence for single seam extraction at 2.2m seam height (where required)
- Shallow subsidence for single seam extraction at 3m seam height (where required)
- Deep subsidence for single seam extraction 3m seam height (where required)
- Subsidence for multi-seam extraction 2.2m seam height (where required)
- Subsidence for multi-seam extraction 3m seam height (where required)
- Overburden depth for each seam
- Extraction height for each seam

In the case of the Pikes Gully Seam, the "shallow" and "deep" subsidence grids were calculated using the subsidence profiles, distance to panel edge and pillar type. The predicted subsidence for the overburden depth was determined proportionally between the subsidence profiles at the two depths. In the lower seams, if the seam above has been subsided, then the multi-seam profile was used instead of the "shallow" and "deep" profiles. Grids were created for both a 2.2m and 3m extraction height. The predicted subsidence for the seam extraction height was determined proportionally between the two seam heights with a maximum of 3m and minimum of 2.2m.

A worked example of the subsidence at a single node is outlined below:

East:	318920
North:	6405200
Distance to closest pillar:	56.6m
Closest pillar:	LW2 TG
Overburden Depth:	63.8m
Pillar Type:	Chain

Using the polynomial equations outlined in Section 2.3.1 of this report in the following format:

$$y = ax^6 + bx^5 + cx^4 + dx^3 + ex^2 + fx + g$$

where x = distance to closest pillar (m) = 56.6m, the following subsidence values are determined:

2.2m seam height for 40m depth:

$1.107\text{x}10^{-5}$ x $(56.6)^2$ - $2.439\text{x}10^{-3}$ x (56.6) -1.186
= - 1.29m

2.2m seam height for 190m depth:

$4.342\text{x}10^{-10}$ x $(56.6)^5$-$0.048\text{x}10^{-8}$ x $(56.6)^4$ + $8.938\text{x}10^{-6}$ x $(56.6)^3$ – $5.303\text{x}10^{-4}$ x $(56.6)^2$ + $1.008\text{x}10^{-2}$ x (56.6) -0.327
= -0.60m

3m seam height for 40m depth:

$4.743\text{x}10^{-6}$ x $(56.6)^2$ – $1.617\text{x}10^{-3}$ x (56.6) -1.681
= -1.76m

3m seam height for 190m depth:

$4.415\text{x}10^{-6}$ x $(56.6)^3$ = $8.411\text{x}10^{-4}$ x $(56.6)^2$ +$2.751\text{x}10^{-2}$ x (56.6) – 0.526
= -0.86m

Determine the subsidence for each seam height proportionally from the overburden depth:

<u>2.2m</u>

$$\left(\frac{56.6-40}{190-40}\right) \times \left((-0.60) - (-1.29)\right) + -1.29 = -1.21$$

<u>3m</u>

$$\left(\frac{56.6-40}{190-40}\right) \times \left((-0.86) - (-1.76)\right) + -1.76 = -1.66$$

Determine the subsidence proportionally from the seam height:

$$\left(\frac{2.52-2.2}{3-2.2}\right) \times \left((-1.66) - (-1.21)\right) + -1.21 = -1.39$$

Therefore the subsidence at the node point is -1.39m.

2.5 Model Outputs and Deliverables

The quantitative model outputs include:

- Differential subsidence contour plots for each seam
- Cumulative subsidence contour plots for each seam in extraction order
- Surface topography after subsidence for each seam

SCT deliverables from the subsidence extrapolation include:

- Differential and cumulative subsidence contour plots for Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett seams
- Topographic surface plots with subsidence for the cumulative subsidence of each seam
- DXF of subsidence (differential and cumulative) for each seam
- DXF of surface topography post subsidence, cumulative after each seam

3. RESULTS FOR 3D SUBSIDENCE PREDICTIONS

A subsidence model was developed for the Ashton Mine area based on the mine plans, overburden depths and extraction heights provided for the Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seams. The results of the four seams are discussed separately.

3.1 Pikes Gully Seam

The Pikes Gully mine plan consists of 8 panels oriented nor-northeast, with Longwall panels 6 and 7 consisting of a and b extraction panels so as to not mine under Bowmans Creek. Longwall 8 has a narrow longwall configuration. The subsidence contours for the Pikes Gully Seam are presented in Figure 20. At the time of this assessment, extraction of the Pikes Gully Seam is substantially completed.

The minimum subsidence is contoured at 0.02m corresponding with surveying accuracy. The maximum subsidence for Longwall panels 1-6 is approximately 1.6m and is primarily controlled by the seam thickness as the panels are of supercritical width. Longwall 7 is slightly narrower and experiences subcritical subsidence with a maximum subsidence of approximately 1.2m. Longwall 8 panel is significantly narrower and has a maximum subsidence of approximately 0.6m. The chain pillar subsidence is driven by the overburden depth, and ranges from 0.05m in the east to 0.2m in the west.

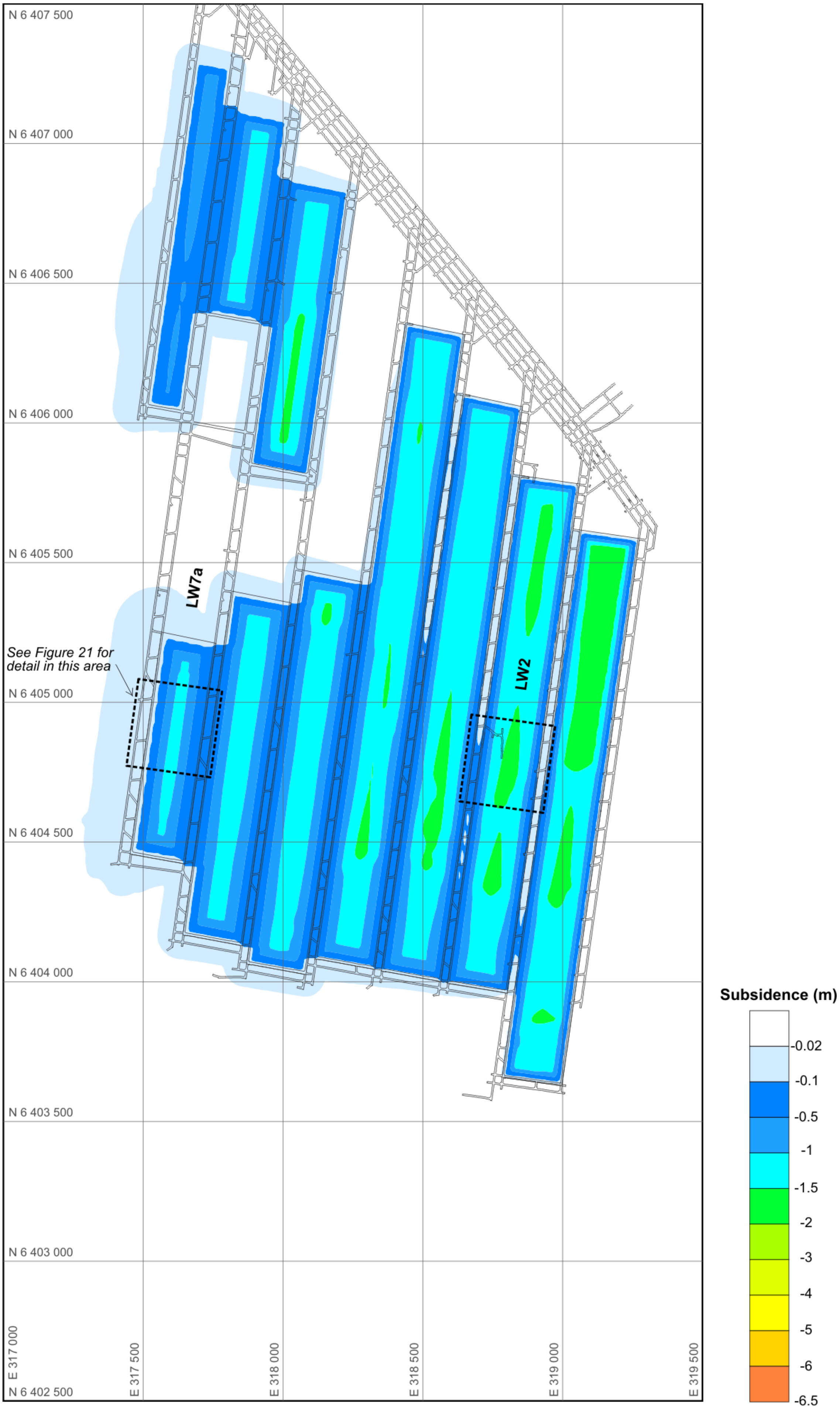


Figure 20: Pikes Gully Seam subsidence.

Magnified insets of longwall panels 2 and 7a, presented in Figure 21, show the steepness of the subsidence contours along the panel edge. The subsidence predictions superimposed onto topography are presented in Figure 22. The 3D vertically exaggerated image shows the longwall subsidence in relation to the topographic features. The panels to the east have steeper subsidence compared with the gentler slope of the subsidence to the west.

3.2 Pikes Gully Seam Subsidence Validation

Two methods of validation were used to assess the Pikes Gully subsidence extrapolation. The extrapolated subsidence predictions were compared with the FLAC 2D model output along the cross section used in the 2D modelling in addition to the actual subsidence data along the XL5 subsidence line. Two separate cross sections were extracted from the 3D model along each validation line. The predicted 3D subsidence extrapolation in addition to the 2D FLAC model data is presented in Figure 23. The extrapolated subsidence lines provide a good fit with the FLAC 2D model data. The following points describe the differences in the profiles:

- The model data shows some asymmetry in the subsidence over the pillars caused from the dipping strata. The asymmetry was not included in the extrapolation due to its variability which is difficult to predict.

- The FLAC 2D model is based on a 3m seam thickness however the seam thickness varies and is less than 3m along the model section, reducing the maximum subsidence from the model subsidence.

- The predicted chain pillar subsidence is greater than anticipated in the FLAC 2D model as the predicted subsidence overestimates the subsidence by producing a linear trend between the shallow and deep subsidence profiles.

- There is some variation in maximum subsidence in Longwalls 3 and 4 between the FLAC 2D results and the 3D extrapolated results. The subsidence is supercritical along these panels and has variation in the maximum subsidence both in the model and naturally. The extrapolated subsidence is based on a constant supercritical maximum subsidence and the variation is due to change in seam thickness.

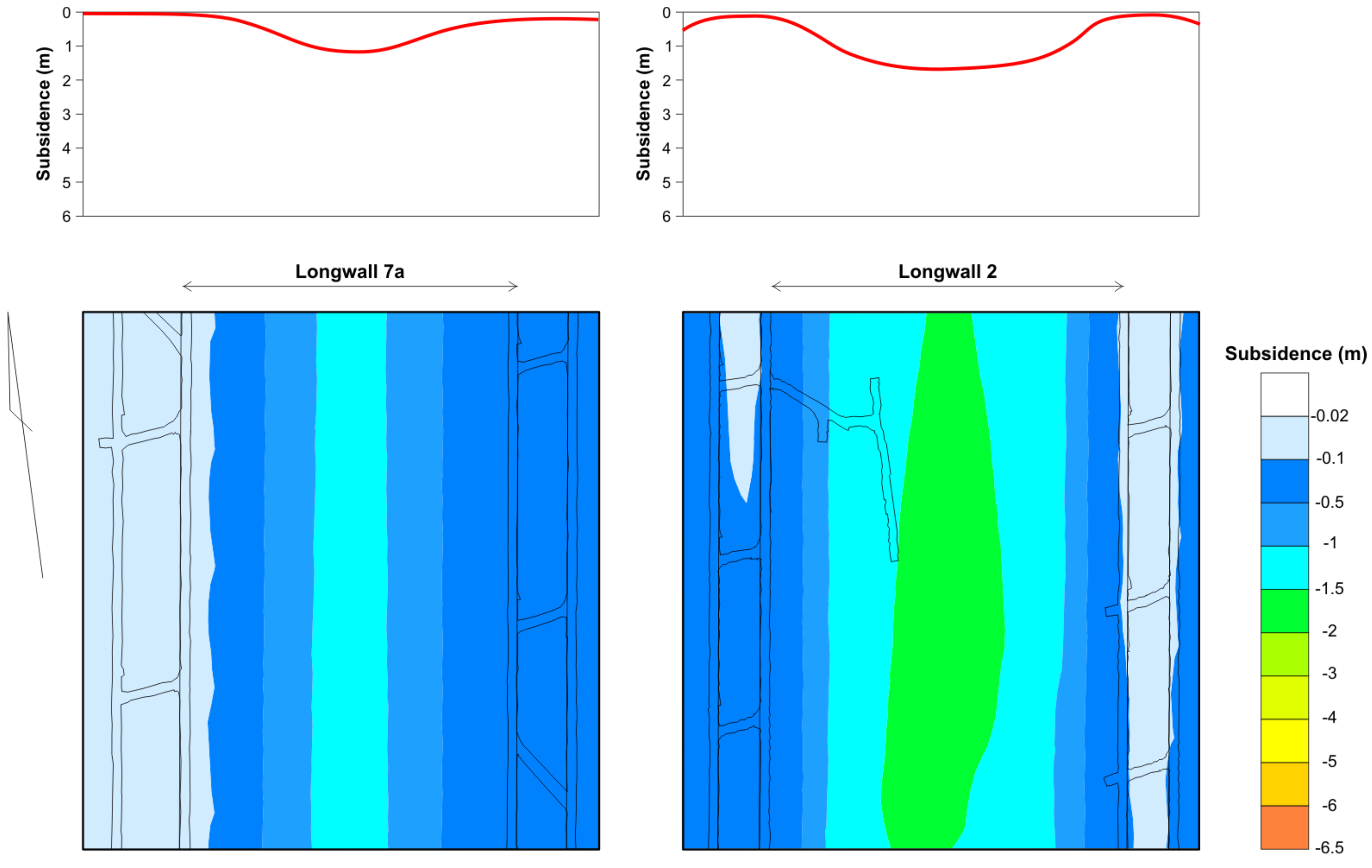


Figure 21: Magnified subsidence for Pikes Gully Seam - Longwalls 2 and 7a.

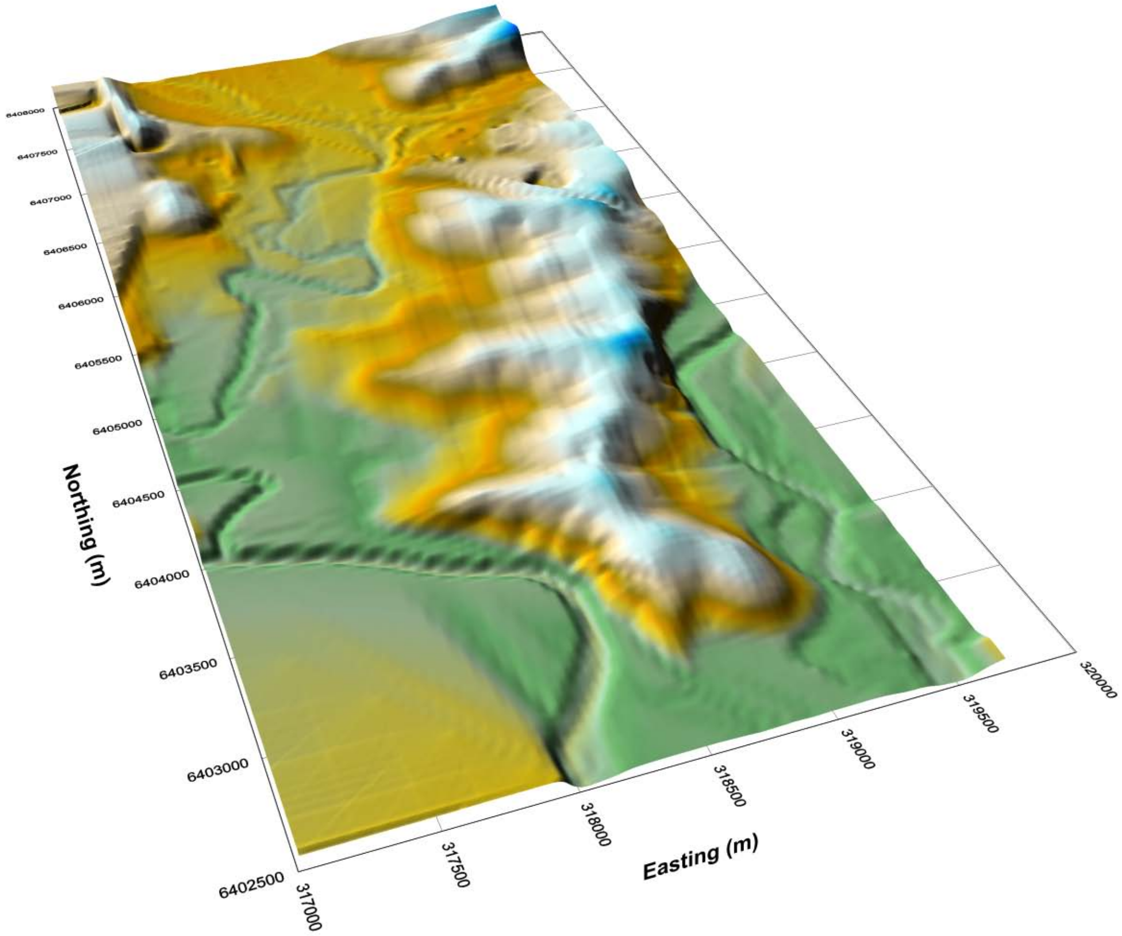


Figure 22: Topographic surface with Pikes Gully Seam subsidence
(vertical exaggeration x 4 - see Appendix 1.1 for large image).

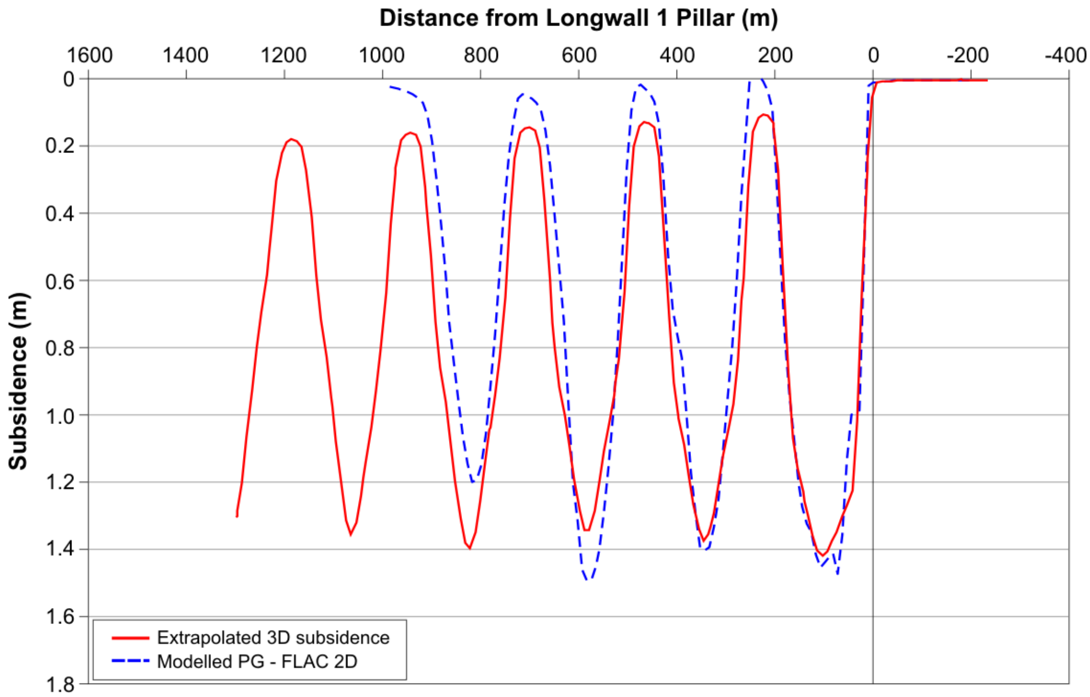


Figure 23: Modelled PG subsidence versus extrapolated 3D subsidence.

The predicted 3D subsidence extrapolation compared with the XL5 subsidence line data is presented in Figure 24. The model data and extrapolated data provide a good comparison. The differences in the subsidence profiles are described in the following:

- The XL5 subsidence data shows an asymmetrical subsidence profile caused from the dipping strata. This was not included in the extrapolation.
- The predicted subsidence uses the upper range of the maximum subsidence dataset and therefore slightly overestimates the actual maximum subsidence.

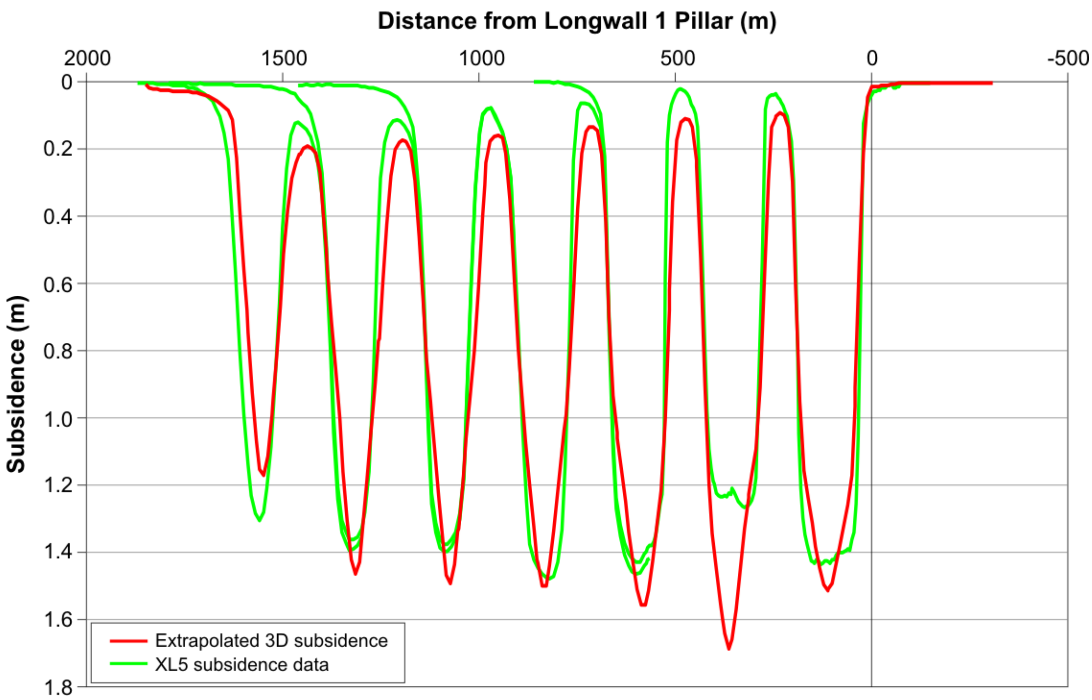


Figure 24: XL5 subsidence versus extrapolated 3D subsidence.

3.3 Upper Liddell Seam

The Upper Liddell Seam mine plan consists of 8 panels in the nor-northeast orientation. Longwalls 4, 6 and 7 have a and b panels so as to not mine below Bowmans Creek. Longwall 8 is a narrow longwall panel. The majority of the mine plan has multi-seam extraction while the southern extents of some longwall panels have single seam extraction and the northern part of Longwall 7a and southern half of Longwall 7b experiences single seam extraction. The Upper Liddell Seam subsidence contours are presented in Figure 25.

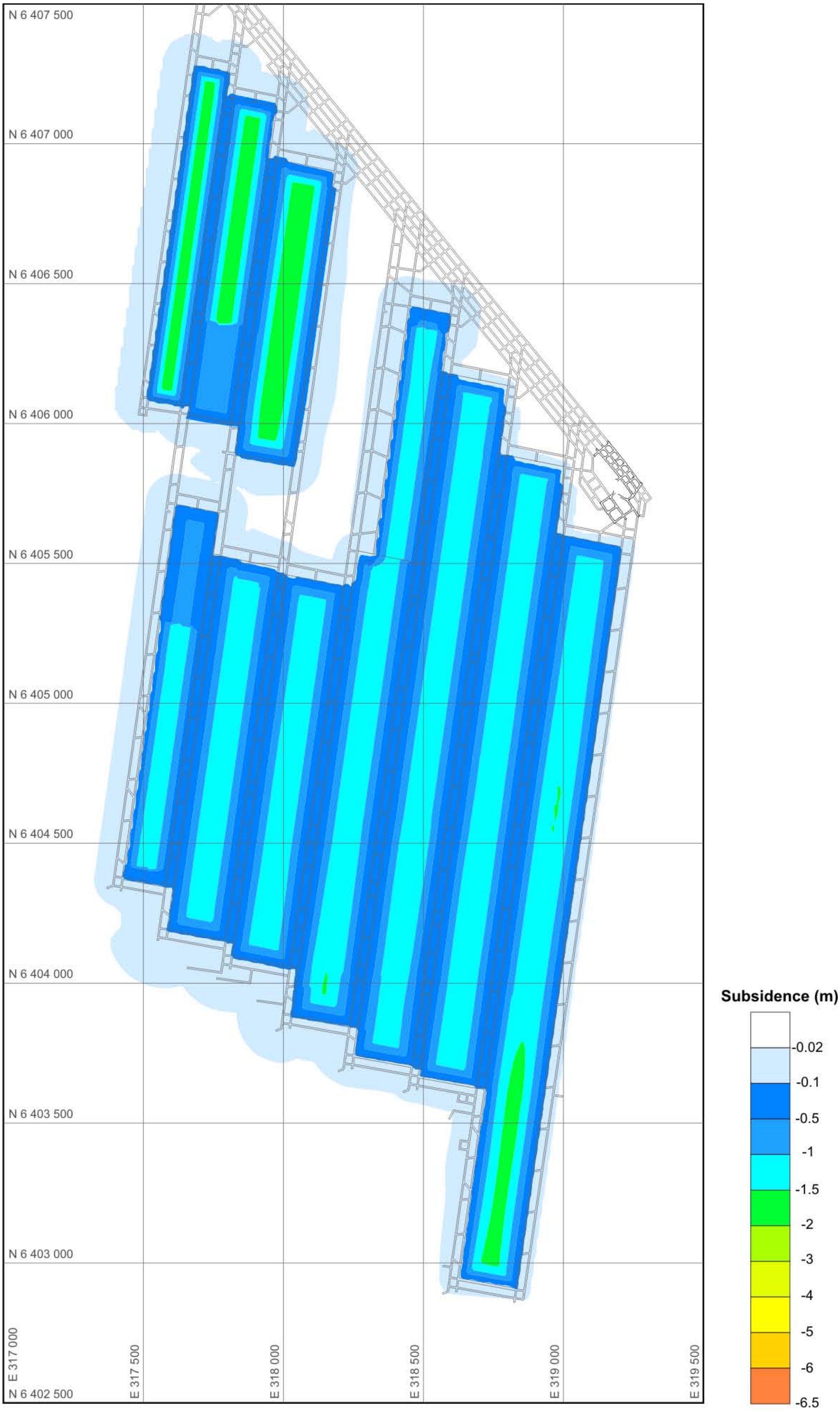


Figure 25: Incremental Upper Liddell Seam subsidence.

The minimum subsidence is contoured at 0.02m corresponding with surveying accuracy. The maximum incremental subsidence for Longwalls 1-7 generally ranges from 1.3m to 1.4m and is primarily controlled by the seam thickness. The multi-seam and single seam subsidence is observably similar in Longwalls 1-4, because the panel widths are supercritical and the multi-seam maximum subsidence is the same as the single seam maximum subsidence. The single seam subsidence in Longwall 7 is noticeably different to the multi-seam subsidence as the panel widths are smaller and are now subcritical, reducing the maximum subsidence. Longwalls 6b, 7b and 8 have a maximum incremental subsidence of approximately 1.8m and the southern end of Longwall 1 has a maximum of 1.6m due to the increase in seam thickness. The chain pillar subsidence generally approximates to 0.2m and is fairly consistent as depicted from the FLAC 2D model.

The cumulative total for the Pikes Gully Seam and Upper Liddell Seam subsidence is presented in Figure 26. Where multi-seam subsidence exists, the maximum subsidence generally ranges from 2.2m to 3m for all Longwall panels. The chain pillar subsidence is generally about 0.5m to 0.6m over the mine area. Magnified insets of Longwall 3, presented in Figure 27, shows the steepness of the subsidence contours along the pillar edge for the cumulative subsidence.

The subsidence predictions superimposed onto topography are presented in Figure 28. The 3D vertically exaggerated image shows the longwall subsidence in relation to the topographic features. The longwall panels are becoming more pronounced on the surface topography where the western panel subsidence is now more obvious than that of the Pikes Gully subsidence only.

3.4 Upper Lower Liddell Seam

The Upper Lower Liddell Seam mine plan consists of 8 panels in the nor-northeast orientation. Longwall panels 6 and 7 have a and b panels so as to not mine below Bowmans Creek. Longwall 8 is a narrow longwall panel. The Upper Lower Liddell Seam mine plan is offset with the Upper Liddell Seam mine plan and is generally stacked with the Pikes Gully Seam mine plan. The mine plan is almost entirely within the previously extracted panels and therefore experiences only multi-seam extraction with the same maximum subsidence across all longwalls. The incremental Upper Lower Liddell Seam subsidence contours are presented in Figure 29.

The minimum subsidence is contoured at 0.02m corresponding with surveying accuracy. The incremental maximum subsidence for all panels generally ranges from 1.4m to 1.8m. The seam is supercritical with the above seam so the variation in maximum subsidence is a result of seam thickness variation. As depicted in the FLAC 2D modelling, the chain pillar subsidence is consistent throughout the mine area at approximately 0.25m.

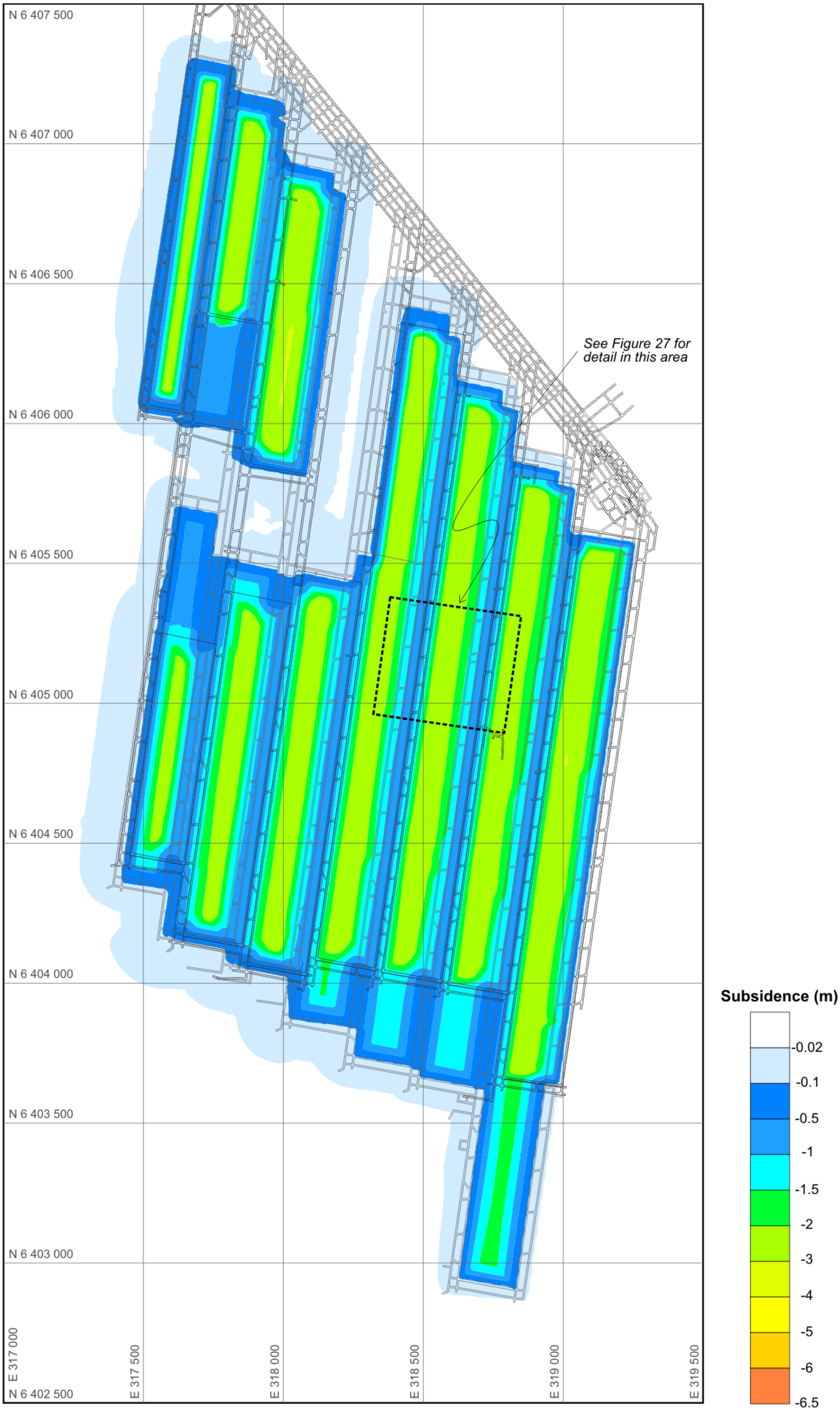


Figure 26: Cumulative Pikes Gully and Upper Liddell Seam subsidence.

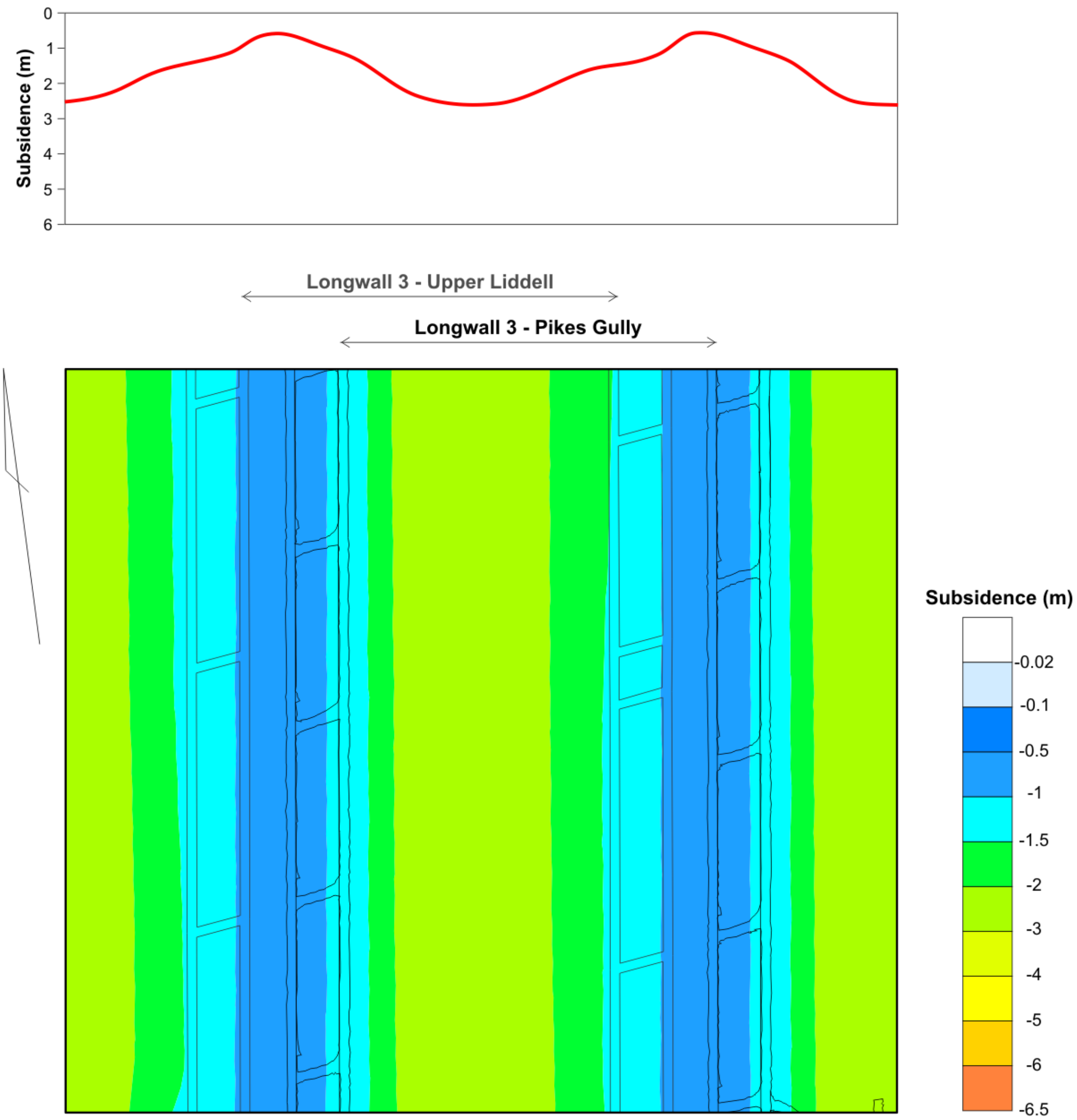


Figure 27: Magnified subsidence for Pikes Gully and Upper Liddell Seam - Longwall 3.

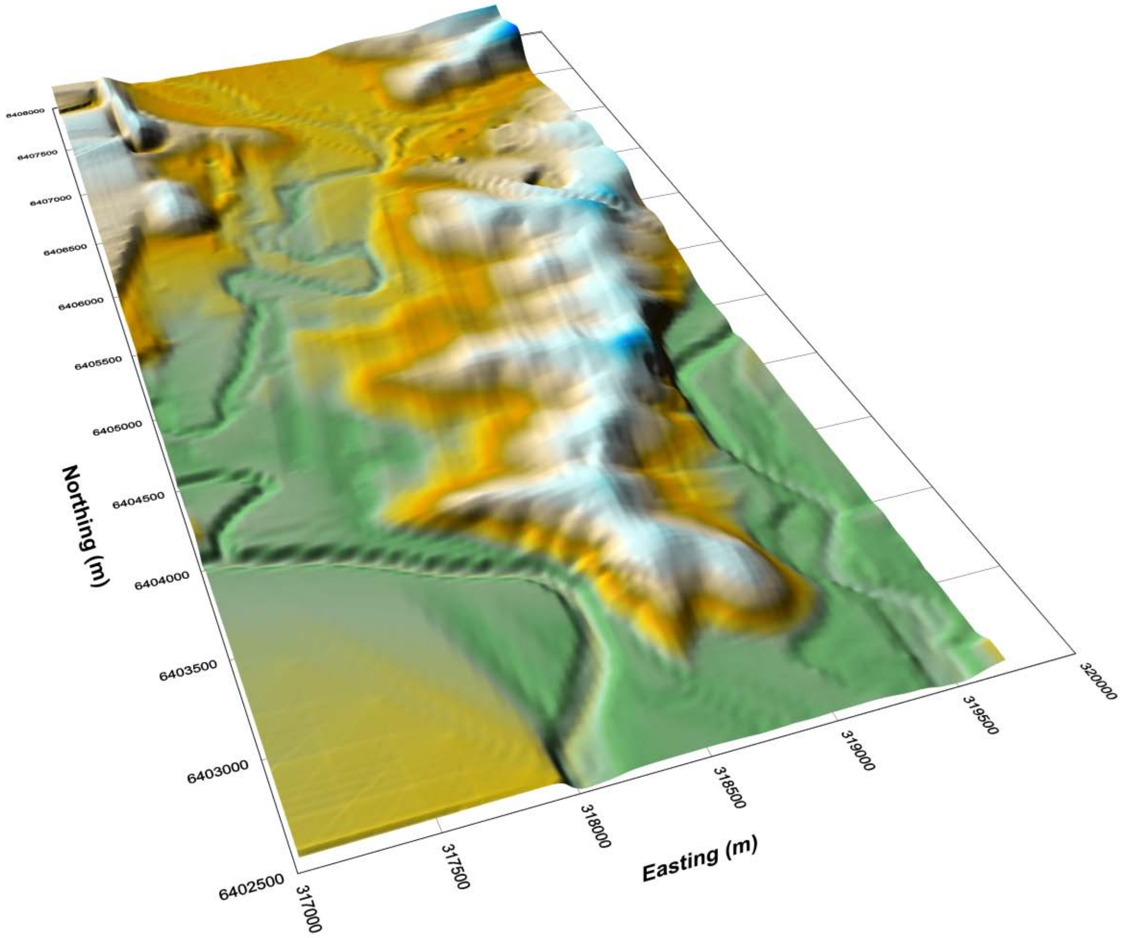


Figure 28: Topographic surface with cumulative Pikes Gully and Upper Liddell Seam subsidence *(vertical exaggeration x 4 - see Appendix 1.2 for large image)*

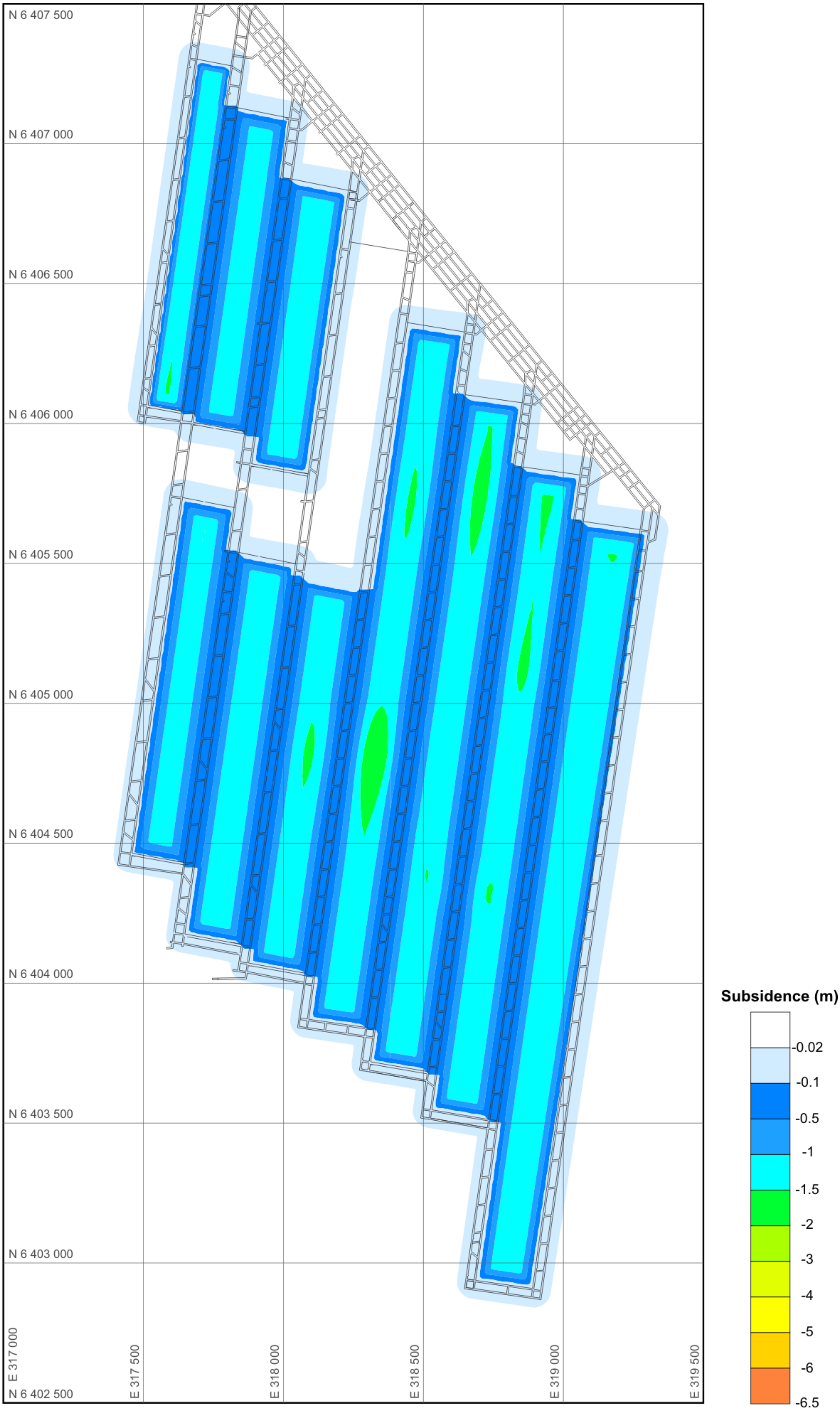


Figure 29: Incremental Upper Lower Liddell Seam subsidence.

The cumulative total for the Pikes Gully Seam, Upper Liddell Seam and Upper Lower Liddell Seam subsidence is presented in Figure 30. The areas that have had extraction from all three panels show maximum subsidence ranging from 3.6m to 4.3m. The regions that did not have Pikes Gully extraction at southern end of Longwalls 1-4, show maximum subsidence ranging from 2.5m to 2.8m while part of Longwall 7b has a maximum subsidence of approximately 2.2m. Chain pillar subsidence generally ranges from 0.7m to 0.9m over the areas with three extracted seams and down to approximately 0.6m with two extracted seams. Magnified insets of Longwall 2, presented in Figure 31, shows the steepness of the subsidence contours along the pillar edge for the cumulative subsidence of three and two extracted seams.

The subsidence predictions superimposed onto topography are presented in Figure 32. The 3D vertically exaggerated image shows the longwall subsidence in relation to the topographic features. The longwall panels are again more pronounced than previous with steeper cumulative subsidence profiles.

3.5 Lower Barrett Seam

The Lower Barrett Seam mine plan replicates the Upper Liddell Seam mine plan, is offset from the Pikes Gully mine plan, and consists of 8 panels in the nor-northeast orientation. Longwalls 4, 6 and 7 have a and b panels so as to not extract below Bowmans Creek. Longwall 8 has a narrow longwall configuration. The mine plan is entirely within the previously extracted panels and therefore experiences multi-seam extraction. The incremental Lower Barrett Seam subsidence contours are presented in Figure 33.

The minimum subsidence is contoured at 0.02m corresponding with surveying accuracy. The maximum subsidence for all panels generally ranges from 1.5m to 2m. The seam is supercritical with the above seam so the variation in maximum subsidence is a result of seam thickness variation. The additional chain pillar subsidence throughout the mine area generally ranges from 0.5m to 0.6m.

The cumulative total for the Pikes Gully Seam, Upper Liddell Seam, Upper Lower Liddell Seam and Lower Barrett Seam subsidence is presented in Figure 34. The areas that have had extraction from all four panels show maximum subsidence ranging from 5m to 6.2m, while the areas that did not have Pikes Gully extraction to the south of Longwalls 1-4 and in Longwall 7a and 7b show maximum subsidence down to approximately 3.8m. Total chain pillar subsidence generally ranges from 1.6m to 1.7m over the areas with all four extracted seams and down to approximately 1.2m with three extracted seams. Magnified insets of Longwall 2, presented in Figure 35, shows the steepness of the subsidence contours along the pillar edge for the cumulative subsidence of three and two extracted seams.

Figure 30: Cumulative Pikes Gully, Upper Liddell and Upper Lower Liddell Seam subsidence.

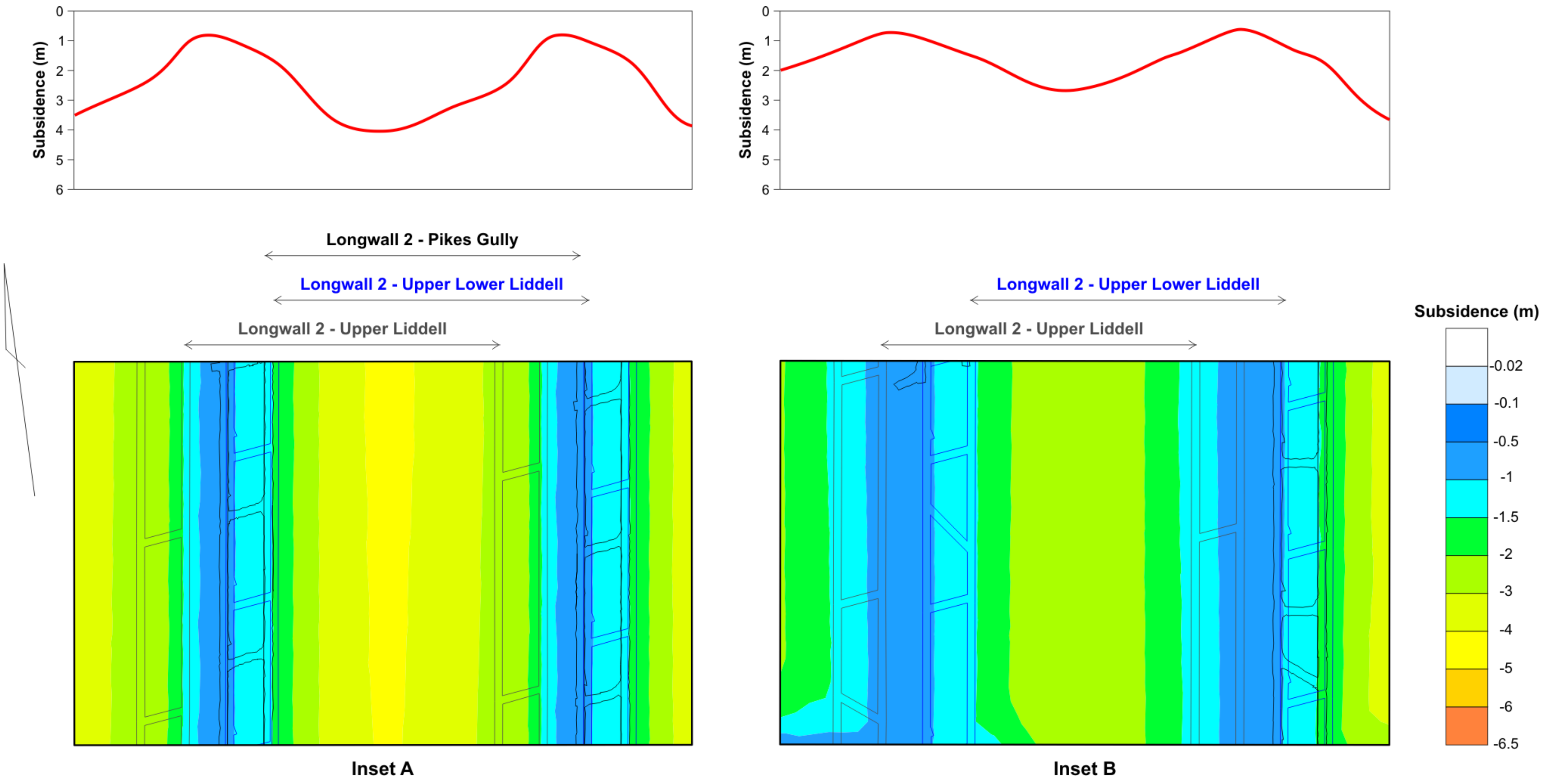


Figure 31: Magnified subsidence for Pikes Gully, Upper Liddell and Upper Lower Liddell Seam - Longwall 2.

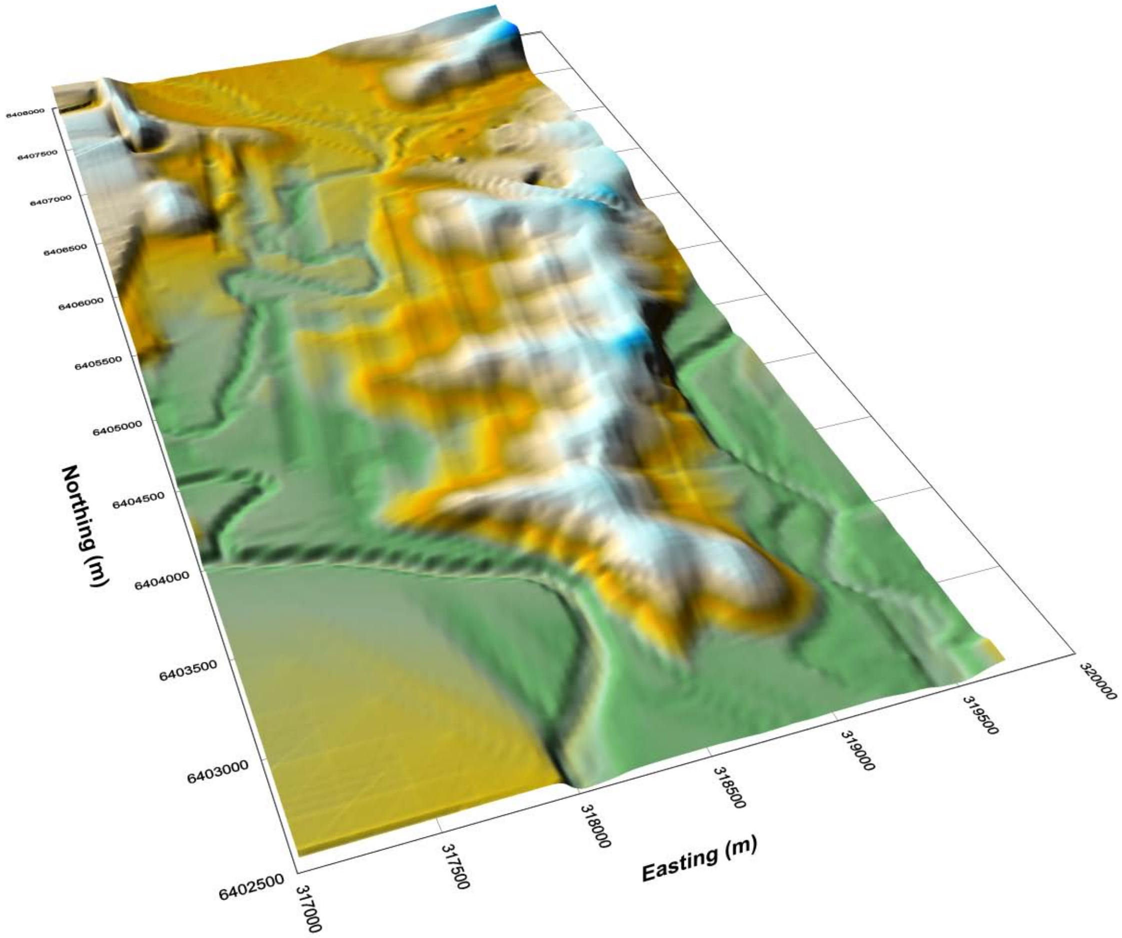


Figure 32: Topographic surface with cumulative Pikes Gully, Upper Liddell and Upper Lower Liddell Seam subsidence
(vertical exaggeration x 4 - see Appendix 1.3 for large image)

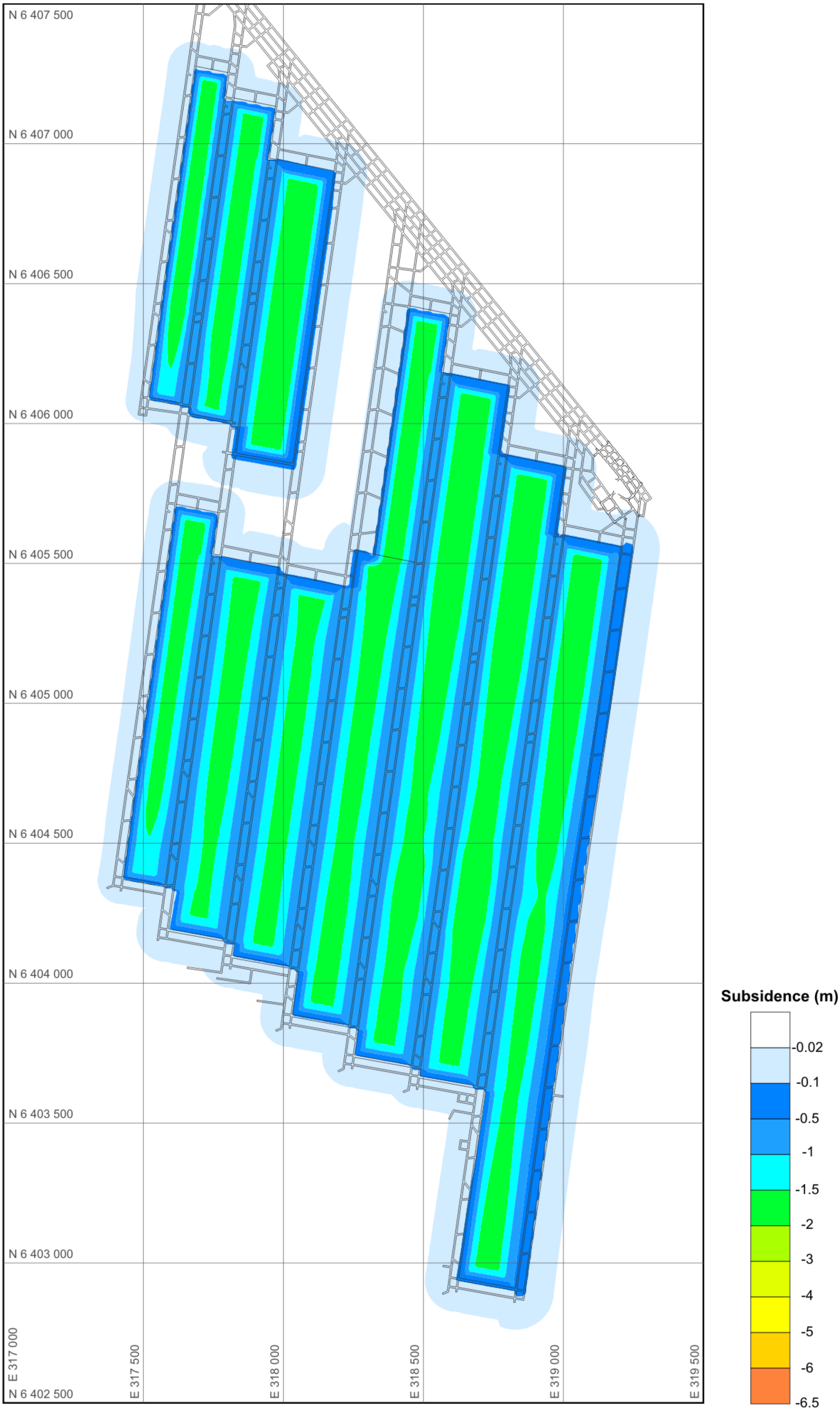


Figure 33: Incremental Lower Barrett Seam subsidence.

Figure 34: Cumulative Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seam subsidence.

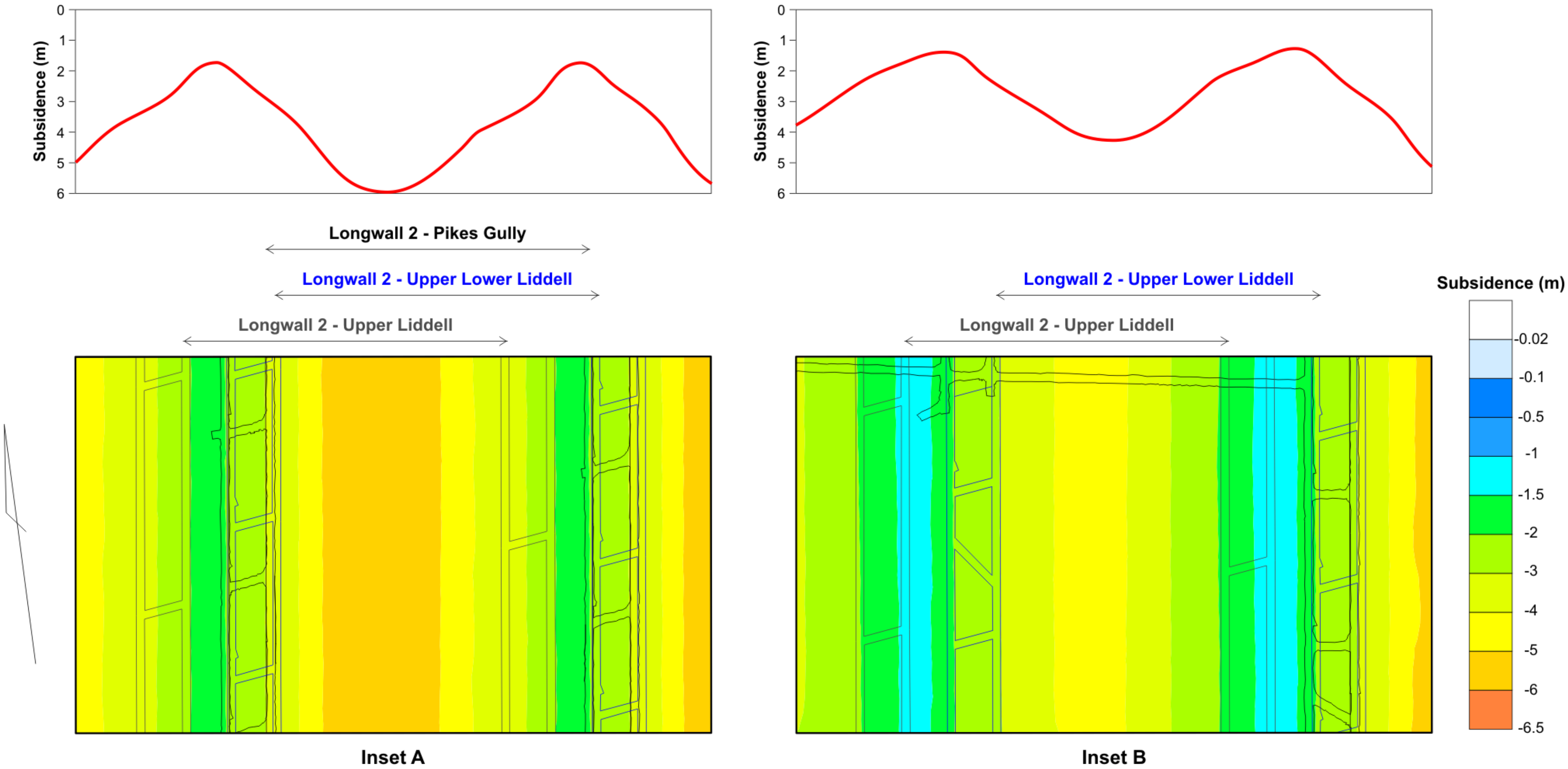


Figure 35: Magnified subsidence for Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seam - Longwall 2.

The subsidence predictions superimposed onto topography are presented in Figure 36. The 3D vertically exaggerated image shows the longwall subsidence in relation to the topographic features. The longwall panels are again more pronounced than previous with steeper cumulative subsidence profiles.

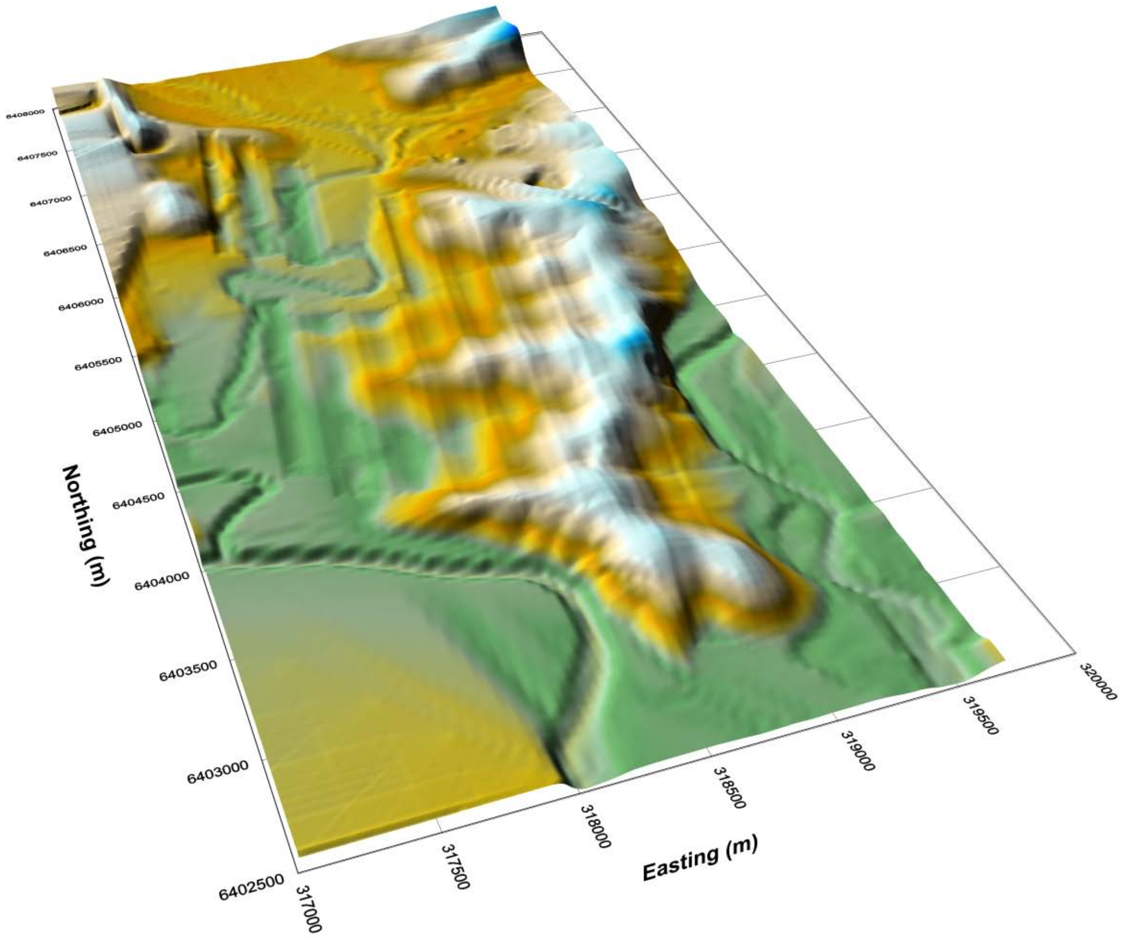


Figure 36: Topographic surface with cumulative Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seam subsidence *(vertical exaggeration x 4 - see Appendix 1.4 for large image)*

3.6 Multi-Seam Subsidence Validation

The cumulative subsidence for all four seams, as determined from the 3D extrapolation, in comparison with the FLAC 2D model section is presented in Figure 37. The extrapolated subsidence has a similar profile to that of the FLAC 2D section however there are differences in the modelled seam thicknesses that must be taken into account, which include:

- The modelled Pikes Gully seam thickness is 3m, however the actual seam thickness along the section is approximately 2.3m
- The modelled Upper Liddell seam thickness is 2.2m, however the actual seam thickness along the section ranges 2.3m to 2.4m
- The modelled Upper Lower Liddell seam thickness is 3m, however the actual seam thickness along the section is below the minimum of 2.2m
- The modelled Lower Barrett seam thickness is 3m, however the actual seam thickness along the section ranges of 2.4m to 3m

These differences in seam thickness will vary the individual seam subsidence components.

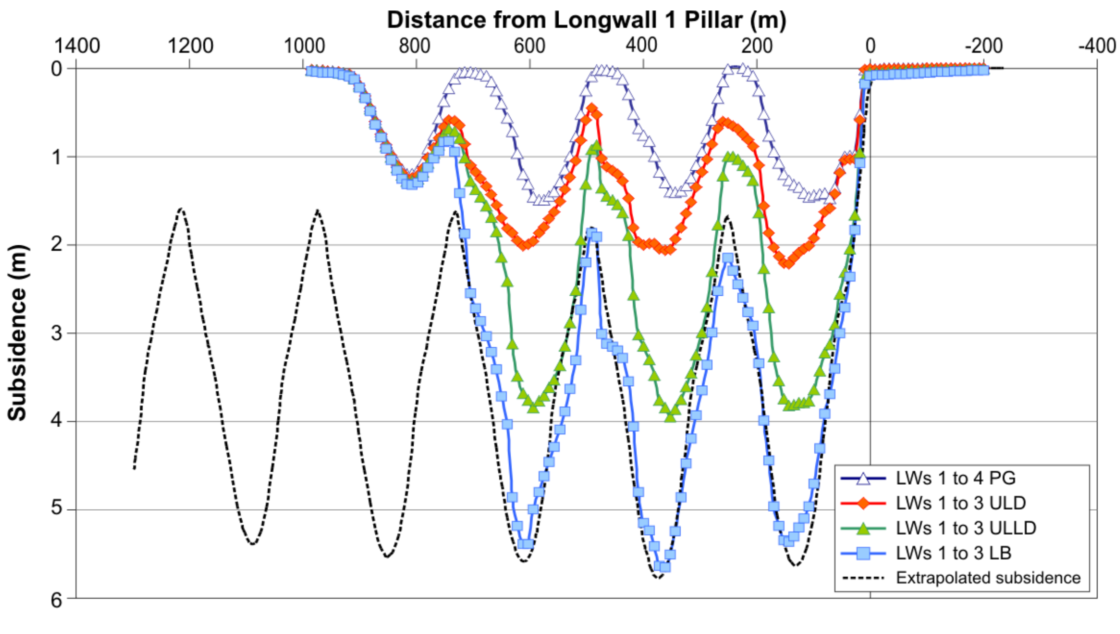


Figure 37: Modelled FLAC 2D subsidence and extrapolated subsidence comparison.

4. DISCUSSION OF ALTERNATE MULTI-SEAM MODELS

Empirical data suggests that multi-seam maximum subsidence can be up to 85% of the total seam thickness for all seams (Li *et al*, 2010). This would suggest that subsidence maximums for the extraction of the Pikes Gully and Upper Liddell Seams only would be up to approximately 4.3m as opposed to the model extrapolation of approximately 3m, which predicts maximum subsidence of approximately 60% of total seam thickness.

In order to assess this possibility, the extrapolated subsidence for the Pikes Gully and Upper Liddell Seams was manipulated to represent 85% of the total seam thickness for multi-seam subsidence areas and not including chain pillar subsidence. The resulting 85% subsidence contours for the combined Pikes Gully and Upper Liddell Seams are presented in Figure 38, with the cumulative 85% subsidence including the Upper Lower Liddell Seam in Figure 39 and the cumulative 85% subsidence including the Lower Barrett Seam in Figure 40.

The 85% data was contoured to be used as an upper limit to investigate an alternate subsidence assessment for the subsidence along the power lines at the southern extent of the mine area. The cross section along the power lines, presented in Figure 41, illustrates the subsidence along the powerlines section for the Pikes Gully Seam only and the cumulative subsidence for the Pikes Gully Seam, Upper Liddell Seam, Upper Lower Liddell Seam and the Lower Barrett Seam subsidence. The maximum subsidence along the powerlines for the Pikes Gully Seam is approximately 1.4m. The maximum predicted subsidence along the powerlines for the Upper Liddell Seam ranges from about 1.5m to 1.9m for single seam extraction to 3.3m to 3.8m for cumulative multi-seam extraction. The maximum predicted 85% subsidence for the combined seams including the Upper Lower Liddell is 5.2m to 6.2m. The maximum subsidence for all four seams including the Lower Barrett Seam is 7.2m to 8.9m.

Multi-seam subsidence at the Liddell Colliery was estimated at 83% of total seam thickness for the Upper Liddell and Middle Liddell multi-seam extraction (Li et al, 2010). This is greater than suggested in the FLAC numerical modelling for the Ashton Mine, however confidence is gained from the numerical modelling of the Blakefield South multi-seam extraction which proved to be correct within the predicted range.

Although the empirical data suggests there are examples where the maximum subsidence is up to 85% of total seam thickness, the numerical modelling in FLAC 2D suggests that for the geology and panel geometries at Ashton, the maximum subsidence may be significantly lower.

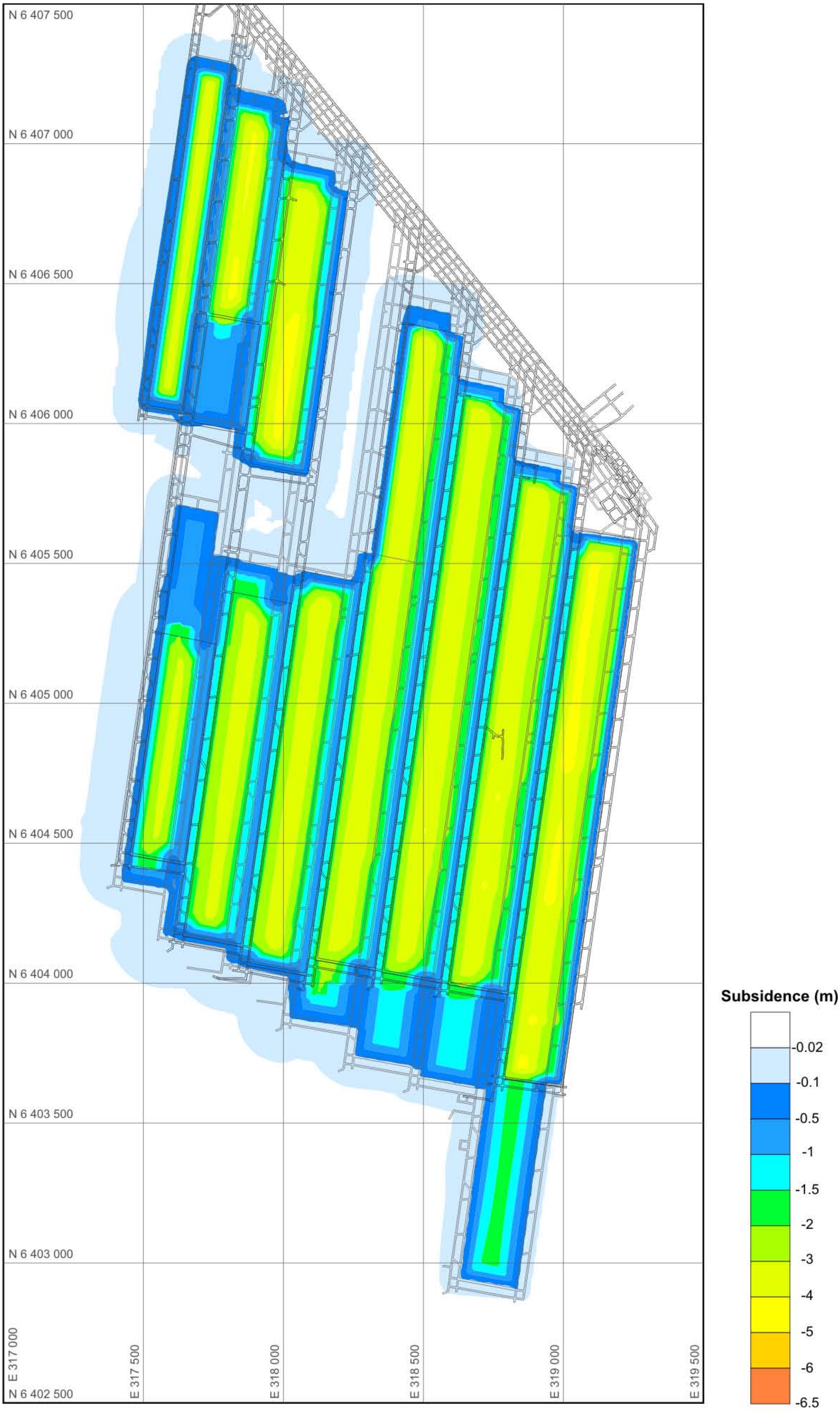


Figure 38: 85% Cumulative Pikes Gully and Upper Liddell Seam subsidence.

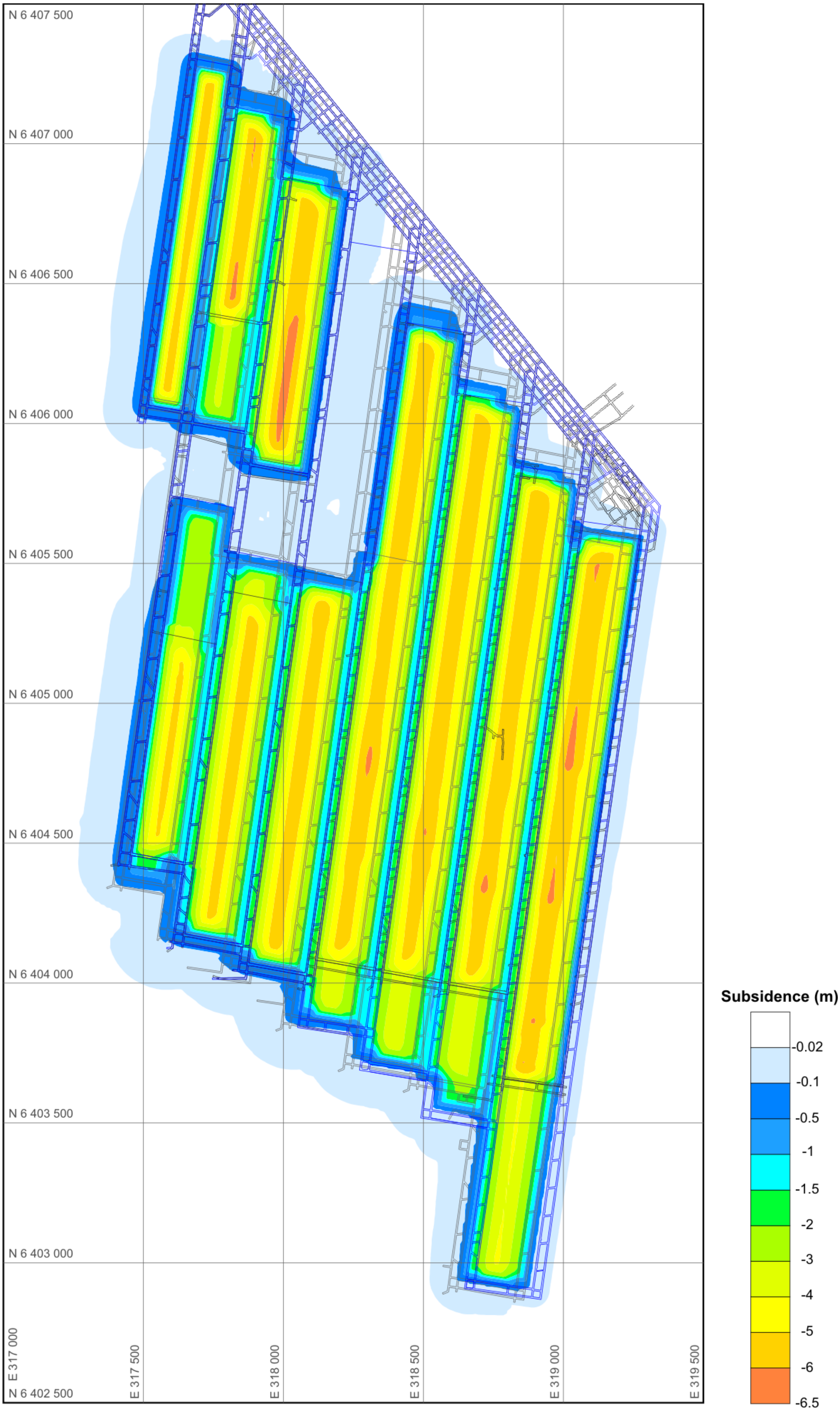


Figure 39: 85% Cumulative Pikes Gully, Upper Liddell and Upper Lower Liddell Seam subsidence.

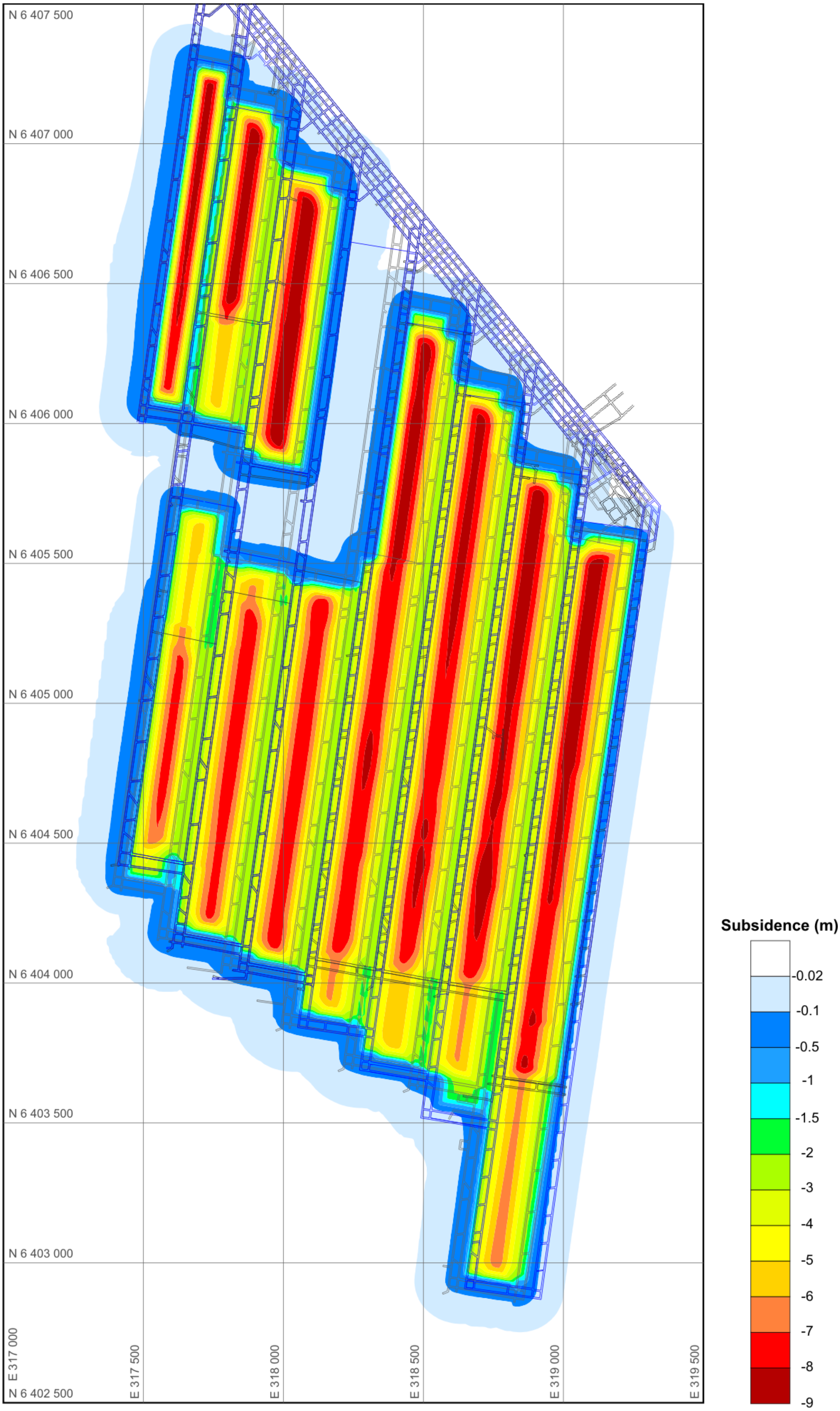


Figure 40: 85% Cumulative Pikes Gully, Upper Liddell, Upper Lower Liddell and Barrett Seam subsidence.

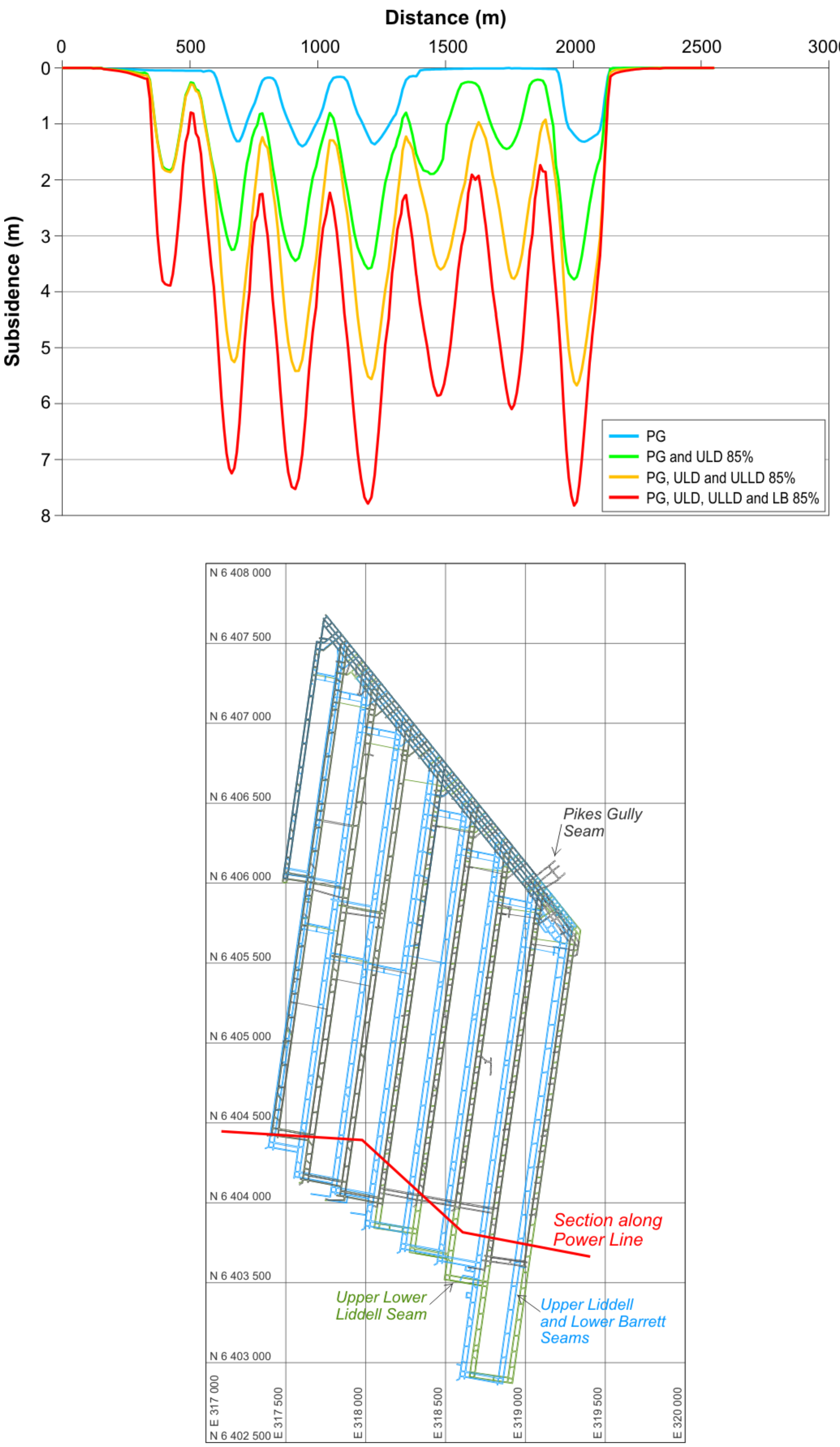


Figure 41: Anticipated subsidence along power line over Pikes Gully, Upper Liddell, Upper Lower Liddell and Lower Barrett Seams.

5. CONCLUSIONS AND RECOMMENDATIONS

The subsidence predictions in this study are produced from 3D extrapolations of 2D subsidence profiles based on FLAC 2D numerical modelling. The primary outcomes of this study are as follows:

- The cumulative maximum subsidence predictions for each seam of the multi-seam extraction is as follows:
  - The Pikes Gully Seam generally ranges from 0.6m to 1.6m subsidence depending on seam thickness and panel width
  - The cumulative Pikes Gully and Upper Liddell Seams subsidence ranges from 2.2m to 3m
  - The Upper Lower Liddell Seam combined with the Pikes Gully and Upper Liddell seams has maximum subsidence ranging from 3.6m to 4.3m
  - The Lower Barrett Seam further increases the cumulative maximum subsidence range for all four seams to 5m to 6.2m
- The predicted cumulative chain pillar subsidence for each seam of the multi-seam extraction is as follows:
  - The Pikes Gully Seam generally ranges from 0.05m to 0.2m
  - The Upper Liddell Seam increases the cumulative chain pillar subsidence range to 0.5m to 0.6m
  - The Upper Lower Liddell Seam increases the cumulative chain pillar subsidence range to 0.7m to 0.9m
  - The total chain pillar subsidence for the four seams including the Lower Barrett Seam ranges 1.6m to 1.7m

Ongoing subsidence monitoring is recommended during multi-seam mining to provide the means for validating the approach used for subsidence predictions in this study, and for future refinements in predicting subsidence impacts. In addition to the current scope of subsidence monitoring, it is recommended to extend XL5 subsidence line west of Longwall 7 to investigate the angle of draw. The XL5 line is currently stopped at Bowmans Creek, however there is a "far field' line beyond Bowmans Creek which should capture this information. It is also recommended to extend the XL5 line to the eastern side of Glennies Creek to investigate movement across the creek. This could be a couple of pegs on the eastern side of the creek to provide a reference point for the XL5 line.

Numerical modelling was not conducted on Longwall 8 narrow longwall as the FLAC modelling was based on panels 1-4. It is therefore recommended to locate a subsidence crossline across Longwall 8 to monitor and validate the subsidence predictions. There is a planned XL13 line that should capture the Longwall 8 subsidence.

6. REFERENCES

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SCT Report ASH3536: Response to Enquiry of Pillar Width Assessment for Ashton Mini Wall Area – Ashton SMP LW/MW 5-9, unpublished 14 May 2009.

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7. GLOSSARY

The terms in this glossary are defined as used in this report, although based on industry terminology.

Angle of Draw The angle between a vertical line from the goaf edge to the surface and a direct line from the goaf edge to the 20mm subsidence line. Note: an angle of 26.5 degrees is equal to a distance to the goaf edge of half the depth

Barrier Pillar A block of coal left unmined adjacent to a longwall panel whereby the overlying strata is only affected by subsidence from one longwall panel

Chain Pillar The block of coal left unmined between two longwall panels whereby the overlying strata experiences the subsidence effects from both longwall panels

Critical Subsidence The change from subcritical to supercritical subsidence, where the panel width to depth ratio reaches the maximum possible subsidence for the overburden depth

Cumulative Subsidence The change from subcritical to supercritical subsidence, where the panel width to depth ratio reaches the maximum possible subsidence for the overburden depth

Dip The angle from the horizontal plane to the plane of the strata or coal seam

Extraction Height	The height of coal that is mined in the longwall panel which may be more or less than the seam height
Goaf	The void left from Longwall panel extraction whereby the overlying strata collapses to fill the void
Incremental Subsidence	The additional subsidence caused by the extraction of each additional longwall panel, i.e., the cumulative subsidence minus any previous subsidence
Longwall Panel	The additional subsidence caused by the extraction of each additional longwall panel. i.e., the cumulative subsidence minus any previous subsidence
Maximum Subsidence	The greatest subsidence across a longwall panel along the subsidence profile
Overburden Depth	The thickness of strata between the surface and the seam
Panel Width	The shortest distance across a longwall panel
Pillar Subsidence	The minimum subsidence over a chain pillar
Polynomial Equation	An equation with variables and constants in the form: $f(x) = a_n x^n + a_{n-1} x^{n-1} + \ldots + a_1 x + a_0$ where n must be a nonnegative number, coefficients (a_n, $a_{n-1},\ldots,a_1,a_0$) are real numbers and the degree of the function is the highest value of n where a_n is not equal to zero.
Subcritical Subsidence	When the panel width to depth ratio is bigger than the point where maximum subsidence for the overburden depth occurs
Subsidence Profile	The subsidence along the cross section of the surface above a longwall panel
Supercritical Subsidence	When the panel width to depth ratio is bigger than the point where maximum subsidence for the overburden depth occurs

APPENDIX 1 - POLYNOMIAL EQUATION COEFFICIENTS

Table A1.1: Polynomial Equation Coefficients for Pikes Gully Seam Subsidence Profiles

LW	Seam Height	Depth	Pillar Type	Distance into Goaf (m)	a	b	c	d	e	f	g
1-6	2.2m	40m	Barrier	2 to 50		-2.720×10^{-8}	3.577×10^{-6}	-1.425×10^{-4}	1.349×10^{-3}	-1.452×10^{-2}	2.473×10^{-2}
				50 to 107.5					1.107×10^{-5}	-2.439×10^{-3}	-1.186
			Chain	-15 to 50	-4.362×10^{-10}	4.035×10^{-8}	-3.831×10^{-7}	-3.144×10^{-5}	-2.629×10^{-4}	-1.203×10^{-3}	-0.003
				50 to 107.5					1.107×10^{-5}	-2.439×10^{-3}	-1.186
		190m	Barrier	-180 to 20					-1.937×10^{-6}	-6.138×10^{-4}	-6.157×10^{-2}
				20 to 107.5			9.024×10^{-9}	3.931×10^{-7}	-3.170x10-7	6.858×10^{-3}	-9.243×10^{-2}
			Chain	-15 to 20				-1.905×10^{-7}	-3.714×10^{-5}	-1.18×10^{-3}	-0.24
				20 to 107.5		4.342×10^{-10}	-9.948×10^{-8}	8.938×10^{-6}	-5.303×10^{-4}	1.008×10^{-2}	-0.3265
	3.0m	40m	Barrier	2 to 50			4.312×10^{-7}	-1.766×10^{-5}	-9.118×10^{-4}	8.777×10^{-4}	-1.848×10^{-3}
				50 to 107.5					4.743×10^{-6}	-1.617×10^{-3}	-1.681
			Chain	-15 to 50	-3.590×10^{-10}	3.779×10^{-8}	-5.184×10^{-7}	-3.201×10^{-5}	-2.489×10^{-4}	-1.134×10^{-3}	-0.003
				50 to 107.5					4.743×10^{-6}	-1.617×10^{-3}	-1.681
		190m	Barrier	-180 to 20					-1.937×10^{-6}	-6.138×10^{-4}	-6.157×10^{-2}
				20 to 107.5			8.439×10^{-9}	1.842×10^{-6}	-5.853×10^{-4}	1.587×10^{-2}	-0.1716
			Chain	-15 to 20				-1.905×10^{-7}	-3.714×10^{-5}	-1.18×10^{-3}	-0.24
				20 to 107.5				4.415×10^{-6}	-8.411×10^{-4}	2.751×10^{-2}	-0.5262
7	2.2m	130m	Barrier	-80 to 20				-2.141×10^{-7}	-3.012×10^{-5}	-1.492×10^{-3}	-4.615×10^{-2}
				20 to 97.5			-2.006×10^{-8}	7.128×10^{-6}	-6.779×10^{-4}	2.623×10^{-3}	7.488×10^{-2}
			Chain	-20 to 20					-5.861×10^{-5}	-2.103×10^{-3}	-0.1645
				20 to 97.5			-2.862×10^{-8}	1.047×10^{-5}	-1.172x10-3	3.073×10^{-2}	-0.4552
		190m	Barrier	-200 to 20				-2.093×10^{-8}	-7.856×10^{-6}	-1.046×10^{-3}	-7.233×10^{-2}

LW	Seam Height	Depth	Pillar Type	Distance into Goaf (m)	Coefficients a	b	c	d	e	f	g
				20 to 97.5			1.358×10^{-8}	-6.684×10^{-7}	-1.604×10^{-4}	-1.826×10^{-5}	-3.134×10^{-2}
			Chain	-20 to 20					-3.713×10^{-5}	-1.249×10^{-3}	-0.2402
				20 to 97.5			4.562×10^{-8}	-8.680×10^{-6}	4.903×10^{-4}	-1.646×10^{-2}	-8.371×10^{-2}
	3.0m	130m	Barrier	-80 to 20				-2.141×10^{-7}	-3.012×10^{-5}	-1.492×10^{-3}	-4.615×10^{-2}
				20 to 97.5			-1.071×10^{-8}	8.356×10^{-6}	-1.149×10^{-3}	2.632×10^{-2}	-0.222
			Chain	-20 to 20					-5.861×10^{-5}	-2.103×10^{-3}	-0.1645
				20 to 97.5				6.232×10^{-6}	-1.055×10^{-3}	2.978×10^{-2}	0.4535
		190m	Barrier	-200 to 20				-2.093×10^{-8}	-7.856×10^{-6}	-1.046×10^{-3}	-7.233×10^{-2}
				20 to 97.5			3.698×10^{-8}	-4.409×10^{-6}	-6.753×10^{-5}	1.830×10^{-3}	-8.131×10^{-2}
			Chain	-20 to 20					-3.713×10^{-5}	-1.249×10^{-3}	-0.2402
				20 to 97.5			6.903×10^{-8}	-1.242×10^{-5}	5.832×10^{-4}	-1.461×10^{-2}	-0.1337
8	2.2m	130m	Barrier	-80 to 15			-5.141×10^{-9}	-9.316×10^{-7}	-5.841×10^{-5}	-1.796×10^{-3}	-4.630×10^{-2}
				15 to 67.5			-5.307×10^{-8}	1.850×10^{-5}	-1.613×10^{-3}	2.965×10^{-2}	-0.2316
			Chain	-20 to 15					-9.333×10^{-5}	-2.859×10^{-3}	-0.1660
				15 to 67.5			1.003×10^{-7}	-9.332×10^{-6}	9.417×10^{-5}	-7.746×10^{-3}	-0.1086
		190m	Barrier	-200 to 20			-1.849×10^{-10}	-9.094×10^{-8}	-1.560×10^{-5}	-1.248×10^{-3}	-6.732×10^{-2}
				20 to 67.5			4.290×10^{-8}	-6.229×10^{-6}	3.004×10^{-4}	-8.575×10^{-3}	-5.360×10^{-3}
			Chain	-20 to 0					-3.333×10^{-6}	-2.167×10^{-4}	-0.2330
				0 to 67.5			-2.556×10^{-9}	3.648×10^{-7}	-1.580×10^{-5}	8.696×10^{-5}	-0.2330
	3.0m	130m	Barrier	-80 to 15				-3.353×10^{-7}	-4.523×10^{-5}	-1.954×10^{-3}	-4.835×10^{-2}
				15 to 67.5			3.872×10^{-7}	-5.640×10^{-5}	2.684×10^{-3}	-7.139×10^{-2}	0.5476
			Chain	-20 to 15					-9.333×10^{-5}	-2.859×10^{-3}	-0.1660

LW	Seam Height	Depth	Pillar Type	Distance into Goaf (m)	Coefficients						
					a	b	c	d	e	f	g
				15 to 67.5			3.204×10^{-7}	-4.157×10^{-5}	1.468×10^{-3}	-2.806×10^{-2}	-1.547×10^{-2}
		190m	Barrier	-200 to 20			-1.849×10^{-10}	-9.094×10^{-8}	-1.560×10^{-5}	-1.248×10^{-3}	-6.732×10^{-2}
				20 to 67.5			1.060×10^{-7}	-1.637×10^{-5}	8.330×10^{-4}	-1.986×10^{-2}	7.857×10^{-2}
			Chain	-20 to 25					-1.120×10^{-5}	-3.867×10^{-4}	-0.2333
				25 to 67.5				4.431×10^{-7}	-5.300×10^{-5}	6.830×10^{-4}	-0.2409

Table A1.2: Polynomial Equation Coefficients for Upper Liddell Seam 2.2m Subsidence Profiles

LW	Depth	Pillar Type	Distance into Goaf (m)	Coefficients					
				a	b	c	d	e	f
TG1	(multi-seam)	Barrier	-50 to 0			-2.089×10^{-6}	-1.638×10^{-4}	-4.367×10^{-3}	-0.008
			0 to 107.5	-5.178×10^{-10}	1.329×10^{-7}	-9.928×10^{-6}	1.867×10^{-4}	-1.287×10^{-2}	-8.034×10^{-2}
1-6		Barrier	-120 to 0			-1.532×10^{-7}	-3.185×10^{-5}	-2.419×10^{-3}	-9.630×10^{-2}
			0 to 107.5	-3.842×10^{-10}	9.528×10^{-8}	-6.072×10^{-6}	1.143×10^{-5}	-9.470×10^{-3}	-0.1003
		Chain	-20 to 10				-1.735×10^{-18}	-1.231×10^{-3}	-0.2281
			10 to 107.5		-4.349x10-8	1.242x10-5	-1.090x10-3	1.845x10-2	-0.3275
	80m	Barrier	-50 to 10			-5.282×10^{-7}	-5.119×10^{-5}	-1.767×10^{-3}	-2.639×10^{-2}
			10 to 107.5	9.859×10^{-10}	-3.739×10^{-7}	5.181×10^{-5}	-2.983×10^{-3}	4.490×10^{-2}	0.2488
		Chain	-20 to 10				-4.667×10^{-5}	-1.460×10^{-3}	-3.060×10^{-2}
			10 to 107.5	9.859×10^{-10}	-3.739×10^{-7}	5.181×10^{-5}	-2.983×10^{-3}	4.490×10^{-2}	-0.2488
	220m	Barrier	-250 to 0			-1.920×10^{-8}	-8.431×10^{-6}	-1.283×10^{-3}	-9.371×10^{-2}
			0 to 107.5		4.349×10^{-9}	1.070×10^{-6}	-2.649×10^{-4}	-5.602×10^{-4}	-0.1061
		Chain	-20 to 10				-4.667×10^{-5}	-1.460×10^{-3}	-0.4006
			10 to 107.5		1.447×10^{-8}	-1.515×10^{-6}	-9.465×10^{-5}	1.367×10^{-3}	-0.4233
7 & 4b	(multi-seam)	Barrier	-120 to 10		-1.737×10^{-9}	-4.682×10^{-7}	-4.326×10^{-5}	-1.924×10^{-3}	-5.663×10^{-2}
			10 to 80			5.885×10^{-7}	1.683×10^{-4}	-3.711×10^{-2}	0.2727
		Chain	-20 to 10				1.200×10^{-4}	-3.507×10^{-3}	-0.2324
			10 to 80			2.206×10^{-6}	-1.350×10^{-4}	-1.874×10^{-2}	-8.345×10^{-2}

LW	Depth	Pillar Type	Distance into Goaf (m)	Coefficients					
				a	b	c	d	e	f
7	180m	Barrier	-200 to 0				-2.273×10^{-6}	-8.700×10^{-4}	-8.414×10^{-2}
			0 to 80			9.853×10^{-7}	-8.231×10^{-5}	-6.913×10^{-3}	-8.461×10^{-2}
		Chain	-20 to 10				-4.000×10^{-5}	-1.747×10^{-3}	-0.2988
			10 to 80		3.784×10^{-8}	-5.459×10^{-6}	2.131×10^{-4}	-6.345×10^{-3}	-0.2722
8	(multi-seam)	Barrier	-220 to 0			-1.651×10^{-8}	-7.539×10^{-6}	-1.169×10^{-3}	7.811×10^{-2}
			0 to 62.5			9.523×10^{-6}	-8.146×10^{-4}	-6.089×10^{-3}	-9.078×10^{-2}
		Chain	-20 to 10				1.200×10^{-4}	-3.507×10^{-3}	-0.2324
			10 to 62.5			7.483×10^{-6}	-6.027×10^{-4}	-1.077×10^{-2}	-0.1293

Table A1.3: Polynomial Equation Coefficients for Upper Lower Liddell Seam 3.0m Subsidence Profiles

LW	Pillar Type	Distance into Goaf (m)	Coefficients						
			a	b	c	d	e	f	g
1-6	Barrier	-220 to 10					$-8.605x10^{-7}$	$-4.103x10^{-4}$	$-4.924x10^{-2}$
		10 to 107.5		$1.220x10^{-9}$	$-4.553x10^{-7}$	$6.353x10^{-5}$	$-3.794x10^{-3}$	$6.115x10^{-2}$	-0.3512
	Chain	-20 to 0					$-6.667x10^{-5}$	$-2.333x10^{-3}$	-0.36
		0 to 107.5	$1.525x10^{-11}$	$-5.637x10^{-9}$	$7.418x10^{-7}$	$-3.781x10^{-5}$	$3.600x10^{-4}$	$-4.505x10^{-3}$	-0.36
7	Barrier	-220 to 10					$8.605x10^{-7}$	$-4.103x10^{-4}$	$-4.924x10^{-2}$
		10 to 97.5				$2.292x10^{-6}$	$-2.070x10^{-4}$	$-2.400x10^{-2}$	0.1977
	Chain	-20 to 0					$-6.667x10^{-5}$	$-2.333x10^{-3}$	-0.36
		0 to 97.5				$3.700x10^{-6}$	$-5.222x10^{-4}$	$-9.495x10^{-4}$	-0.3535
8	Barrier	-220 to 10					$-8.605x10^{-7}$	$-4.103x10^{-4}$	$-4.924x10^{-2}$
		10 to 65			$-5.126x10^{-7}$	$8.175x10^{-5}$	$-3.713x10^{-3}$	$3.136x10^{-3}$	0.2035
	Chain	-20 to 0					$-6.667x10^{-5}$	$-2.333x10^{-3}$	-0.36
		0 to 65			$-2.835x10^{-7}$	$4.798x10^{-5}$	$-2.286x10^{-3}$	$-1.202x10^{-3}$	-0.3586

Table A1.4: Polynomial Equation Coefficients for Lower Barrett Seam 3.0m Subsidence Profiles

LW	Pillar Type	Distance into Goaf (m)	Coefficients					
			a	b	c	d	e	f
TG1	Barrier	-260 to -30				$-3.689x10^{-6}$	$-1.531x10^{-3}$	-0.1622
		-30 to 107.5	$-4.905x10^{-10}$	$1.218x10^{-7}$	$-7.179x10^{-6}$	$-1.136x10^{-4}$	$-4.630x10^{-3}$	-0.4824
1-6	Barrier	-220 to 20				$-2.928x10^{-6}$	$-1.129x10^{-3}$	-0.1111
		20 to 107.5			$-2.457x10^{-6}$	$8.210x10^{-4}$	$-9.096x10^{-2}$	1.35
	Chain	-20 to 20				$9.704x10^{-5}$	$-2.992x10^{-3}$	-0.7012
		20 to 107.5			$2.935x10^{-7}$	$1.083x10^{-4}$	$-3.168x10^{-2}$	0.2036
7	Barrier	-220 to 0				$-2.338x10^{-6}$	$8.126x10^{-4}$	$-7.596x10^{-2}$
		0 to 97.5	$1.845x10^{-9}$	$-5.550x10^{-7}$	$5.951x10^{-5}$	$-2.380x10^{-3}$	$-5.755x10^{-3}$	-0.065
	Chain	-20 to 20				$-1.493x10^{-4}$	$-4.312x10^{-3}$	-0.7061
		20 to 97.5				$2.123x10^{-4}$	$-3.960x10^{-2}$	-0.1448
8	Barrier	-220 to 0				$-2.338x10^{-6}$	$8.126x10^{-4}$	$-7.596x10^{-2}$
		0 to 65		$-4.394x10^{-7}$	$7.074x10^{-5}$	$-3.278x10^{-3}$	$5.000x10^{-3}$	$-6.544x10^{-2}$
	Chain	-20 to 20				$-1.493x10^{-4}$	$-4.312x10^{-3}$	-0.7061
		20 to 65				$6.479x10^{-4}$	$-8.080x10^{-2}$	0.5124

APPENDIX 2 – ENLARGEMENT OF TOPOGRAPHIC SURFACES WITH SUBSIDENCES

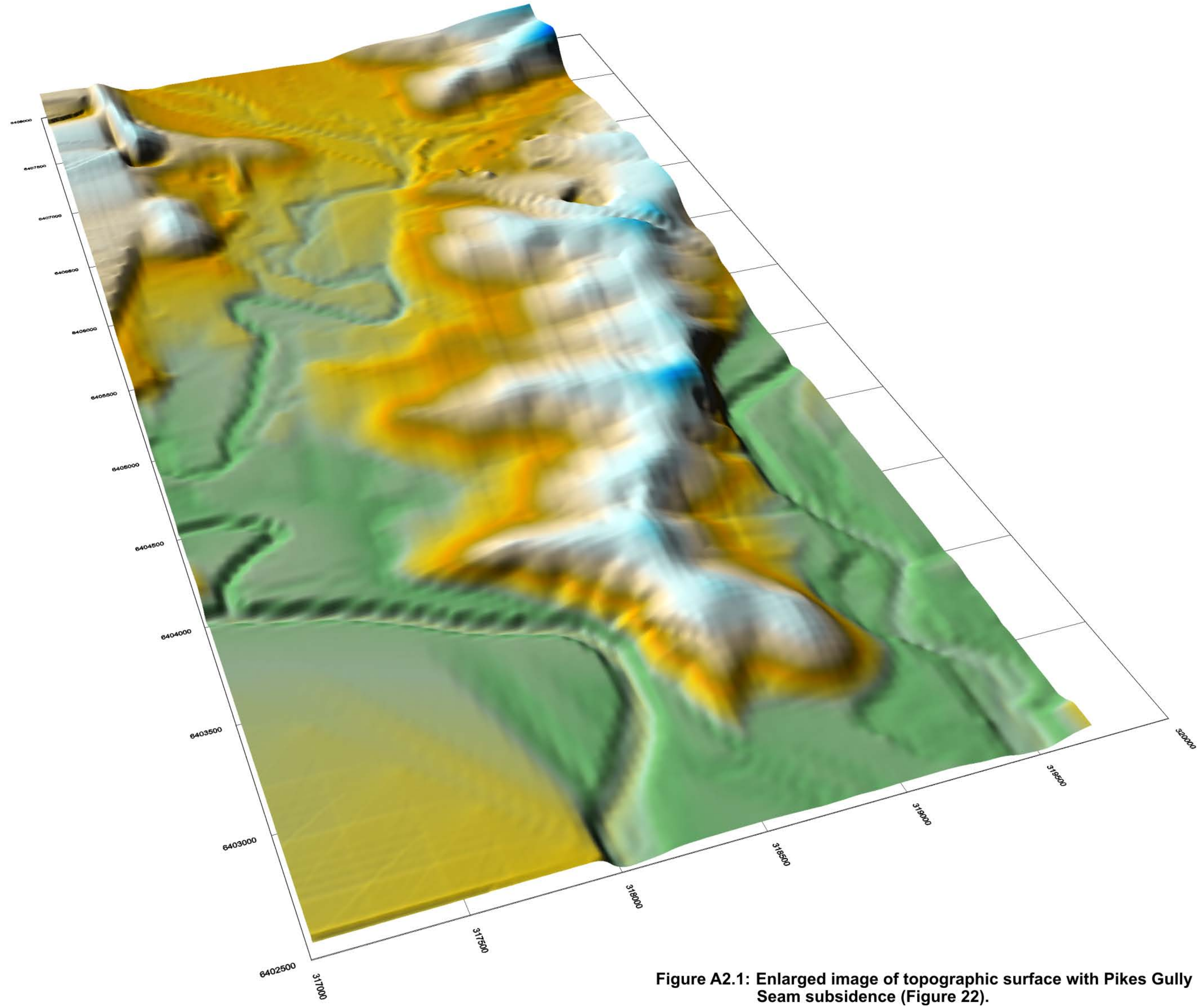

Figure A2.1: Enlarged image of topographic surface with Pikes Gully Seam subsidence (Figure 22).

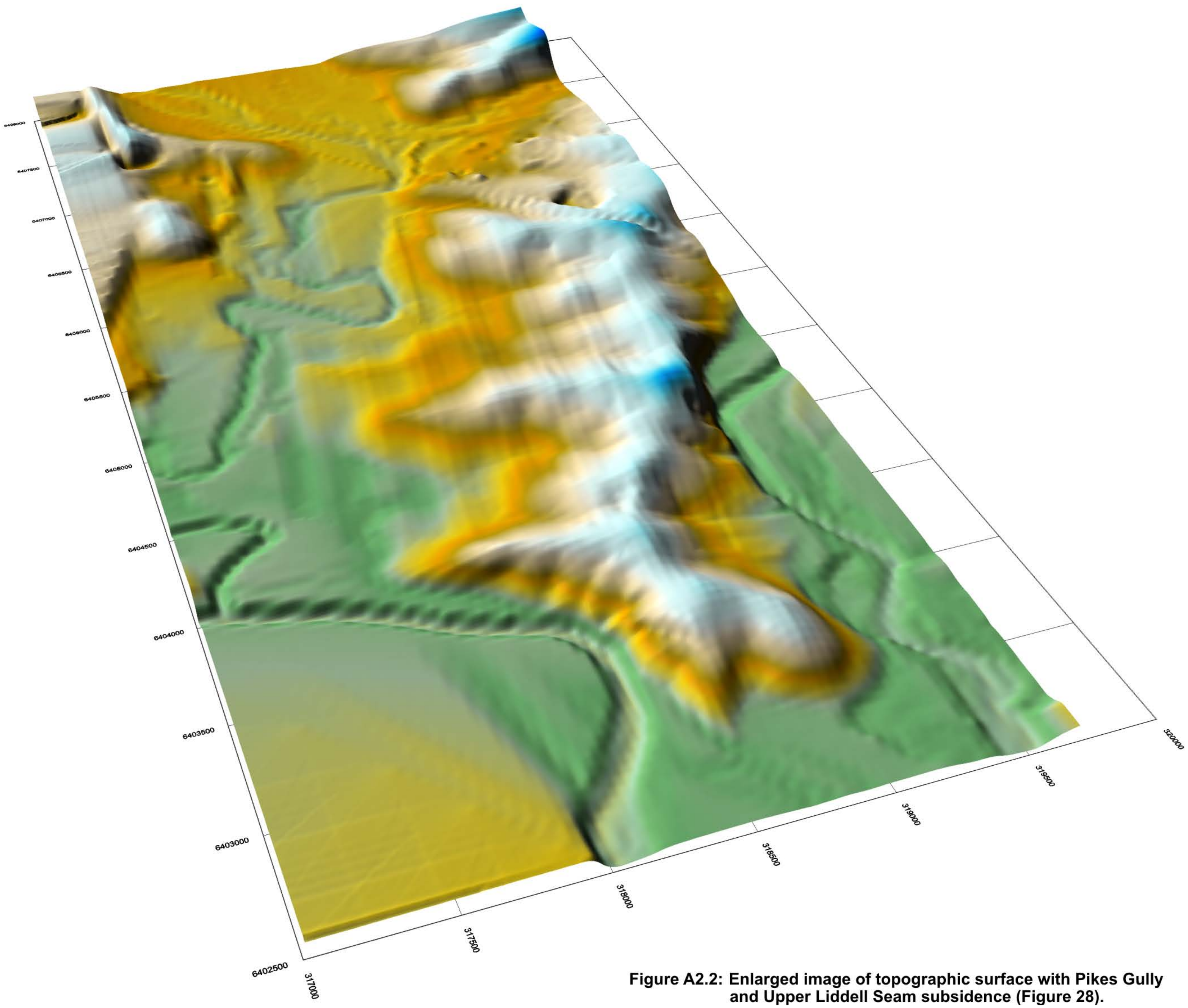

Figure A2.2: Enlarged image of topographic surface with Pikes Gully and Upper Liddell Seam subsidence (Figure 28).

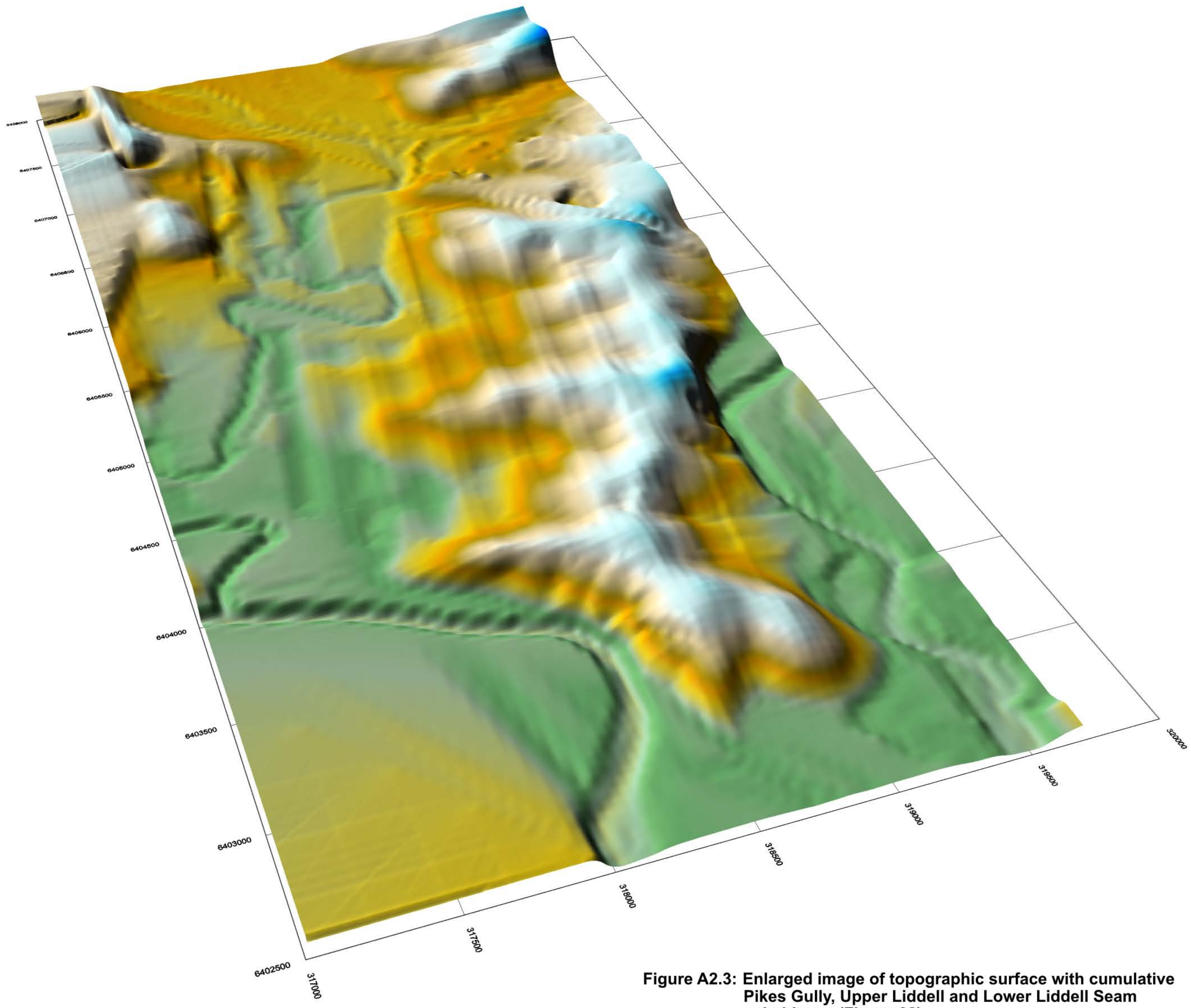

Figure A2.3: Enlarged image of topographic surface with cumulative Pikes Gully, Upper Liddell and Lower Liddell Seam subsidence (Figure 32).

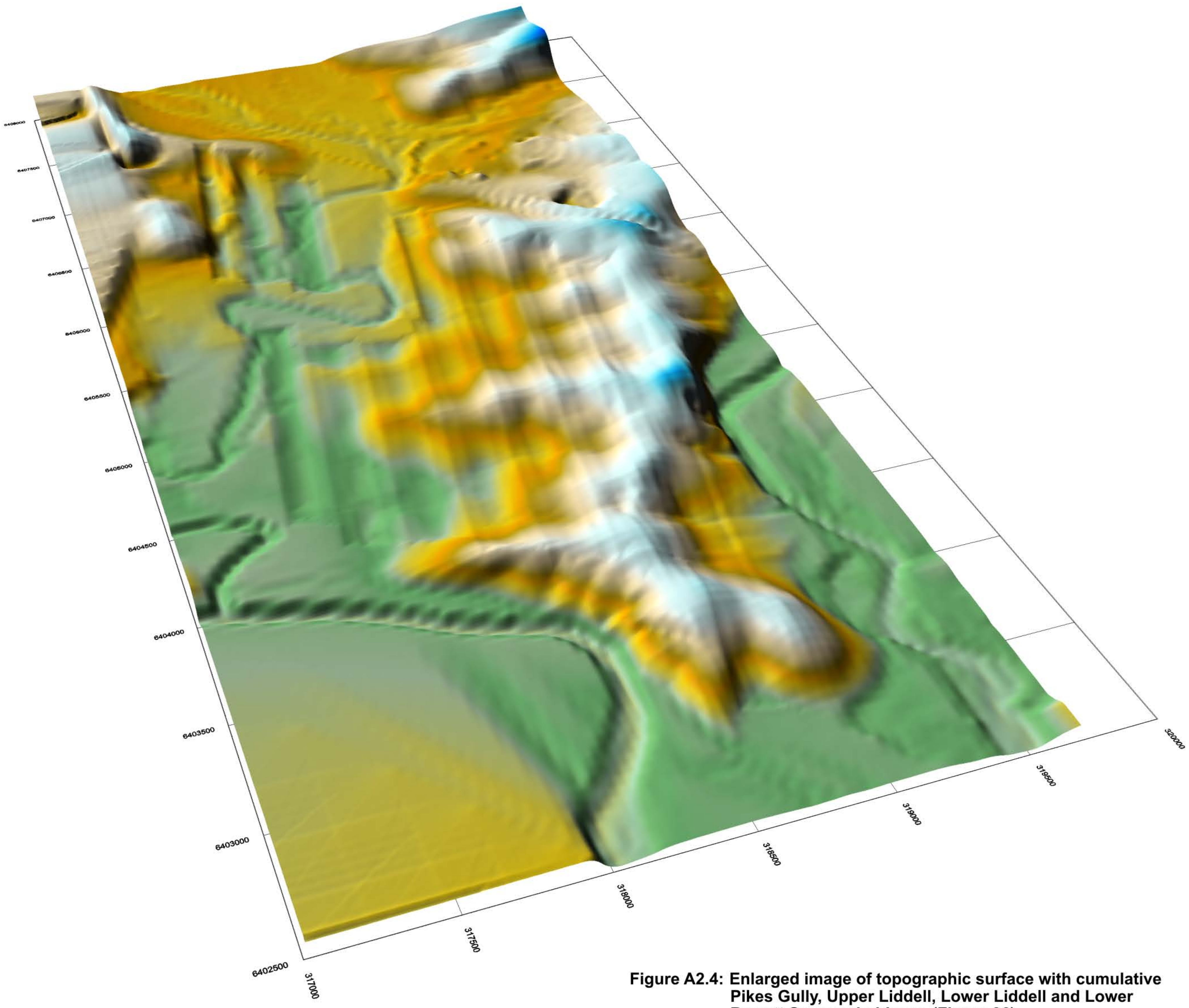

Figure A2.4: Enlarged image of topographic surface with cumulative Pikes Gully, Upper Liddell, Lower Liddell and Lower Barrett Seam subsidence (Figure 36).