

J | Subsidence Report





R E P O R T T O :

HANCOCK GALILEE PTY LTD

Kevin's Corner Subsidence 3D Extrapolation

HAN3722

REPORT TO

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SUBJECT

Kevin's Corner Subsidence
3D Extrapolation

REPORT NO

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DATE

17 December 2010

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1. INTRODUCTION

This report provides a 3D subsidence prediction model for the D Seam at the proposed Kevin's Corner Mine. Predictions of both subsidence and tilt have been determined using empirical methods for creating subsidence profiles.

Kevin's Corner consists of three proposed mine areas including the Northern, Central and Southern areas. The D Seam is thicker in the Southern and Central areas while the seam splits off in the northern area leaving a reduced working section. The Kevin's Corner mine plan is presented in Figure 1.

The 3D subsidence profile consists of an extrapolation of 2D subsidence profiles to 3D, to include the entire mine plan.

2. METHODOLOGY

2D subsidence profiles were created using empirical methods and extrapolated to encompass the mine area in 3D. In-house code was formulated to extrapolate the 2D subsidence profiles to 3D. The model consists of three 10x10m grids separately encompassing the Northern, Central and Southern mine areas. Subsidence is determined at each grid point and superimposed onto the topography.

Surfer 9 is used for modelling the subsidence surfaces and calculating tilt. Surfer 9 is a contouring and 3D surface mapping software package that facilitates the manipulation and presentation of 3D models.

2.1 Mine Data

Mine data supplied and used for the subsidence predictions include:

- Proposed mine plan
- D Seam RLs
- Topography RLs

2.2 Geological Characterisation

The DL2 ply was used as the D Seam floor for modelling. The DL2 seam ply dips approximately to the west at 1.5°. The overburden thickness is a combination of the seam dip to the west and an increase in topography to the west. The relation between the D seam floor and topography RLs is presented in Figure 2.

The general overburden strata for the D Seam consists of an interbedded sedimentary sequence. As there are no bridging units, it is anticipated that the lithology is similar to that of other sites with a subsidence ratio of 0.65 x extraction height.

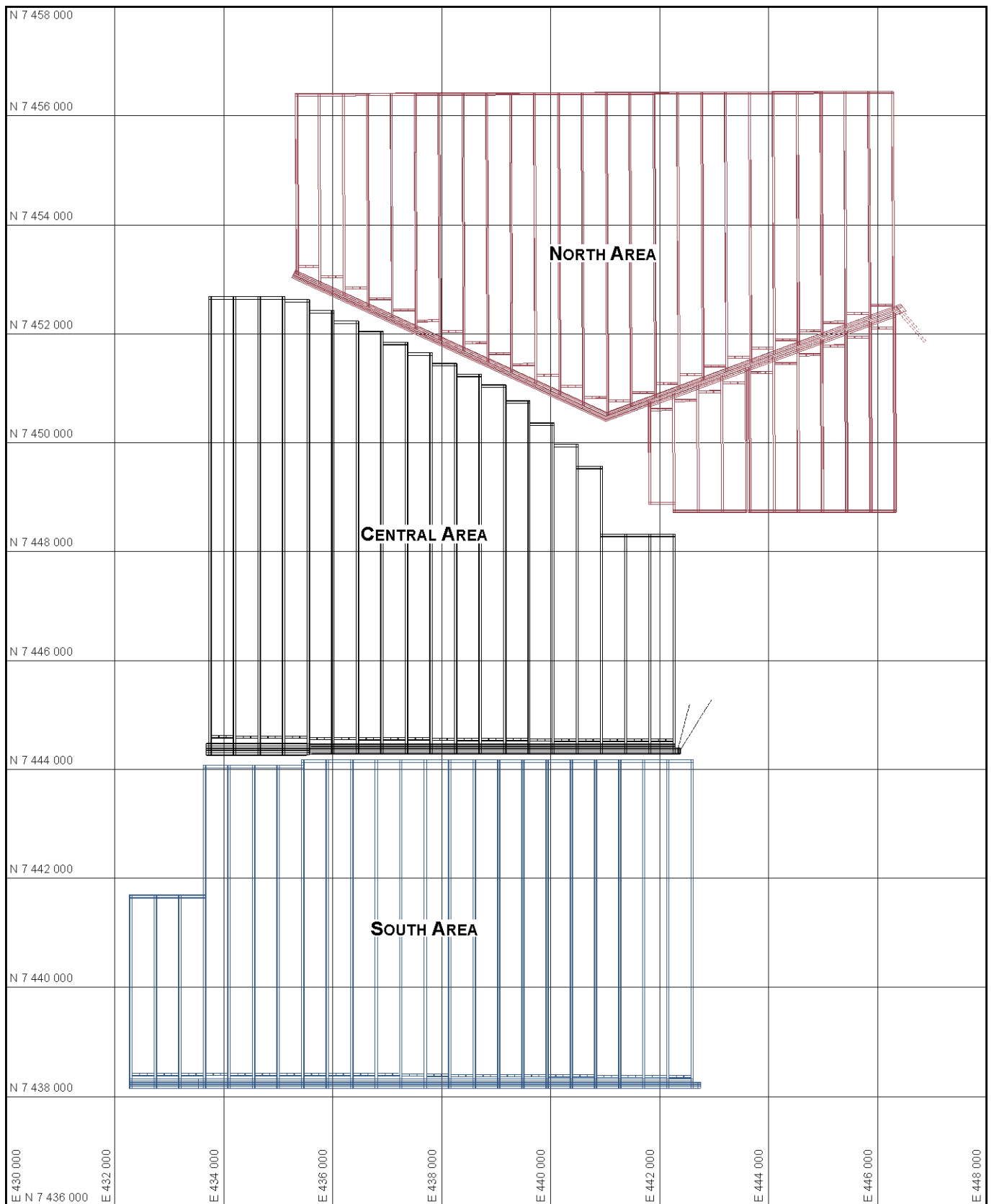


Figure 1: Mine plan showing North, Central and South Areas.

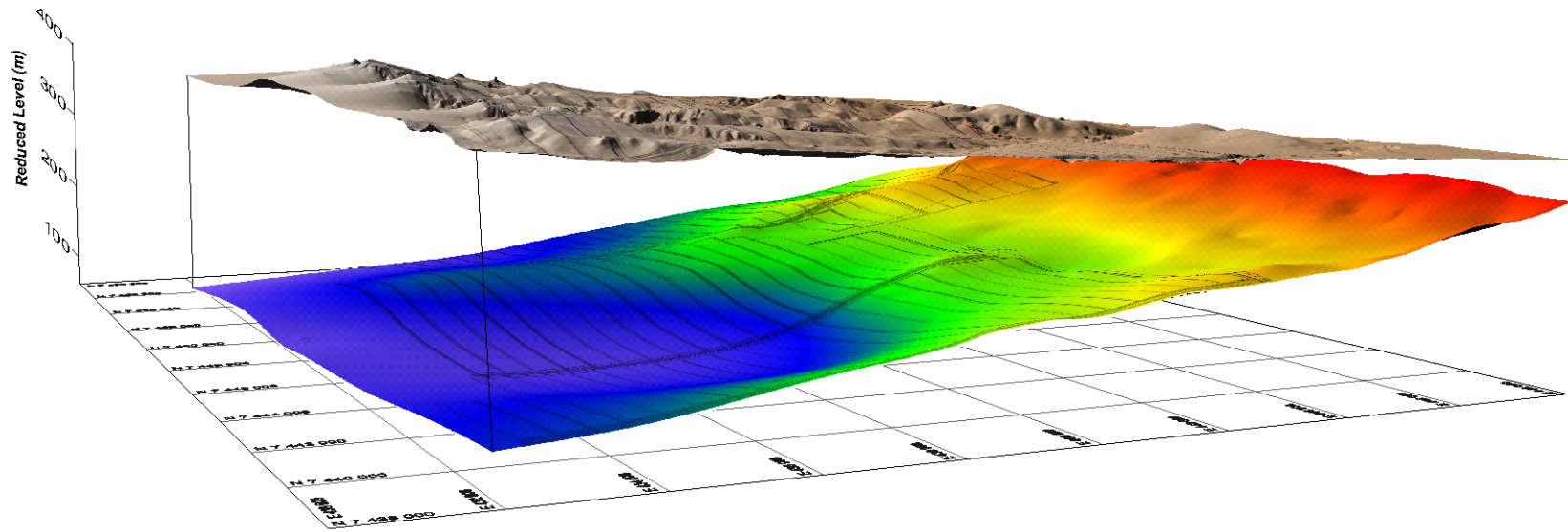


Figure 2: Plan showing relationship between D Seam floor and topography RLs.

2.3 Subsidence Profiles

2D subsidence profiles were developed for the proposed extraction height, panel width and pillar widths for both the maximum and minimum depth over the mine plan. Profiles were also developed for barrier and chain pillar instances. The components of the subsidence profiles include the maximum subsidence, point of inflection, abutment subsidence and angle of draw. From these 2D subsidence profiles, the subsidence about the mine area is calculated with reference to the overburden thickness, distance from the pillar edge and pillar type.

The maximum subsidence was determined using the maximum subsidence/seam thickness and panel width to depth ratio profile as outlined in Figure 3. The width to depth ratios were critical to supercritical for the mine areas, equating to 0.65 x extraction height.

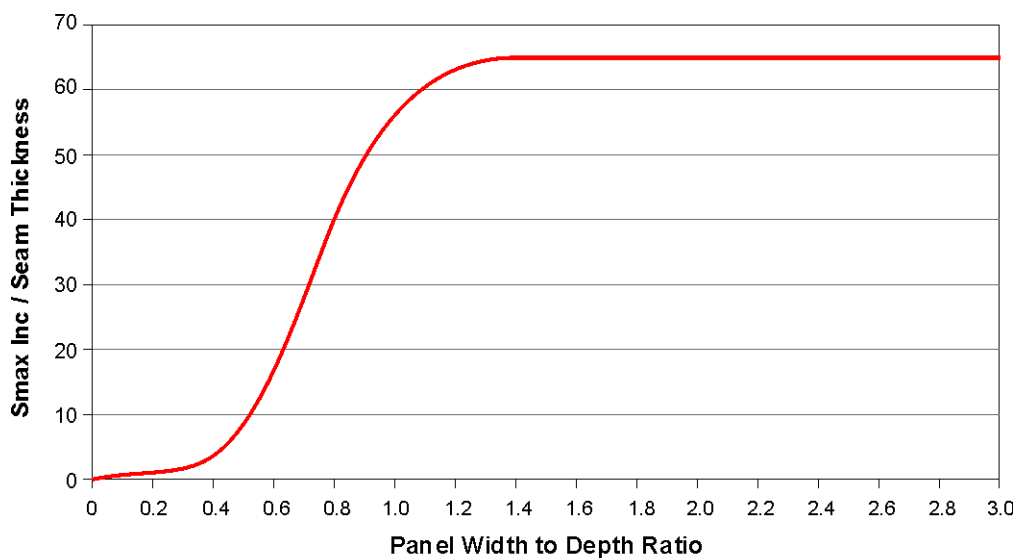


Figure 3: Prediction curves for maximum incremental subsidence.

(Source: MSEC Report August 2007).

The point of inflection of the subsidence curve is $\frac{1}{4}$ of the panel width for critical extraction. The critical extraction panel width was determined for both depths and inflection distance from panel edge was calculated. The distance from panel edge for the maximum subsidence is twice the point of inflection.

Abutment subsidence over the pillars was determined from SCT's database of numerical modelling of other mines in the area.

An angle of draw of 26.5 degrees was used for the 20mm subsidence contour (Whittaker and Reddish, 1989).

A summary of the longwall geometry and calculated components used for creating the subsidence profiles are presented in Table 1. The northern area has a different set of details as the working section height is less than that of the central and southern areas.

Table1: Subsidence Curve Details

	Northern Area		Central and Southern Areas	
Depth	80m	300m	80m	300m
Panel Width	410m		410m	
Pillar Width	30m		40m	
Working Section	3m		4.5m	
Width/Depth Ratio	> 1.4	1.4	> 1.4	1.4
Max. Subsidence*	1.95m		2.93m	
20mm Subsidence	89m	335m	89m	335m
Curve Inflection	28m	102.5m	28m	102.5m

* Determined from Figure 3

The profiles created from the specifics in Table 1 are presented in Figure 4. The left side of the profiles represent the barrier pillar edge while the right side of the profile represents the chain pillar. Equations were fitted to the subsidence profiles, manipulating the curve to ensure flattening at the peaks and troughs.

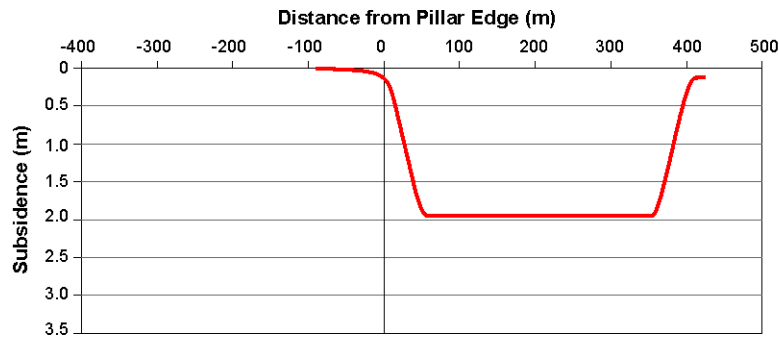
The following polynomial equation format was used for the subsidence profiles:

$$y = ax^5 + bx^4 + cx + d$$

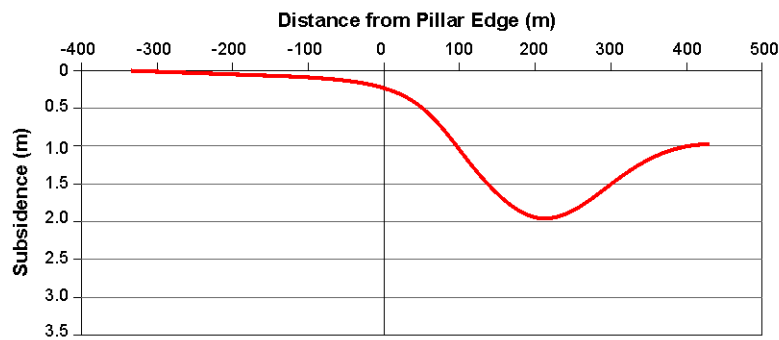
where a, b, c and d coefficients are tabulated in Table 2.

Table 2: Subsidence Profile Equation Variables

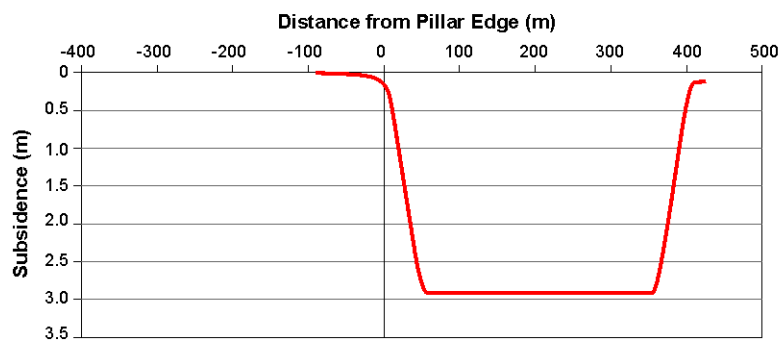
Mine Area	Depth	Pillar Type	Over Pillar or Goaf	Variables			
				a	b	c	d
North	80m	Barrier	Pillar		-2.120x10 ⁻⁵	-3.169x10 ⁻³	-0.12
			Goaf	1.591x10 ⁻⁵	-1.330x10 ⁻³	-8.093x10 ⁻³	-0.12
		Chain	Pillar		-2.667x10 ⁻⁵	-1.067x10 ⁻³	-0.13
			Goaf	1.603x10 ⁻⁵	-1.346x10 ⁻³	-7.372x10 ⁻³	-0.13
	300m	Barrier	Pillar		-2.334x10 ⁻⁶	-1.433x10 ⁻³	-0.23
			Goaf	3.164x10 ⁻⁷	-9.729x10 ⁻⁵	-1.742x10 ⁻³	-0.23
		Chain	Pillar		-8.000x10 ⁻⁵	-2.600x10 ⁻³	-1.0
			Goaf	1.868x10 ⁻⁷	-5.792x10 ⁻⁵	-6.111x10 ⁻⁴	-1.0
Central And South	80m	Barrier	Pillar		-1.580x10 ⁻⁵	-2.723x10 ⁻³	-0.12
			Goaf	2.661x10 ⁻⁵	-2.238x10 ⁻³	-8.186x10 ⁻³	-0.12
		Chain	Pillar		-2.667x10 ⁻⁵	-1.067x10 ⁻³	-0.13
			Goaf	2.673x10 ⁻⁵	-2.255x10 ⁻³	-7.462x10 ⁻³	-0.13
	300m	Barrier	Pillar		-3.781x10 ⁻⁵	-5.807x10 ⁻³	-0.23
			Goaf	4.153x10 ⁻⁷	-1.275x10 ⁻⁴	-4.468x10 ⁻³	-0.23
		Chain	Pillar		-3.000x10 ⁻⁵	-1.100x10 ⁻³	-0.99
			Goaf	3.370x10 ⁻⁷	-1.043x10 ⁻⁴	-2.212x10 ⁻³	-0.99



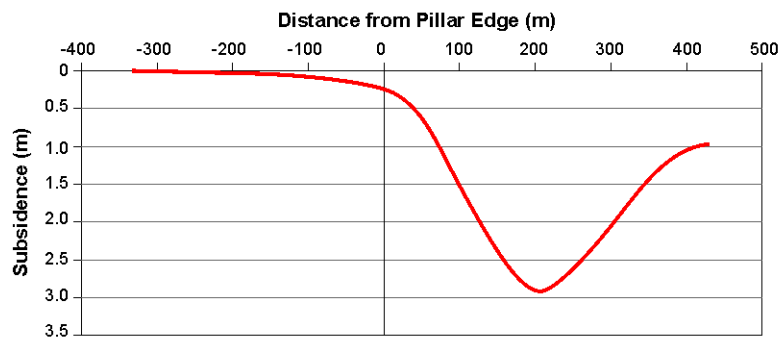
a) North Area 80m depth - 3m extraction height.



b) North Area 300m depth - 3m extraction height.



c) South and Central Areas 80m depth - 4.5m extraction height.



d) South and Central Areas 300m depth - 4.5m extraction height.

Figure 4: Subsidence profiles for 3.0m and 4.5m extraction heights.

2.4 Node Subsidence

In house code is used to create, determine and assign the following information to each node in a 10x10m grid:

- Coordinates
- Distance from pillar edge
- Closest pillar
- Pillar type – chain or barrier
- 80m Subsidence
- 300m Subsidence
- Overburden depth

The 80m and 300m subsidence grids are calculated using the subsidence profiles, distance to panel edge and pillar type. The predicted subsidence for the overburden depth is determined proportionally between the shallow subsidence and deep subsidence.

2.5 Tilt

Tilt is determined from the slope of the subsidence surface model and is presented in mm/m. Tilt is a gradient combining the z changes in both the x and y directions:

$$Tilt = \sqrt{\left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2}$$

2.6 Model Outputs and Deliverables

The quantitative model outputs for the subsidence predictions include:

- Differential subsidence contour plots
- Surface topography after subsidence
- Differential Tilt contour plots after subsidence
- Surface tilt of topography after subsidence

SCT deliverables include:

- Subsidence Contour Plots
- Topographic Surface plots with subsidence
- Subsidence Tilt plots
- Tilt plots of Topography with subsidence
- DXF of surface topography post subsidence
- 10x10m grid DAT file of surface topography with subsidence

3. RESULTS – PREDICTED SUBSIDENCE MODELS

Based on the proposed mine plan and overburden depths, subsidence prediction models were developed individually for each mine area due to the large mine plan extent and varying characteristics, and include the Northern, Central and Southern areas. The results are presented separately for each mine area.

3.1 Northern Mine Area

The northern mine area consists of 35 (25 + 10) North-South aligned longwall panels. The predicted subsidence contours for the northern mine area are presented in Figure 5.

The minimum subsidence is contoured at 0.02m, corresponding with surveying accuracy. The maximum subsidence is predicted to be 1.95m for all panels, with the entire mine area subsiding at supercritical. Maximum subsidence is reached at a closer distance to the pillar edge at shallower overburden depths. Therefore the panels in the east have sharper subsidence profiles than the west.

The pillar abutment subsidence increases to the west as the overburden thickness increases. The overburden thickness over the northern area panels ranges from approximately 70m to 290m. Chain pillar subsidence for this overburden depth range is approximately 0.1m in the East, grading to 0.9m in the West. Localised topographic variations create minor variations in the pillar subsidence.

The subsidence predictions superimposed onto the topography are presented in Figure 6. The orthogonal image presents the longwall panel subsidence in relation to the topographic variations while the plan view shows the final topographic contours post subsidence.

The additional tilt created from the predicted subsidence is at its maximum at the point of inflection on the subsidence profile. The tilt contours for the northern area are presented in Figure 7. The maximum tilt on the shallowest longwall panel in the northern area is 40mm/m. The maximum tilt for the deepest panel in the west is 20mm/m. Note: the diagonal tilt trends on the corners on the panels are a relic of the modelling and are not predicted to occur.

The contoured slope for the final topography after subsidence is presented in Figure 8. The maximum slope over the longwall panels in the final topography after subsidence is in the order of 400mm/m. This slope is related to the steeper topography in the west of the northern mine area.



Figure 5: Predicted subsidence contours - North Area .

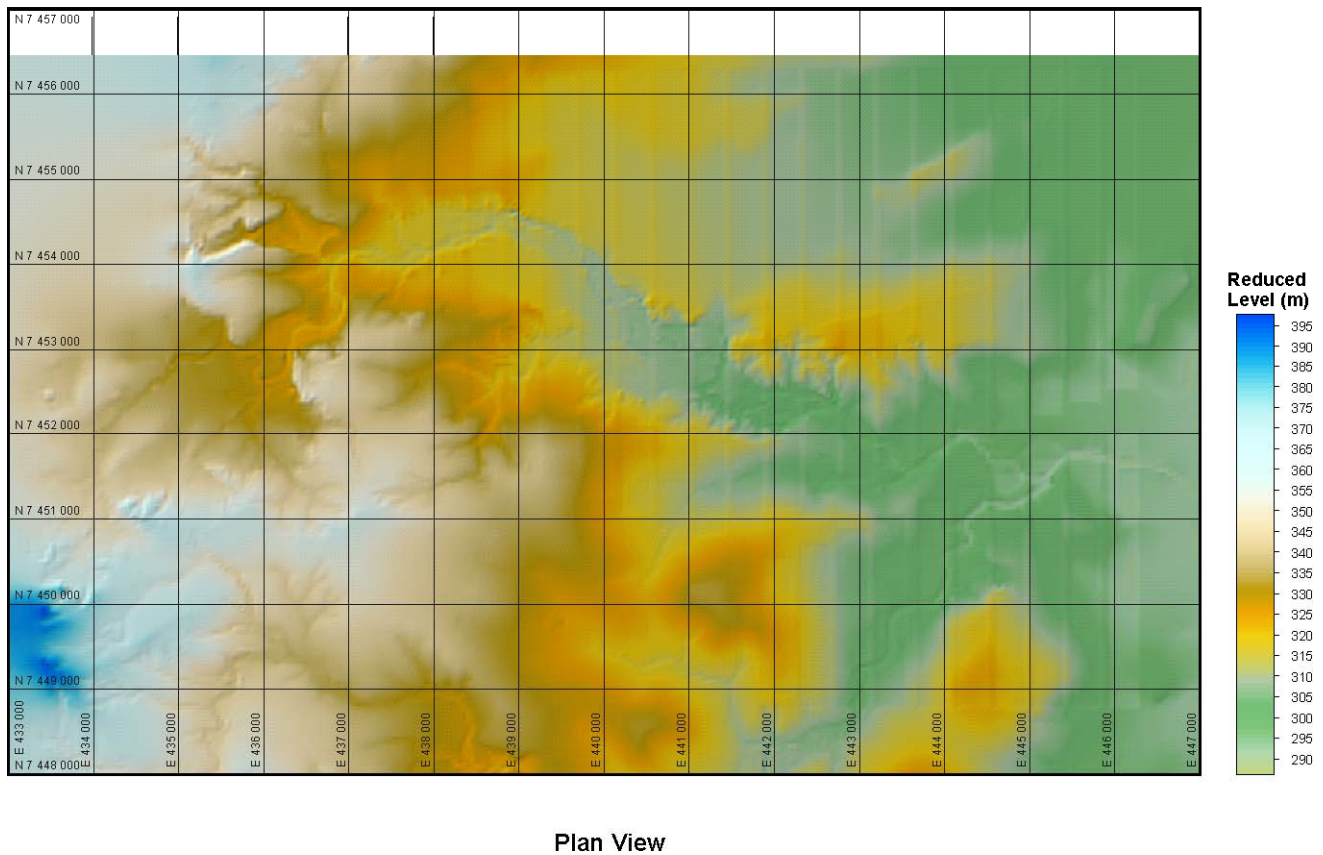
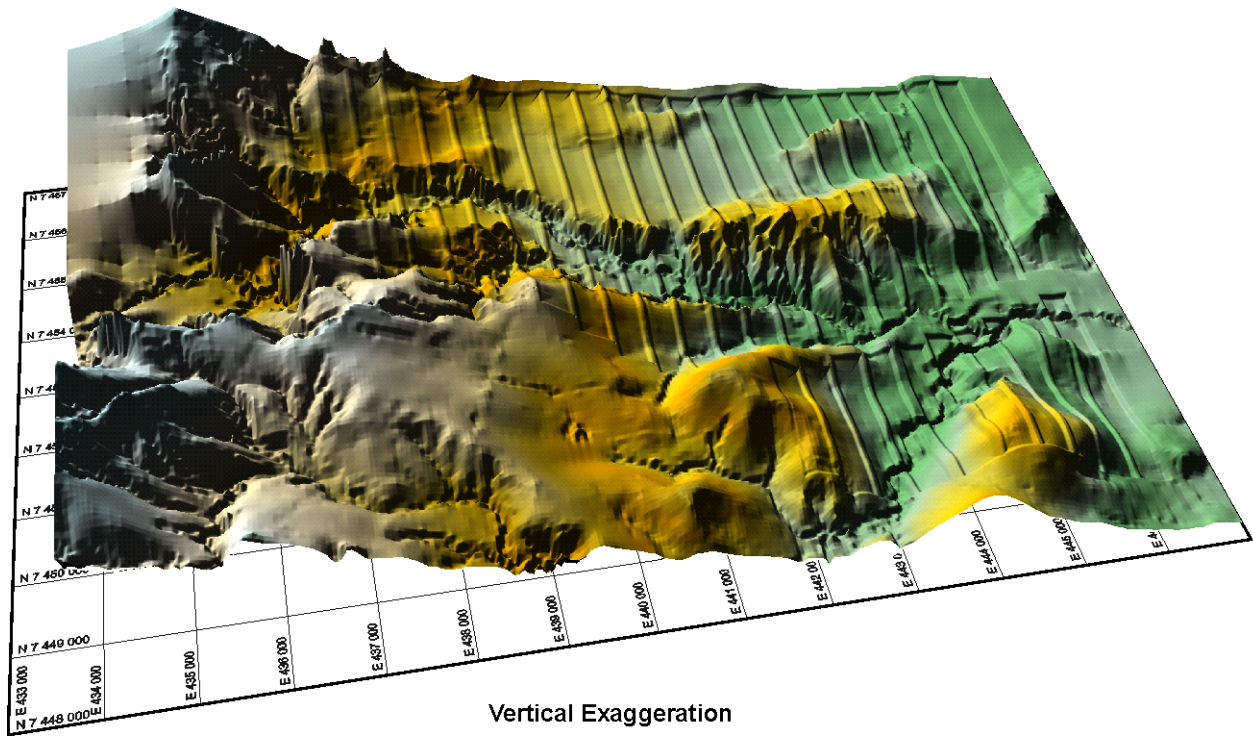


Figure 6: Plan showing topography with subsidence - North Area.

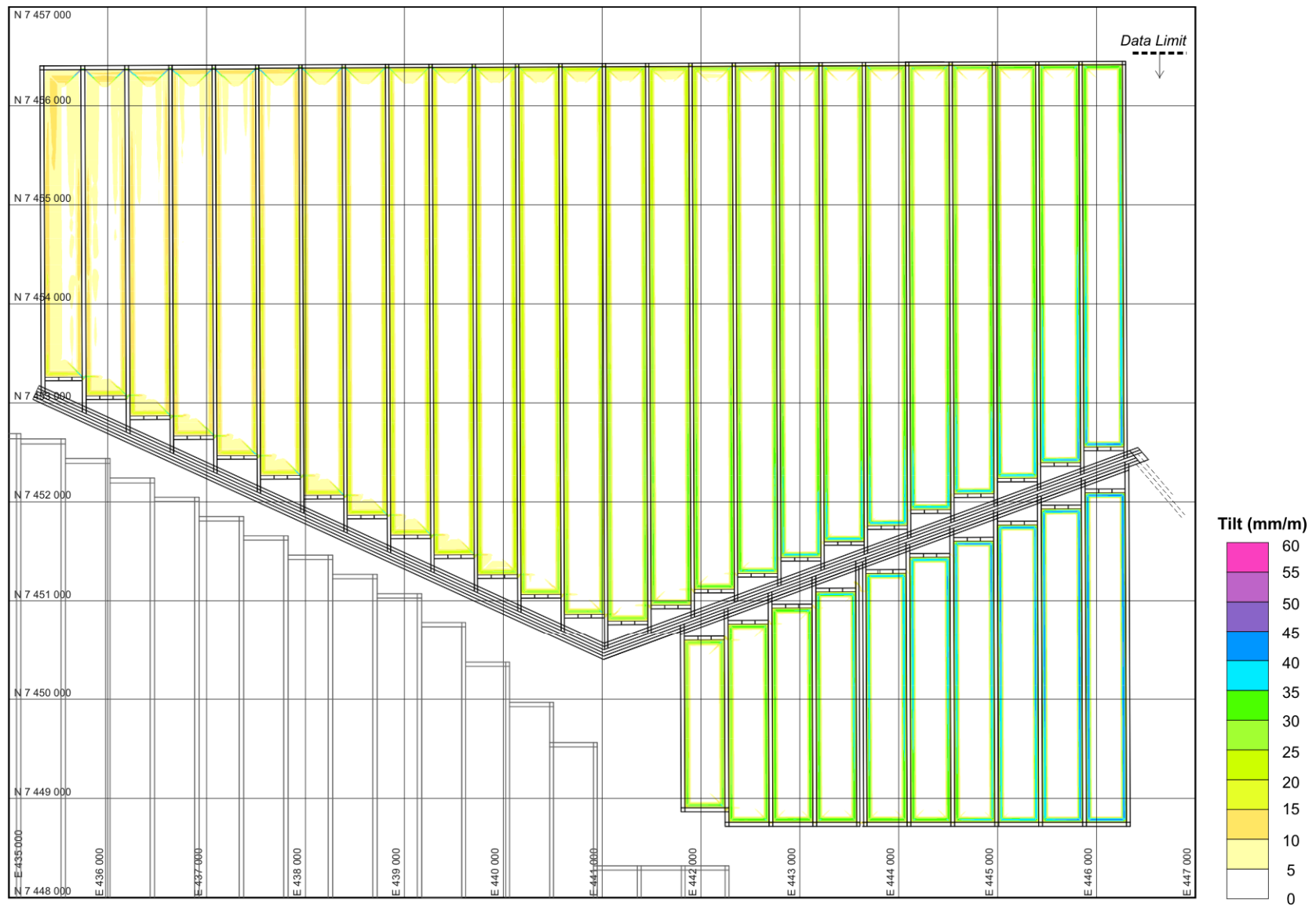


Figure 7: Tilt contours - North Area.

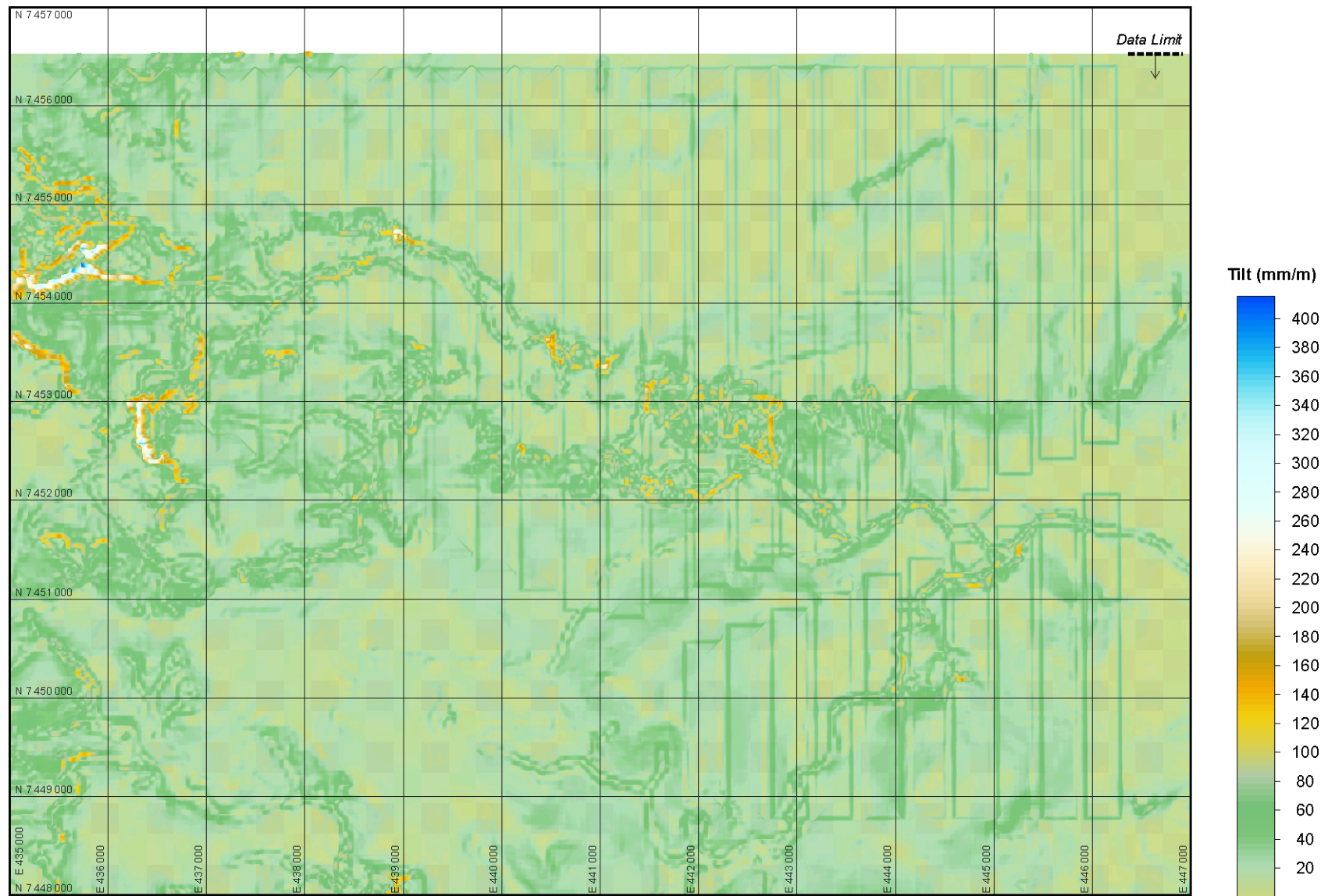


Figure 8: Plan showing slope of topography after subsidence - North Area.

3.2 Central Mine Area

The central mine area consists of 19 North-South aligned longwall panels. Figure 9 shows the predicted subsidence contours for the central mine area. The minimum subsidence is contoured at 0.02m. The maximum subsidence is predicted to be 2.93m for all panels, with the entire mine area subsiding at supercritical. Subsidence profiles in the east are again sharper and reach maximum subsidence at a closer distance to the pillar edge than the west, due to shallower overburden depths in the east. Zoomed in subsidence profiles for the shallowest and deepest longwall panels are presented in Figure 10. This magnification outlines the steepness of the subsidence contours along the pillar edge.

The overburden over the central mine area ranges from approximately 140m to 300m depth. The pillar abutment subsidence increases to the west as the overburden thickness increases. The chain pillar subsidence is approximately 0.4m in the east and grading to 1.0m in the west. Localised topographic variations create minor variations in the pillar subsidence.

The subsidence predictions superimposed onto the topography are presented in Figure 11 for the central mine area. The orthogonal image presents the longwall panel subsidence in relation to the topographic variations while the plan view shows the final topographic contours post subsidence.

The tilt contours for the central area are presented in Figure 12. The maximum tilt on the shallowest longwall panel in the central area is approximately 55mm/m. This is higher than that of the northern area due to the increased extraction thickness. The maximum tilt for the deepest panel in the west is approximately 25mm/m. Note: the diagonal tilt trends on the corners on the panels are a relic of the modelling and are not predicted to occur. Magnified plots of the tilt contours for the shallowest and deepest longwalls are presented in Figure 13. The zoomed in contours show the tilt increasing and decreasing again moving away from the pillar edge.

The contoured slope for the final topography after subsidence is presented in Figure 14. The maximum slope over the longwall panels in the final topography after subsidence is approximately 260mm/m. This slope is related to the steeper topography in the west of the central mine area.

3.3 Southern Mine Area

The southern mine area consists of 23 North-South aligned longwall panels. Figure 15 shows the predicted subsidence contours for the southern mine area. The minimum subsidence is contoured at 0.02m. The maximum subsidence is predicted to be 2.93m for all panels, with the entire mine area subsiding at supercritical. Subsidence profiles in the east are again sharper and reach maximum subsidence at a closer distance to the pillar edge than the west, due to shallower overburden depths in the east.

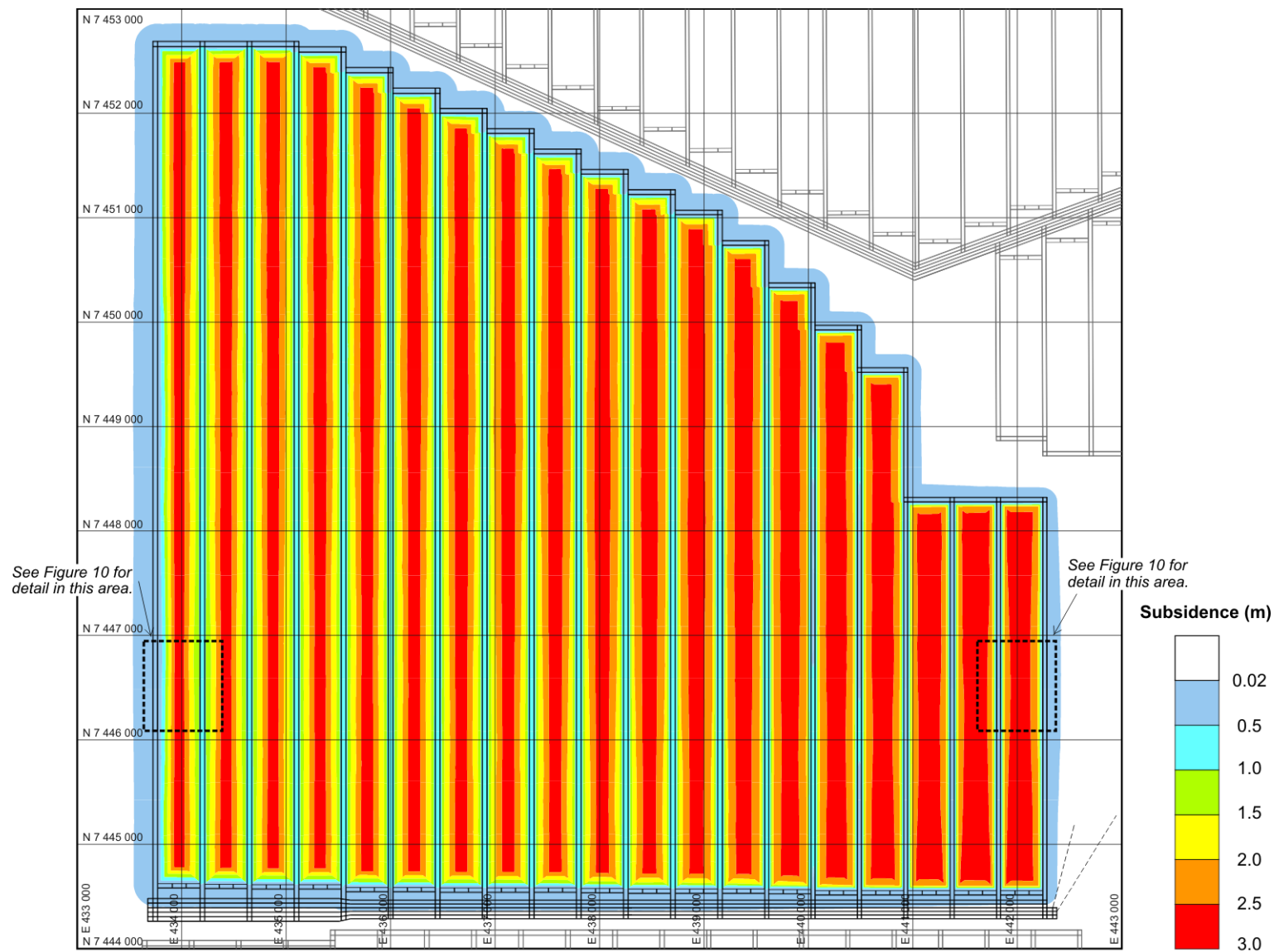


Figure 9: Predicted subsidence contours - Central Area.

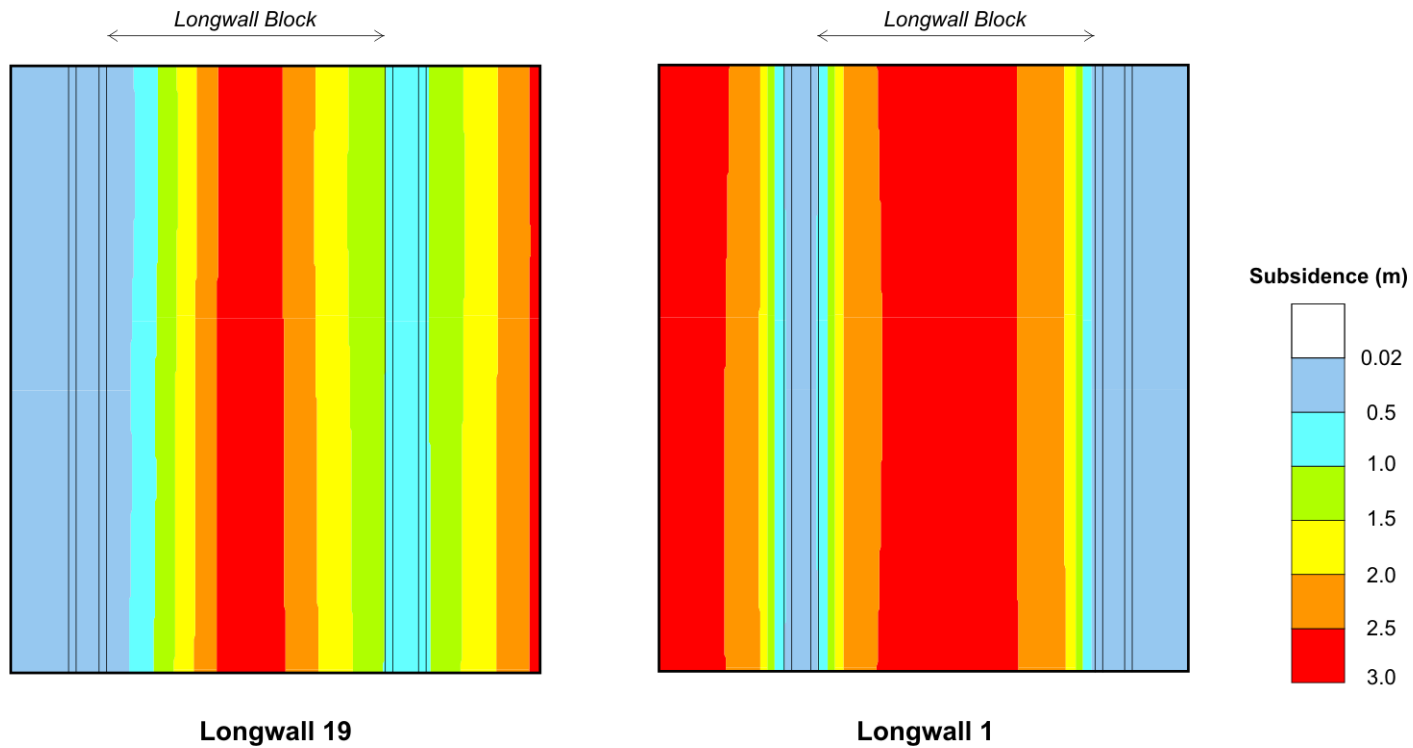


Figure 10: Predicted subsidence contours for Longwalls 1 and 19 - Central Area.



Figure 11: Plan showing topography with subsidence - Central Area.

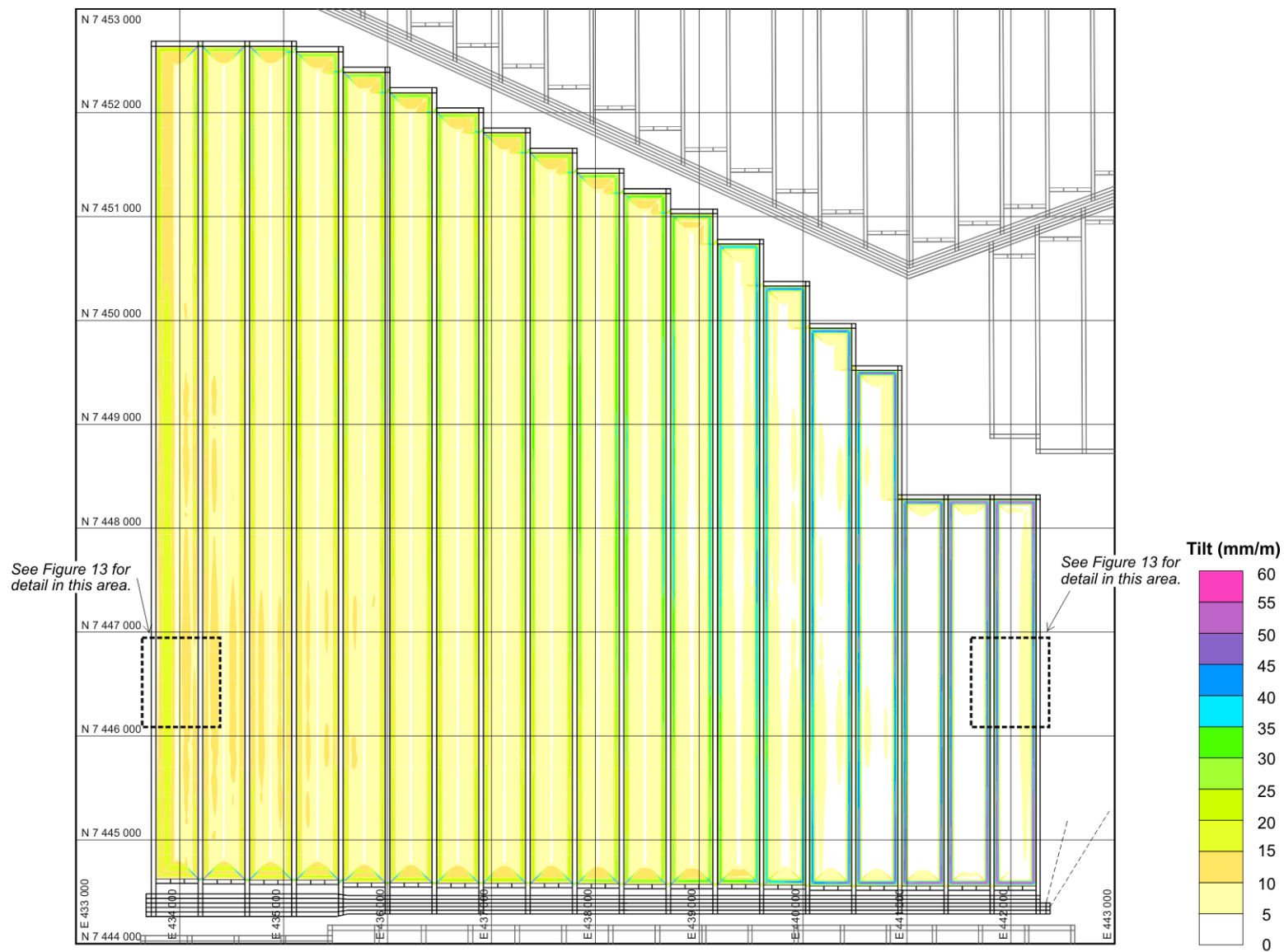


Figure 12: Tilt contours - Central Area.

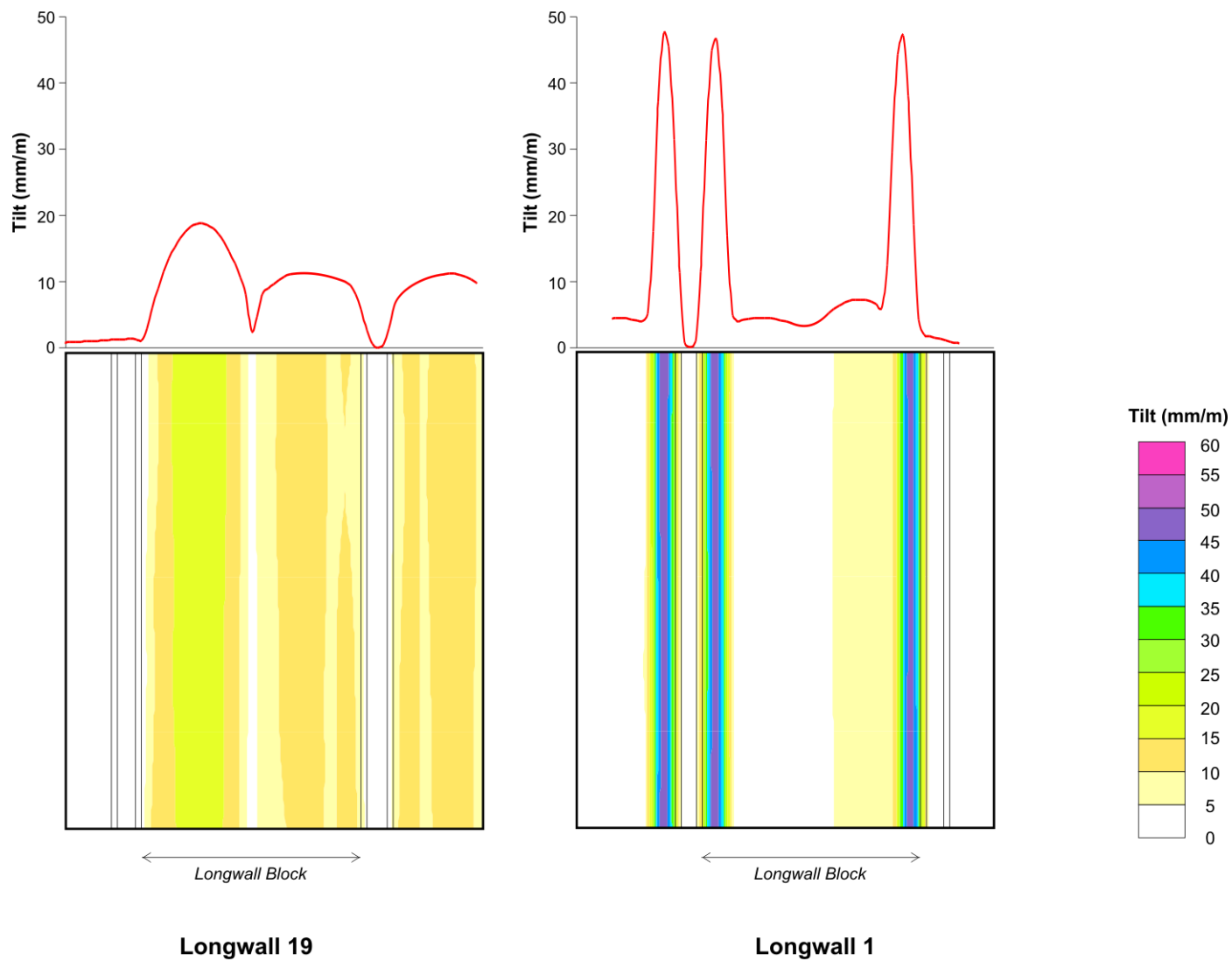


Figure 13: Tilt contours for Longwalls 1 and 19 - Central Area.

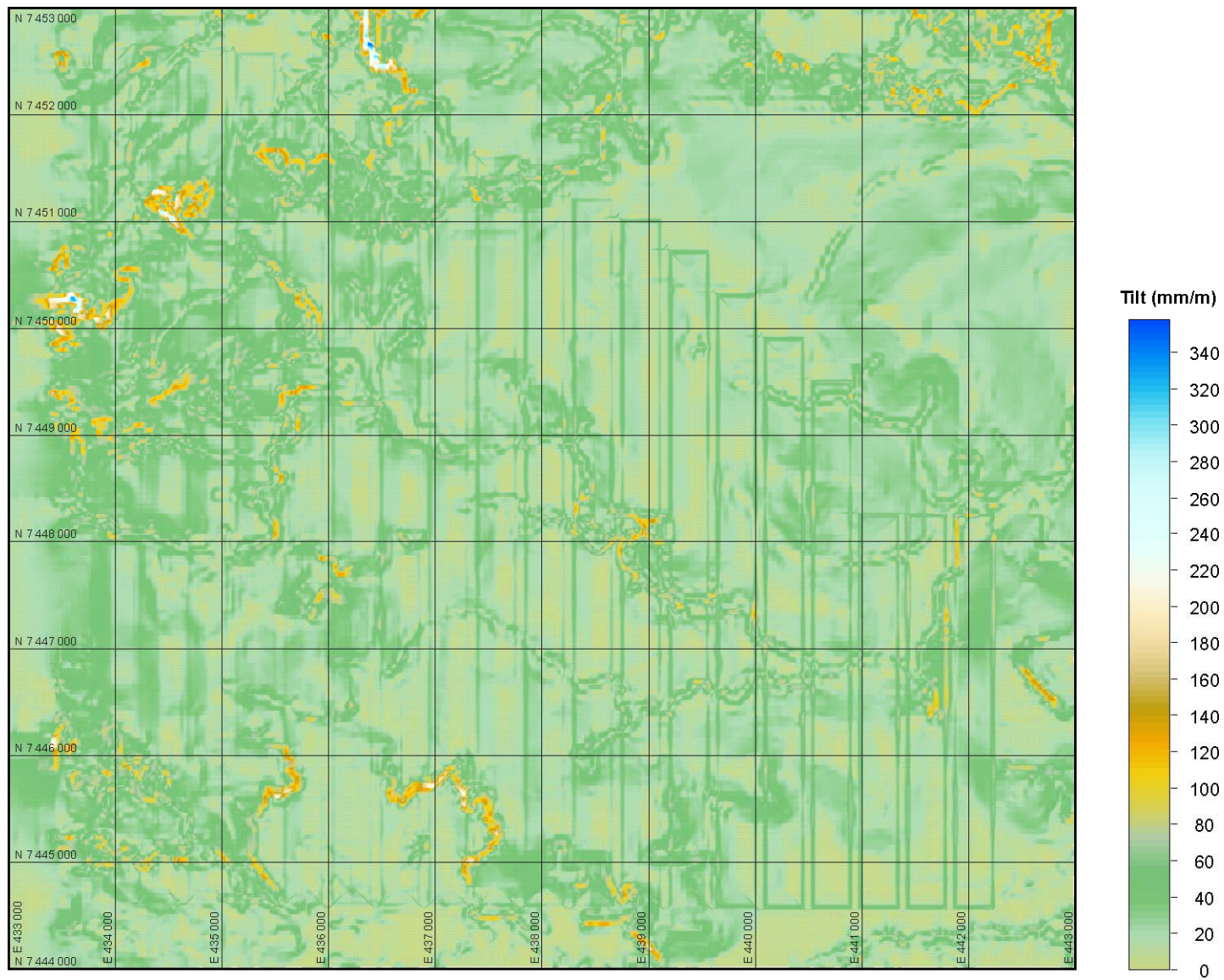


Figure 14: Plan showing slope of topography after subsidence - Central Area.

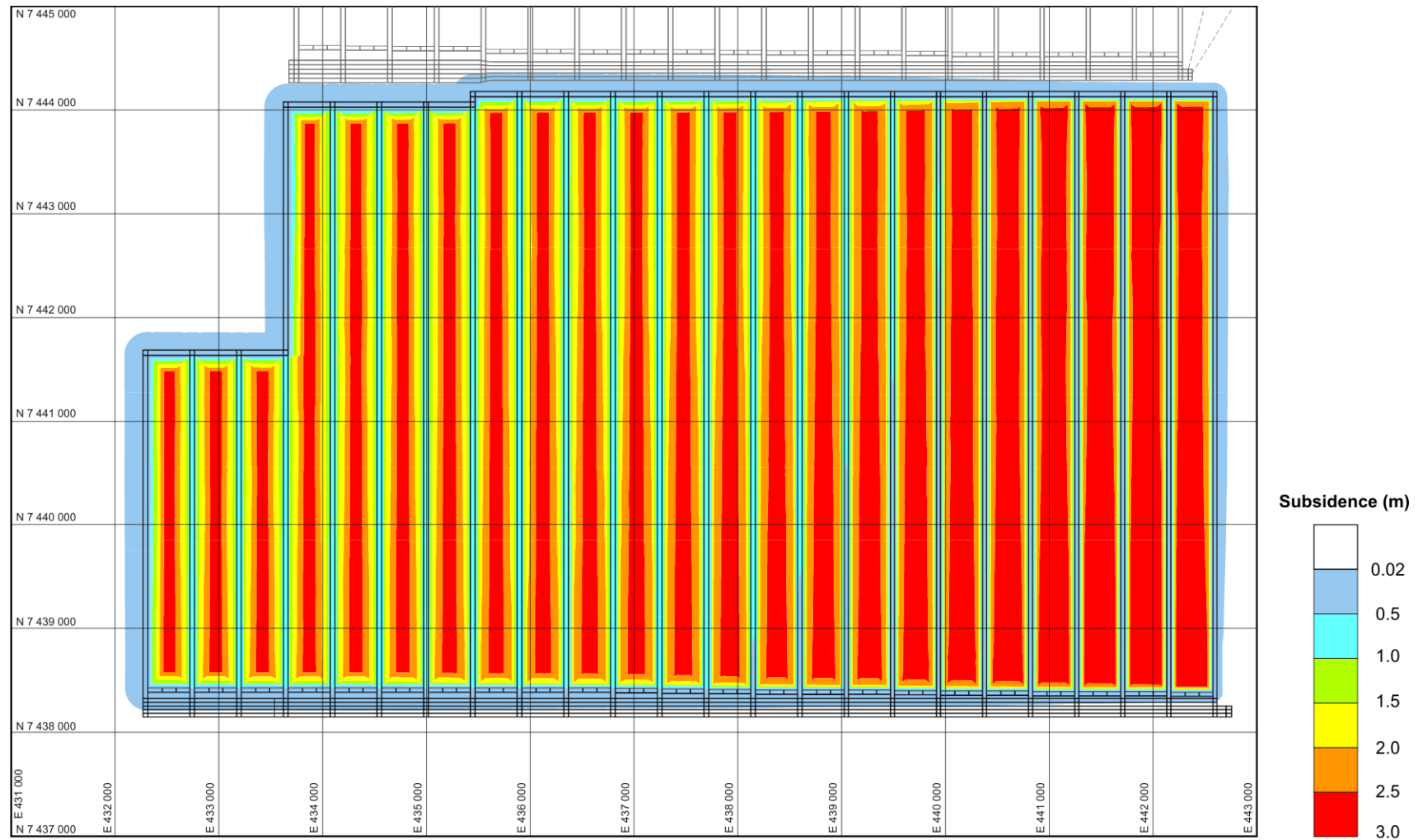


Figure 15: Predicted subsidence contours - South Area.

The pillar abutment subsidence increases to the west as the overburden thickness over the southern area panels increases from approximately 120m in the east to 280m in the west. The chain pillar subsidence is approximately 0.4m in the east and grading to 0.8m in the west. Localised topographic variations create minor variations in the pillar subsidence.

The subsidence predictions superimposed onto the topography are presented in Figure 16 for the southern mine area. The orthogonal image presents the longwall panel subsidence in relation to the topographic variations while the plan view shows the final topographic contours post subsidence.

The tilt contours for the southern area are presented in Figure 17. The maximum tilt on the shallowest longwall panel in the southern area is approximately 60mm/m. The maximum tilt for the deepest panel in the west is approximately 25mm/m. Note: the diagonal tilt trends on the corners on the panels are a relic of the modelling and are not predicted to occur.

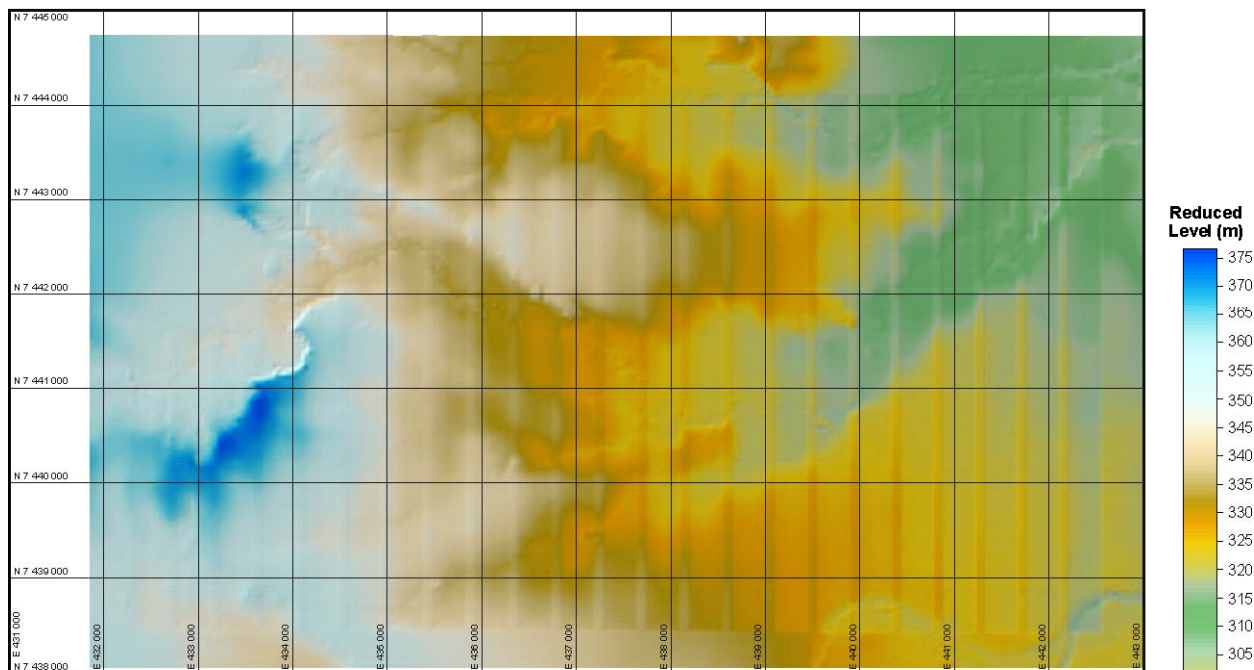
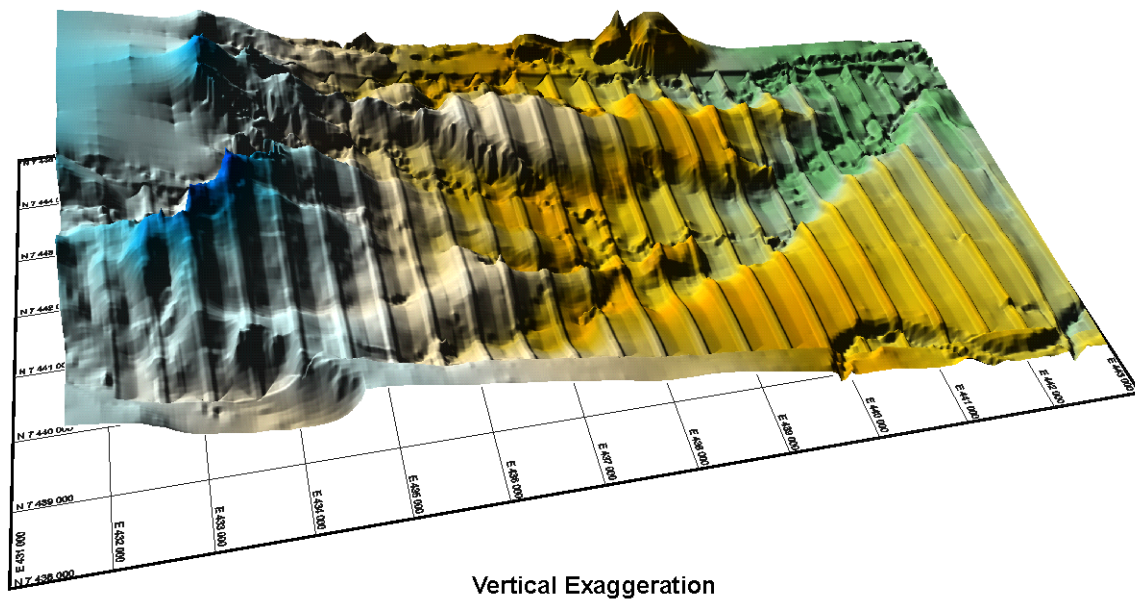
The contoured slope for the final topography after subsidence is presented in Figure 18. The maximum slope over the longwall panels in the final topography after subsidence is approximately 320mm/m. This slope is related to the steeper topography in the west of the central mine area.

4. CONCLUSIONS AND RECOMMENDATIONS

The subsidence predictions in this study have been based on empirical methods for determining subsidence profiles. The primary outcomes of this study are as follows:

- Maximum subsidence for the North mine area is 1.95m for all panels while the maximum Subsidence for the South and Central mine areas is 2.93m for all panels.
- Subsidence over the chain pillars in the North mine area ranges from 0.1m to 0.9m, chain pillar subsidence in the Central mine area ranged from 0.4m to 1.0m, while chain pillar subsidence in the South mine area ranged from 0.4m to 0.8m.
- Maximum tilt for the North mine area is 40mm/m in the shallowest panel and 20mm/m in the deepest panel. Maximum tilt for the deepest panels in the Central and Southern mine areas is 25mm/m, while the maximum tilt for the shallowest panel is 55mm/m in the Central mine area and 60mm/m in the South mine area.

To further improve the subsidence predictions, it is recommended to produce a numerical caving model whereby subsidence profiles from this can be used for the 3D subsidence extrapolation.



Plan View

Figure 16: Plan showing topography with subsidence - South Area.

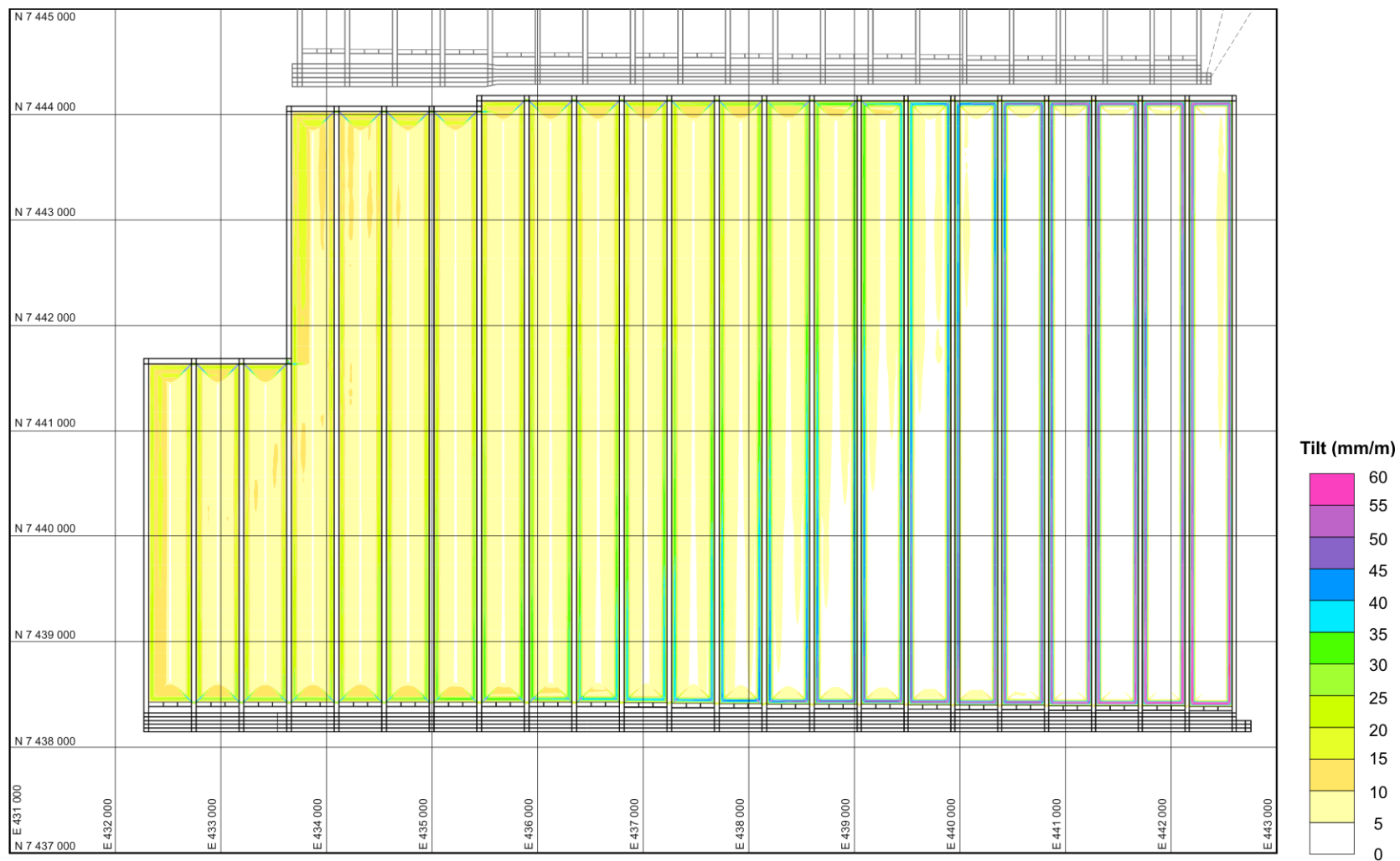


Figure 17: Tilt contours - South Area.

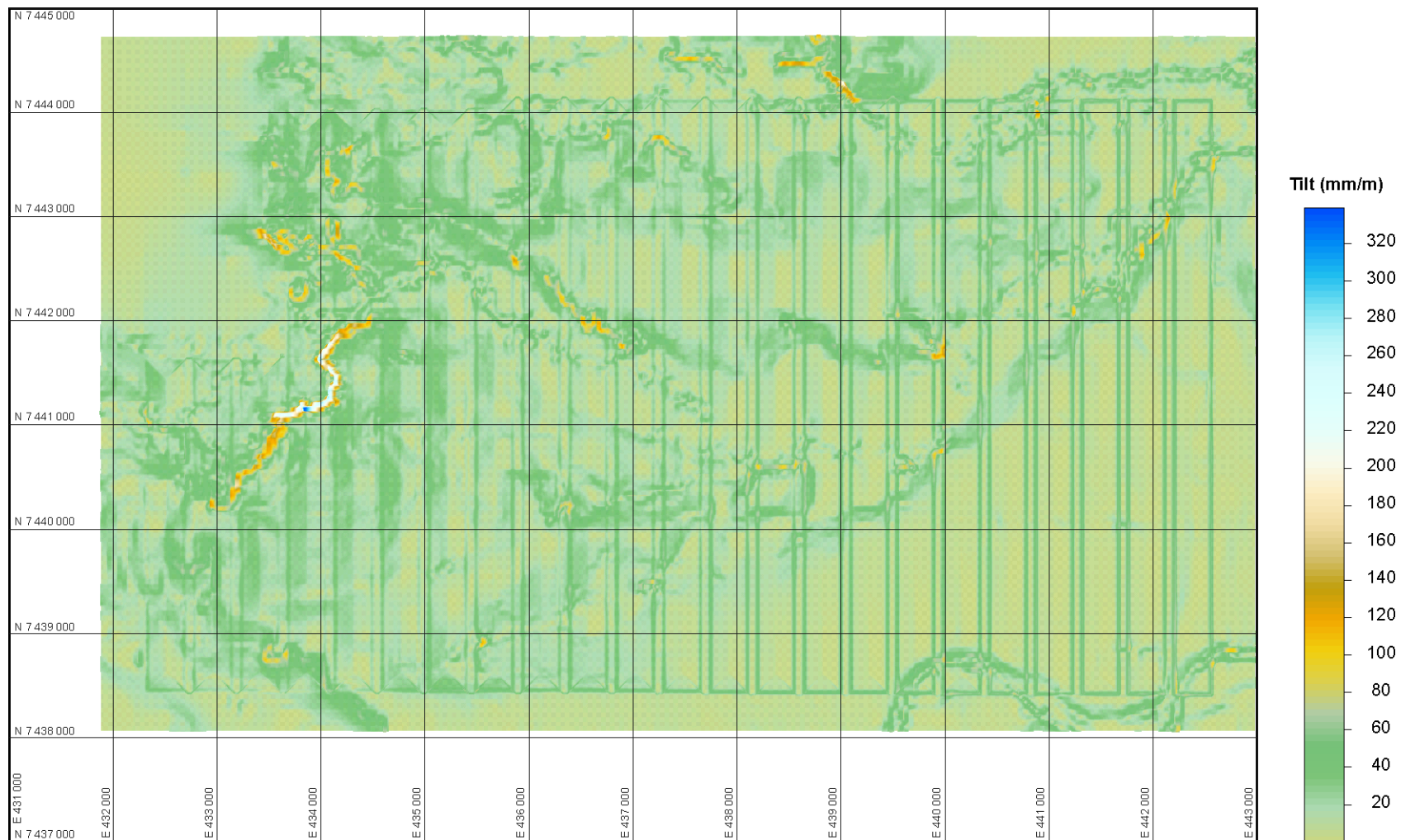


Figure 18: Plan showing slope of topography after subsidence - South Area.

5. REFERENCES

MSEC, 2007, 'General discussion on systematic and non-systematic mine subsidence ground movements', August 2007, unpublished.

Whittaker and Reddish, 1989, 'Subsidence, Occurrence, Prediction and Control', Elsevier, Amsterdam.