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21 July, 2013

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Report No. SPV-003/6

Dear Peter,

Subject: Further Discussion on the Potential Impacts to Sunnyside East and Carne West Temperate Highland Peat Swamps on Sandstone due to the Proposed Springvale LWs 416 to 417

1.0 Introduction

This report provides additional information and discussion on the differences between Springvale Mine's LW 411 and the proposed LWs 416 and 417 mining geometries and associated subsidence effects in regard to the circumstances that resulted in the peat slump impacts along East Wolgan Creek above LW411. It is understood that there are still concerns about whether peat slump impacts will occur again in the Sunnyside East and Carne West TPHSS's due to LWs 416 to 417.

As discussed in **DgS, 2012**, it is expected that surface cracking above the narrower 262 m wide longwall panels 416 to 417 will be minor along the Sunnyside East and Carne West Creek valleys. Both valleys are considered to be surface expressions of Type 1 Geological Structure Zones (Carne and Deanes Creek Lineament) as described in **Palaris, 2013**.

It should also be recognised that the Springvale Mine plans to continue longwall mining to the east of LW417 and the predicted cumulative subsidence, tilt and contours recently prepared for LWs 416 to 417 in **DgS, 2013** have been referred to in this study.

2.0 Method

A comprehensive review of measured subsidence effects v. mining geometry, geology and surface topography (i.e. valley or plateau) has already been presented in **DgS, 2012** and considered adequate to develop management strategies to control future impacts to the environment due to longwall mining.

The influence of valley geometry and geology on observed and predicted subsidence impacts has been previously addressed subjectively, based on observed subsidence affects above a range of longwall panel geometries and surface topographies.

Further assessment of the differences between the East Wolgan Creek experience and other valleys undermined by a range of longwall mining geometries has been completed in this report and includes the following:

- A comparison between valley profiles within Type 1 Geological Structure Zones, the subsidence impacts that have occurred, and the mining geometries involved at Springvale and Angus Place Mines.

- Predictions of valley closure and uplift movements using the **ACARP, 2002** Southern Coalfield prediction model (**ACARP, 2002**) that was updated in **MSEC, 2007** and calibrated to Springvale observations using a valley profile or shape factor by DgS.

The location of mining geometry, creeks and Type 1 geological structure and cover depth contours for the Springvale and Angus Place Mines are presented in **Figures 1a** to **1c**.

3.0 Background

The outcomes of subsidence impact assessment reviews completed to-date for Springvale and Angus Place Mines by DgS have identified the following key variables that have influenced mine subsidence effects and surface impacts generally:

(i) The presence of massive, high strength sandstone units decrease subsidence due to stiffer spanning (i.e. arching action) above *sub-critical* and *critical* longwall panels. Decreasing the panel widths by 20% from 315 m to 261 m would be expected to result in a reduction in subsidence and surface impact.

Note: The DgS model includes subsidence prediction curves that are based on measured subsidence and mining geometries with Low, Moderate and High Subsidence Reduction Potential (SRP). The massive sandstone strata above the Angus Place and Springvale Longwalls has been assessed to have Moderate to High SRP for the range of geological conditions present (see point (ii) for further details).

(ii) Type 1 and possibly Type 2 geological structures (**Palaris, 2013**) can result in an increase in subsidence due to the effects of a weaker rock mass around these structures.

Note: This phenomenon has been identified along an incised valley section of Narrow Creek, where the subsidence above Angus Place's 262 m wide LW940 was 1.75 m compared to a typical range of 1.10 m to 1.36 m on the adjacent plateau areas. This represents an increase in maximum subsidence of 30 to 60% due to Type 1 Faulting.

A similar increase in subsidence has occurred along East Wolgan Creek for LW411, where the massive strata would have been assumed to have High SRP above the 315 m wide panel. The measured subsidence after LW411 was completed was 0.89 m for a predicted range of 0.40 m to 0.58 m assuming a High SRP, and represents an apparent subsidence increase of 53% to 122%.

The DgS model predicts a maximum subsidence range of 0.67 m to 0.86 m when a Moderate SRP is adopted for the 315 m wide panel, and has therefore been used to make subsidence predictions in fault affected areas. Final subsidence of 1.248 m has been measured on the M-Line above LW411 with predictions ranging from 1.12 m to 1.31 m using Moderate SRP curves.

Smaller subsidence increases have developed above 255 m to 265 m wide panels in Type 1 geological structure zones at Springvale, so that it has not been necessary to reduce the SRP from High to Moderate for the proposed LWs 416 to 418.

(iii) Sub-critical longwall panels with width/cover depth ratios < 0.75 have caused significantly lower impact than critical width longwalls with W/H between 0.75 and 1.0.

Note: Most of the measured surface impacts to-date, such as slope and rock bar cracking and peat slumps, have developed above 'critical' 293 m and 315 m wide longwalls with one observed impact above a 'critical' 262 m wide panel LW940 above Narrow Creek where cover depth was 330 m (W/H = 0.79).

(iv) It would be expected that valleys that are deeper and narrower tend to develop higher tensile and compressive strains than shallower and broader valleys when subsided. Near surface geology also influences the response to mine subsidence effects.

Note: Dilation within rock masses beneath the floor of valleys and their side walls or slopes are associated with natural weathering processes. It is caused by vertical and horizontal stress relief (i.e. unloading) as the creeks cut down through the strata over many millennia. Mine subsidence tends to exacerbate this process, resulting in additional valley closure and uplift movements.

Industry experience has found mining induced valley closure and uplift movements are generally higher in rock masses with greater 'locked in' horizontal stress and where overlying valleys are deeper and narrower with steep side slopes (e.g. the Nepean and Cataract River Gorges in the Southern Coalfield).

A graphical summary of the measured v. predicted subsidence effect profiles along the B-Lines at Springvale and Angus Place are provided in **Attachment A**.

4.0 Review of Valley Geometry and Subsidence Impacts

A review of the valley geometry and subsidence impacts in them at Springvale and Angus Place is discussed in the next few sections. A review of the impacts to East Wolgan Swamp that was presented in **DgS, 2011** is also included.

4.1 Valley Geometry

Survey results and associated impacts to valleys within Type 1 geological structure zones above the extracted Springvale longwalls 1 and 401 to 415 and the Centennial Angus Place LWs 920 to 970 have been summarised in **Table 1**. The location of the survey lines are shown in **Figure 1a**.

A total of 14 valley cross sections have also been derived from the surface level contours shown in **Figure 2a** with *Surfer11®*. The sections were generally located where mine subsidence effects and/or impacts had been measured and reported. The maximum valley side slope gradients are presented in **Figure 2b**.

The valley profiles have been measured based on their top width, depth and side slopes for impact assessment purposes. The profiles are shown graphically in **Figures 3a** to **3e** with geometric details provided in **Table 1**.

The valley profiles for East Wolgan, Sunnyside East and Carne West Creeks have been translated to a central axis with the centre set at the base of each valley and are shown in **Figure 4a** and **4b**. The valleys above the proposed panels are generally shallower and broader than East Wolgan and Narrow Creeks (as mentioned in previous reports) but similar to the other undermined valleys present above the Springvale and Angus Place mining leases' that have had 'minor' surface cracking impacts in accordance with the SMP approval conditions.

The predicted final cumulative subsidence, tilt and strain contours for Springvale and Angus Place are presented in **Figures 5a** to **5c**. The final strain contour predictions indicate that:

(i) the 315 m wide panel strains were 20% to 30% higher than the 260 m wide panels, and

(ii) the panels adjacent to the solid coal are likely to have higher strains than panels above the chain pillars, due to reduced differential subsidence above the compressing chain pillars.

The predicted contours are based on a 'smooth subsidence profile' model however, and do not capture the potential strain increasing effects of subsidence interaction with geological structure or valley closure mechanisms.

The likely strain ranges and subsequent impacts to the valleys above LWs 416 to 418 have therefore been further assessed with reference to the valley profiles and closure/uplift phenomenon in the following sections.

Table 1 - Measured Valley Geometries and Subsidence Affects for Springvale and Angus Place Longwalls

Creek	**Valley XL**	**LW***	**Panel Width W (m)**	**Cover Depth H (m)**	**Valley Width W_v (m)**	**Valley Floor RL(m)**	**Average Valley Crest RL(m)**	**Valley Depth H_v (m)**	**Max Side Slopes (o)**	**Final S_{max} (mm)**	**Tilt (mm/m)**	**Tensile Strain (mm/m)**	**Comp. Strain (mm/m)**	**Observed Impact**
Narrow	1	940	262	330	671	1094.9	1140.0	45	14 - 19	1.75	12 - 18	3.5 - 6.5	4 - 16	100 mm wide tension crack on slope; **0.5 - 1 m deep erosion channels in peat**
Narrow	2	950	293	340	447	1097.7	1136.8	39	23-25	*1.89*	*17 - 25*	*6 - 8*	*7 - 10*	Nil
East Wolgan	3	411	315	340	560	1080.0	1133.5	54	20-22	1.248	7 - 13	2-13	13 - 18	**2 x 5m diameter peat slumps to 1m depth**; 10-40 mm wide cracks & 100 mm uplift in rock bar.
Kangaroo	4	940	263	290	1085	1079.4	1129.1	50	8-17	1.012	2 - 13	3-5	15	Nil
Kangaroo	5	950	293	290	680	1098.7	1122.1	23	4-11	*1.89*	*15 - 22*	*5 - 7*	*6 - 9*	50 mm wide cracks & 30 mm uplift of rock bar
Kangaroo	6	970	293	300	1093	1114.6	1141.5	27	7-10	1.05	15 - 23	6	7 - 16	10 - 110 mm tension cracks & 91 mm uplift near channel
Southern	7	407-9	265	360	460	1142.8	1166.8	24	8-13	1.06	3 - 4	2 - 4	3 - 13	nil
Southern	8	410-412	315	375	1165	1138.5	1170.8	32	11-12	1.10	6 - 9	4 - 16	7 - 17	nil
Sunnyside East	9	418	261	360	600	1078.0	1100.8	23	12-16	*1.04*	*4 - 6(9)*	*2 - 4 (8)*	*4 - 6 (12)*	Not mined yet
Sunnyside East	10	417	261	370	521	1096.1	1143.0	47	13-21	*1.06*	*4 - 6(9)*	*2 - 4 (8)*	*4 - 6 (12)*	Not mined yet
Sunnyside East	11	416	261	380	532	1120.0	1155.0	35	11-14	*1.10*	*4 - 7(9)*	*2 - 4 (8)*	*4 - 6 (12)*	Not mined yet
Carne West	12	419	261	360	432	1077.8	1104.0	26	11-17	*1.05*	*4 - 6(9)*	*2 - 4 (8)*	*4 - 6 (12)*	Not mined yet
Carne West	13	418	261	360	691	1096.9	1123.8	27	7-13	*1.05*	*4 - 6(9)*	*2 - 4 (8)*	*4 - 6 (12)*	Not mined yet
Carne West	14	417	261	365	800	1100.0	1155.8	56	11-13	*1.04*	*4 - 6(9)*	*2 - 4 (8)*	*4 - 6 (12)*	Not mined yet

Italics - Subsidence effect predictions given in lieu of measured values; shaded - Critical panel geometries with W/H > 0.75; **Bold** - Peat erosion impacts.

4.2 East Wolgan Swamp Impact Review

4.2.1 Peat Slumping Impacts

Piping or slumping of alluvium (peat) to 1 m depth has affected two areas of approximately 5 m in diameter along East Wolgan Swamp after mining of LWs 411, 412 and 950. LW411 was extracted between March 2006 and October 2007. LW412 was mined between December 2007 and June 2009 with LW950 mined between August 2008 and August 2009.

As discussed in **Aurecon, 2009**, a mine water transfer scheme to Wallerawang Power Station has been operating since 2006. Between 2002 and March 2006, continuous mine water discharge of 2-4 ML/day had been released down East Wolgan Creek until an alternative route was commissioned in 2006. Emergency Mine Water Discharges (EMWDs) of 3ML/day were released down East Wolgan Creek during 2007, with 8ML/day released over the period between March, 2008 and February, 2009.

It was noted during the preparation of Subsidence Management Reports in 2008, that the EMWDs were not reaching the stream flow monitoring station downstream of East Wolgan Swamp. An inspection of the swamp above LW411 in December, 2008 found that "mine water discharge was flowing into a cavity at the base of the swamp". A later inspection carried out in early April 2009 (after the discharge had ceased) found that there had been some irregular movement within East Wolgan Swamp. The movement included erosion, siltation and surface slumping of the peat material at two locations. Shortly after this finding, Springvale Mine and Angus Place notified the relevant Government Departments and commissioned several consultants to complete groundwater (Aurecon) and geophysics studies (GHD) to determine the possible causes of the irregular movements.

The two slumps noted were approximately 200 metres apart, with the first slumped area in the tensile strain zone just outside of the western limits of LW411. The first (upstream) slump may have been caused by piping within the peat material followed by subsequent collapse of the piped area. The second slump occurred over the extraction limits of LW411 and near the peak tensile strain on the measured subsidence profile. It is noted that the slump features did not occur until after LW412 and 950 had increased the initial LW411 panel subsidence of 0.9 m to 1.3 m.

No flow loss was observed around the first slump as water entering the slump appeared to be consistent with flows exiting the slump area. However, complete water loss occurred at the 2nd most downstream slump location above LW411. It is also noted that natural flows are very rare and have not been observed since continuous mine water discharge ceased in 2006.

The outcomes of the detailed investigations identified the coincidence of sub-parallel geological structure with the side extraction limits of LW411 probably resulted in significant voids developing in the near surface rock mass (to depths of up to 90m) due to mine subsidence. Deep vibrating wire piezometers in Borehole SPR39, which is located above the chain pillar between LW411 and 412, indicated groundwater response down to RL975 during the EMWDs in 2008. Pressure head increases were identified approximately 1 week after the EMWDs were being released, suggesting direct hydraulic connection to the dilated strata from the surface. Further details of the slumps and groundwater responses are discussed in **Aurecon, 2009**.

It is important to note that similar 'piping' features have also developed naturally outside the limits of longwall extraction within the mining area (see **Figure 2a**). A slumping feature 8 m in diameter and 1.8 m deep was noted by DgS on Kangaroo Creek above the unmined LW960 in 2010. Several ‘piping’ features have also developed naturally within Sunnyside East Swamp and vegetation has also been cleared by Forests NSW with routine back burning.

Aurecon also noted that the impacts to Narrow Creek peat swamps above LW940 were significantly lower than East Wolgan Creek after it had been undermined by a critical-width, 260 m wide longwall panel. The key difference there was that the creek (and faulting) were orientated almost perpendicular to the longwall block and were therefore not subject to the same level of stress and strain on the plane of the fault as occurred along the East Wolgan lineament.

The slumps are therefore considered to be primarily the result of a complex geomorphologic process that occurs when erodible peat exists above open geological structure (driven by valley stress-notching) is exacerbated by mine subsidence and then subject to concentrated surface run-off or mine water discharges.

Further discussion on swamp impacts v. mine subsidence effect differences are presented in the following sections.

4.2.2 Observed Mine Subsidence Effects

The measured and predicted subsidence and strain profiles (EWS-Line) across East Wolgan Swamp to-date are shown in **Figures 6a** and **6b**.

The profiles indicate irregularities in both subsidence and strain has occurred above the barrier pillar between LWs 411 and 950. It would normally be expected that the subsidence profile would be convex (hogging curvature) and develop tensile strains outside of the mining limits. However, the influence of the valley above the pillar can be clearly seen whereby compressive strains have developed at the base of the valley of up to 12 mm/m.

The subsidence profile indicates near surface strata has moved upwards and downwards locally, which suggests the presence of near surface voids and buckling failures have occurred due to subsidence of 0.9 m above LW411 initially. The buckling is commonly seen in valley floors that have been rotated on one side by a subsidence trough, resulting in a direct increase of compressive stress across the floor of the valley. Similar stress increases can occur if the valley is directly undermined and subject to concave curvatures (see **Figure 6c**).

Similar behaviour can also occur outside the angle of draw (i.e. the limit of vertical subsidence) to longwall panels due to differential displacements or rotation of near surface strata in the horizontal plane from far-field, horizontal stress relief effects (see **Figure 6d**).

Both mechanisms can generate both valley closure and opening movements, which can result in apparent strain anomalies when compared to normal subsidence trough development in flat terrain (i.e. plateaus).

The strain profile after LW412 and 950 were commenced shows a reversal from a compressive strain of 12 mm/m to a tensile strain of 1 mm/m. This change was probably caused by the development of 250 mm to 300 mm of subsidence over the barrier pillar under additional loading between LW411 and LW950. Normal convex bending deformations would have occurred in response to the strata cantilevering out across the two adjacent goaves.

It is assessed that the tensile strain then reverted back to compressive strain as subsequent longwall panels were extracted to the east (LW413 to 415) and south (LWs 960 and 970) when further valley closure movements developed.

Similar, but greater strain reversals occurred over LW411 on the valley side slopes (+13 mm/m and -18 mm/m) and also appears to be related to localised buckling behaviour. Based on industry experience, it is expected that the final strains above LW411 on the solid coal barrier side will be larger than the strains observed above subsequent panels that are located between chain pillars. This is because the subsidence above the chain pillars will be greater and reduce the differential subsidence magnitudes across the panels overall (see **Figure 7**).

4.3 Valley Closure and Uplift

Based on a review of measured subsidence effects at Springvale and Angus Place Mines, the prediction of valley closure and uplift needs to consider the influence of valley shape (depth, width and side slopes) and its location and orientation relative to the developing mine subsidence troughs.

As discussed in **ACARP, 2002** and **DgS, 2010**, when creeks and river valleys are subsided, “the observed subsidence in the base of the creek or river is generally less than would normally be expected in flat terrain. This reduced subsidence is due to the floor rocks of a valley buckling upwards when subject to compressive stresses generated by surface deformation.

In most cases in the Newcastle and Southern NSW Coalfields, the observed uplift has extended for several hundred metres outside of steep sided valleys. The impact to valley floors has been greatest to valleys directly undermined by longwall panels.

It should also be understood that these movements are strongly dependent on the level of 'locked-in' horizontal stress immediately below the floor of the gullies and more importantly the bedding thickness of the floor strata (i.e. thin to medium bedded sandstone is more likely to buckle than thicker, massive beds). The influence of the aspect ratio (i.e. valley width/depth) is also recognised as an important factor, with deep, narrow valleys having greater upsidence than broad, rounded ones due to higher horizontal stress concentrations.

Valley closure and uplift movements can also occur along broader drainage gullies and man-made cuttings, where shallow, interbedded surface rock of moderate to high strength is present. The development of upsidence, voids and minor surface cracking may cause localised deviation of surface flows in rocky, ephemeral creek beds into sub-surface routes. The re-routed surface flows would be expected to re-surface downstream of the impacted area if it occurs above deep mining areas, such as Springvale and Angus Place.

4.3.1 Observed Closure and Uplift Impacts at the Springvale and Angus Place Longwalls

To-date, uplift movements of between 30 mm and 100 mm have occurred downstream of the EWS-Line, which crosses East Wolgan Creek above the northern end of LW411. Similar uplift movements of 26 to 98 mm have occurred along the B-Line in the southern valleys above LWs 407 to 412.

Visually detectible buckling of 30 mm in sandstone rock beds occurred along a Kangaroo Creek rock bar above Angus Place's LW950, with 91 mm of uplift measured above LW970 near the base of a broad valley (see **Figure 2a** and **2b**).

The rest of the valleys that have been undermined were all overlain with alluvium and/or peat, and as such, have not resulted in surface cracking being detected due to buckling behaviour. It is likely however, that uplift and buckling movements due to valley closure have developed in the immediate rock mass below the deep alluvium and peat and provide potential voids for the overlying material to be eroded into, thus allowing a cavity to develop back up to the surface.

The observed peat slumps along East Wolgan Creek have probably been caused by this mechanism and are more correctly termed 'piping failures' in geotechnical engineering terms (refer to **Fell *et al*, 1992**). The interaction between the geological structure and tensile strains above LW411 have probably also exacerbated the valley buckling mechanism to generate a significant flow path beneath the peat.

It is noted that although the other valleys in Type 1 geological zones at Springvale and Angus Place have been subject to similar subsidence, valley closure and strains, the peat slumps and erosion channels after mine subsidence development have only developed downstream of points where high mine water discharges were released.

Therefore, the following conditions are considered necessary for piping failures to develop up to the surface:

(i) There are fractures and voids immediately below the peat, and

(ii) concentrated seepage flows (such as emergency mine water discharge) are able to transport significant quantities of peat into the voids.

It follows then, that the reduction of mine subsidence beneath the valleys should therefore reduce the potential for future peat slump features to occur.

4.3.2 Predicted Worst-case Closure and Uplift Impacts for the Springvale & Angus Place Longwalls

Predictions of valley closure have been based on the Southern Coalfield model presented in **ACARP, 2002**. The authors in **MSEC, 2007** acknowledge that the **ACARP, 2002** model predictions are likely to be conservative if used in other coalfields due to differences in horizontal stress and cover depth.

The influence of valley width is also considered to be significant factor in regards to the response of a valley to mine subsidence and horizontal stress changes below the floor of the valleys, but these are not included specifically in the ACARP model. The model at present provides predictions for valley closure for the full width of valleys; however, the valley width itself is not used to make predictions. It has therefore been necessary to review the adjustment factors presented in the **ACARP, 2002** model to account for differences in predicted closure and uplift based on local strain and uplift data.

The following adjustments were made to the updated **ACARP, 2002** model after validation with Springvale and Angus Place measurements:

- Conversion of the measured longitudinal distances from the ends of the panels to equivalent Southern Coalfield conditions, where the average cover depth exceeds 400 m, by multiplying the Springvale distances by 400/H (H = depth of cover in meters).

- The use of $S_{max,inc}$ directly as the closure adjustment factor for the Springvale and Angus Place Panels due to the apparent differences in subsidence v. closure movements (and impacts).

- The predicted valley closure movements have been normalised to valley width to make predictions for the proposed longwalls (see **Figure 8**).

- The initial outcomes of the adjusted input parameters resulted in a reasonable match between measured closure strains, but gave a poor match to the observed uplift values. It was assumed that 1/3 of the predicted uplift values represent the elastic ‘ground swell’ due to the increased compressive stress as shown in *Figure 1.25* in **MSEC, 2007**. The residual 2/3 values were subsequently assumed to represent ‘buckling’ failure movements, which were then compared to observed buckling movements.

  The buckling predictions were found to be still almost twice (i.e. 1.8 times the measured buckling values), which indicated that the broader valleys at Springvale do not have the same response ‘stiffness’ to closure movements in steeper Southern Coalfield gorges. The subsequent reduction factor of 0.545 that was applied to the valley uplift predictions was therefore considered to be a ‘valley shape’ factor in this instance.

A summary of the predicted valley closure, compression strain and uplift displacements for all of the valleys that have been undermined are presented in **Table 2**.

The results in **Table 2** indicate that the East Wolgan Creek Valley is likely to have had the highest closure and buckling movement of 363 mm and 112 mm. The next highest closure and buckling predicted was 275 mm and 106 mm respectively for Narrow Creek. The impacts measured above both valleys have been the highest detected for the two mines respectively.

The rest of the valleys assessed have had predicted buckling and uplift movements ranging from 70 mm to 219 mm (closure) and from 15 to 82 mm (uplift).

The measured impacts to all valleys have ranged from 30 to 100 mm of buckling of rock bars, 10 mm to 110 mm wide tension cracks to side slopes or no impact.

The predictions and observations indicate that 15 mm to 112 mm of near surface void due to buckling may have occurred beneath the floor of the valleys due to mine subsidence.

Table 2 - Predicted Valley Closure and Uplift Impact Summary

Creek	Valley XL	LW*	Panel Width	Valley Width W_v	Valley H_v	Predicted Valley Closure (mm)	Predicted Valley Closure Strain (mm/m)	Measured Compressive Strain (mm/m)	Predicted Valley Buckling (mm)	Meas. Buckling Values (mm)
Narrow	1	940	262	671	45	157	7 - 15	4 - 16	79	Nil
Narrow	2	950	293	447	39	275	8 - 17	*7 - 10 (20)*	106	Nil
East Wolgan	**3**	**411**	**315**	**560**	**54**	**363**	**8 - 19**	**13 - 18**	**112**	**100**
Kangaroo	4	940	263	1085	50	131	6 - 14	15	58	Nil
Kangaroo	5	950	293	680	23	70	4 - 10	*6 - 9 (18)*	50	30 - 50
Kangaroo	6	970	293	1093	27	88	5 - 11	7 - 16	62	91
Southern	7	407-409	265	460	24	88	5 - 11	3 - 13	15	26 - 41
Southern	8	410-412	315	1165	32	219	7 - 16	7-17	82	80 - 100
Sunnyside East	9	418	261	600	23	76	5 - 12	*4 - 6 (12)*	36	*100*
Sunnyside East	10	417	261	521	47	219	7 - 16	*4 - 6 (12)*	72	*100*
Sunnyside East	11	416	261	532	35	177	7 - 15	*4 - 6 (12)*	60	*100*
Carne West	12	419	261	432	26	73	7 - 13	*4 - 6 (12)*	12	*100*
Carne West	13	418	261	691	27	110	6 - 13	*4 - 6 (12)*	43	*100*
Carne West	14	417	261	800	56	248	7 - 15	*4 - 6 (12)*	82	*100*

Italics - Subsidence effect predictions given in lieu of measured values; N.M. = Not mined; shaded - Critical panel geometries with W/H > 0.75. **Bold** - Results for East Wolgan creek. ( ) - Discontinuous movement strains caused by buckling or shearing of near surface strata.

Overall, it is considered that the predicted valley closure and uplift (buckling) results for the eight locations assessed are reasonably consistent with measured strains for the valleys and should therefore be a reliable indicator of impact for the proposed longwalls beneath Sunny Side East and Carne West swamp valleys.

4.3.3 Predicted Worst-case Closure and Uplift Impacts for the Proposed Longwalls 416 to 417

The predicted valley 'closure' and 'upsidence' movements for LWs 416 to 417 from previous studies are summarised in **Table 2** with the calibrated ACARP model.

The predicted values for the ACARP model range between 76 mm and 248 mm for valley closure and from 12 mm to 82 mm for valley buckling. The predicted compressive strains for the valleys range between 5 to 16 mm/m and are marginally higher than the previously predicted range of 4 to 12 mm/m indicated in previous reports. The results for the buckling assessment are also reasonably consistent with the previously assessed buckling prediction of up to 100 mm presented in **DgS, 2012** and **DgS, 2013**.

Due to the uncertainties inherent in the data base when applying it to a different coal field and the lack of impact observed in valleys above sub-critical panel width geometries, it is considered that the predicted impacts due to valley closure and uplift are unlikely to result in more damage than the minor cracking predicted for normal subsidence development of the near surface rocks in **DgS, 2013**.

It is recommended that the **ACARP, 2002** model be reviewed again when further data becomes available from the TPHSS Monitoring and Management Plan.

4.4 Proposed Mining Geometry v. Geological Orientation

There are three notable differences between the East Wolgan Creek case and the proposed longwall geometries for LWs 416 to 417 that are likely to result in lower impacts to the eastern valleys and their interaction with Type 1 geological structures:

(i) Firstly, the angle of orientation between the valleys and the proposed panels will increase to 24^o for Carne West and 51^o for Sunnyside East. The East Wolgan Creek was orientated at 22^o to the side ribs, meaning the potential for increased subsidence and interaction with geological structures is higher. The benefit is more pronounced for Sunnyside East and only marginally improved for Carne West.

(ii) Secondly, the proposed chain pillars for the future sub-critical longwalls have been increased from 42 m to 58 m (a 38% increase), which will increase the supporting capacity of the overburden over multiple panels and reduce tensile strains above the pillars, panels and solid coal at the leading goaf edge due to the reduction in differential subsidence generally.

(iii) Thirdly, the spanning capacity of the strata potentially affected by geological structure has been improved by the reduction in panel width from 315m to 262m to ensure sub-critical ‘arching’ behaviour and keeping the planes of weakness in compression. The critical panel width for LW411 would have introduced tension zones due to bending action into the rock mass and may have increased the potential for planes of weakness to slip due to mine subsidence.

5.0 Conclusions

It is assessed from the results in **Tables 1** and **2** that the development of a peat slump along Sunnyside East and Carne West Creeks due to LWs 416 to 417 is unlikely because of the following factors:

- The valleys above the proposed longwalls 416 to 417 are broader and shallower than East Wolgan Creek valley.

- All of the impacts observed to valleys have occurred above panels with W/H ratios > 0.75. The peat slumping features occurred above a 'critical' width longwall panel with a W/H ratio of 0.93. Zones of tension in the rock mass due to bending action would have increased the potential for planes of weakness in the overburden to slip due to mine subsidence.

- The proposed panels beneath the eastern valleys are 'sub-critical' panels with W/H ratios ranging from 0.73 to 0.69. Arching action in the overburden will enhance stability of geological structure by maintaining compressive forces on the planes of weakness.

- The proposed narrower panels will have significantly wider chain pillars (e.g. 58 m v. 42 m) than previous longwall layouts and will reduce subsidence and strains above the panels and potential interaction with geological structure. The differential subsidence (and strains) above the panel adjacent to the solid coal (i.e. the leading goaf edge) will also be reduced.

- The predicted valley closure and observed uplift along the valleys above Springvale and Angus Place indicate near surface voids of between 15 mm and 112 mm are likely to have developed.

- Apart from the peat slumps, the measured impacts along valleys to-date ranged from 30 to 100 mm of buckling of rock bars, 10 mm to 110 mm wide tension cracks to side slopes or no impact. It is assessed that the impact to the eastern valleys will be similar based on the predicted subsidence, valley closures, strains and buckling due to LWs 416 to 417.

- Despite the similarity in valley depth and higher valley closure and buckling predictions for the proposed longwalls 416 to 417, it is assessed that the likelihood of a peat slump or significant impact occurring to the TPHSS in the Sunnyside East and Carne West Valleys is 'low' provided mine water discharges are excluded from these areas.

For and on behalf of
Ditton Geotechnical Services Pty Ltd

Steven Ditton
Principal Engineer and Director
BE(Civil/Hons) C.P.Eng(Civil), M.I.E.(Aust)

NPER 342140

Attachments:

Figures 1 to 8

Attachment A - Subsidence Data Summary for B-Lines at Springvale and Angus Place

References:

ACARP, 2002. **Subsidence Impacts on River Valleys, Cliffs, Gorges and River Systems**. Project No. C9067, Waddington Kay & Associates, Report WKA110.

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Fell *et al*, 1992. **Geotechnical Engineering of Embankment Dams**. Fell, R., MacGregor, P. and Stapledon, D. AA Balkema.

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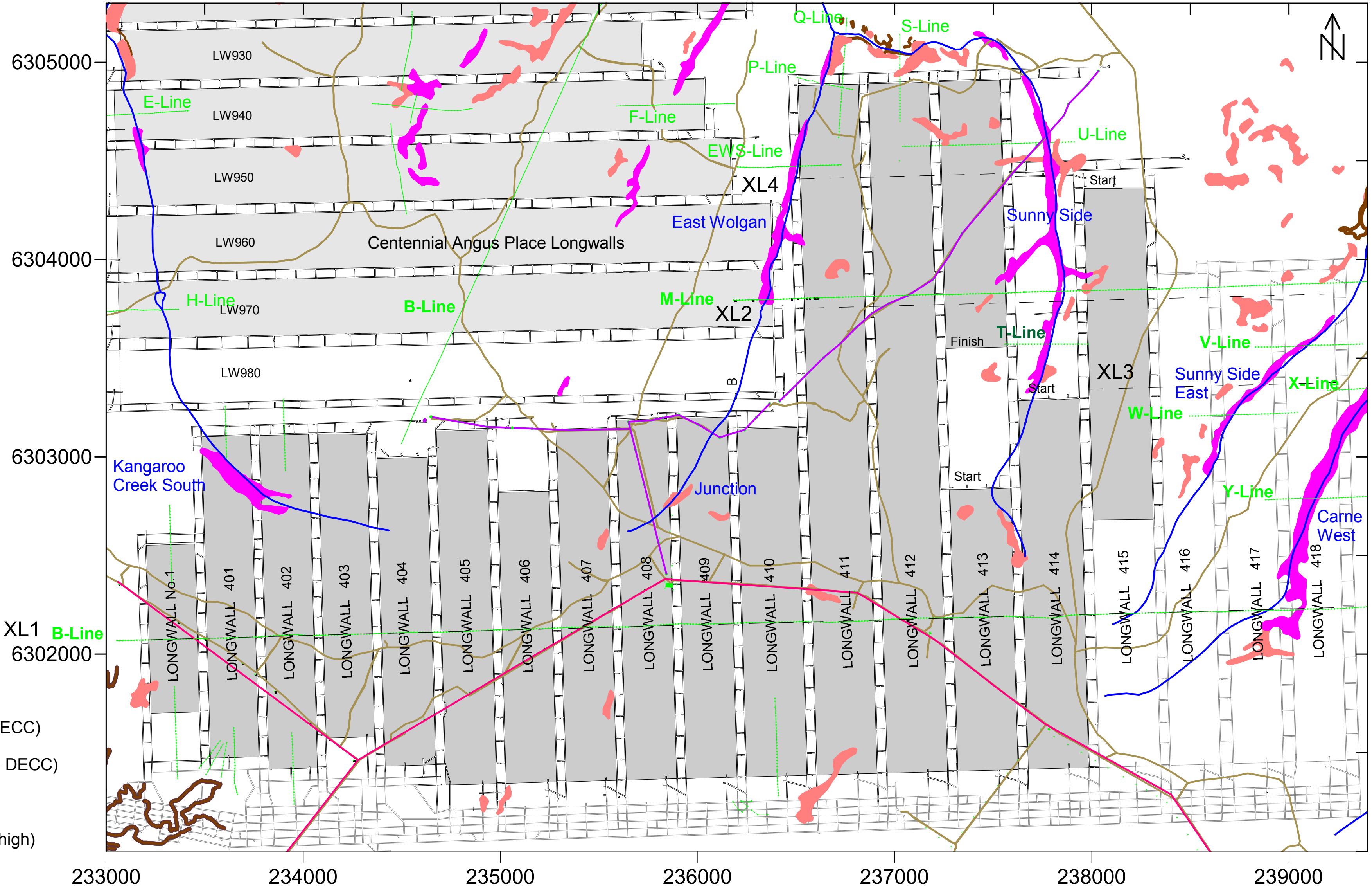
Palaris, 2013. **Geological Structure Zones in Angus Place and Springvale Mine Extension Areas**. Palaris Report No. CEY1504-01 (January).



Key

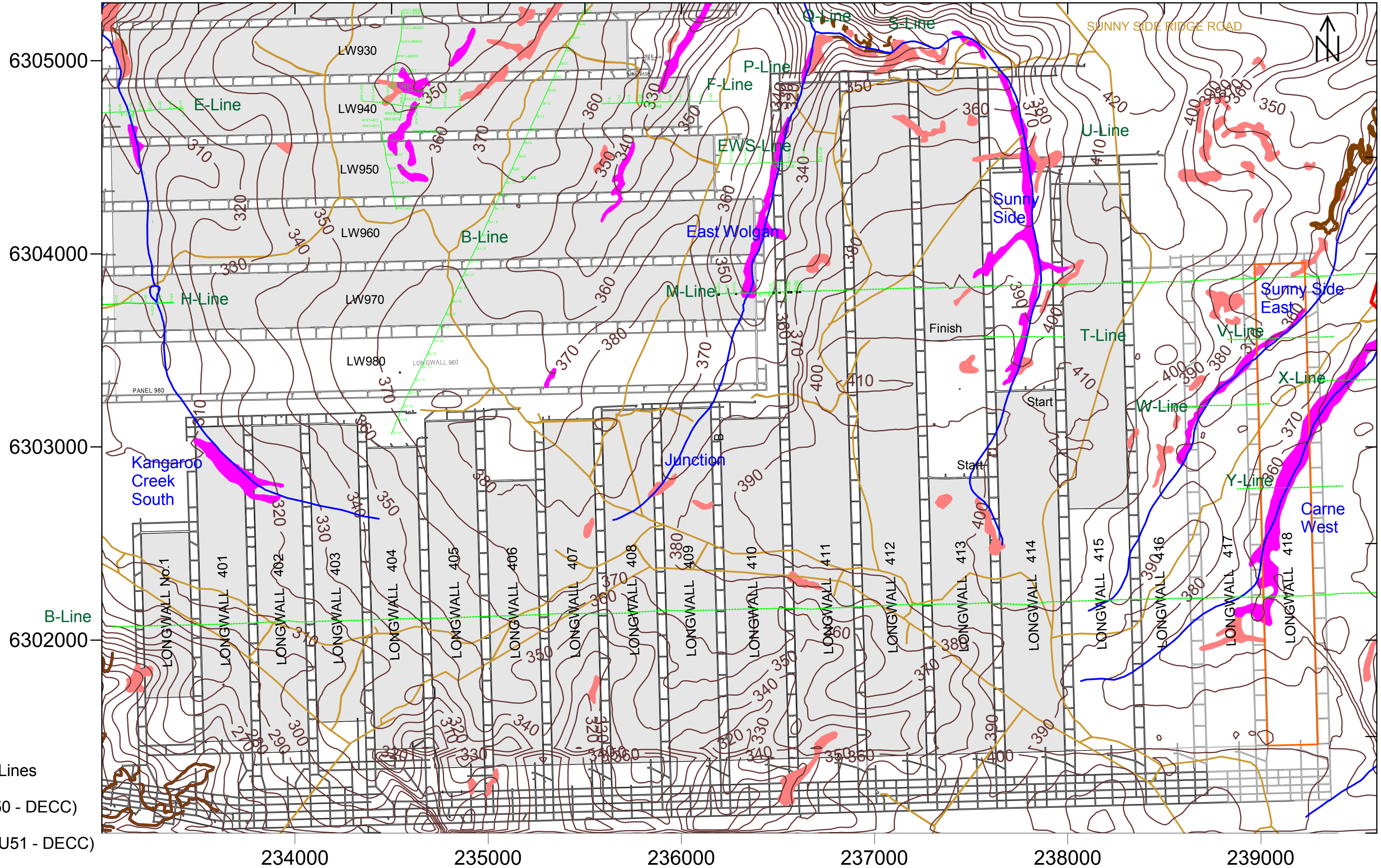
- Existing Subsidence Lines
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Creeks
- Rock Formations (5-20 m high)
- Existing mine workings
- Proposed mine workings
- Extracted longwall
- Endeavour Energy 66kV Line
- Mine Site 11kV Line
- NSW Forests Fire Trails

DgS

Ditton Geotechnical Services Pty Ltd

Engineer:	S.Ditton
Drawn:	S.Ditton
Date:	09.05.13

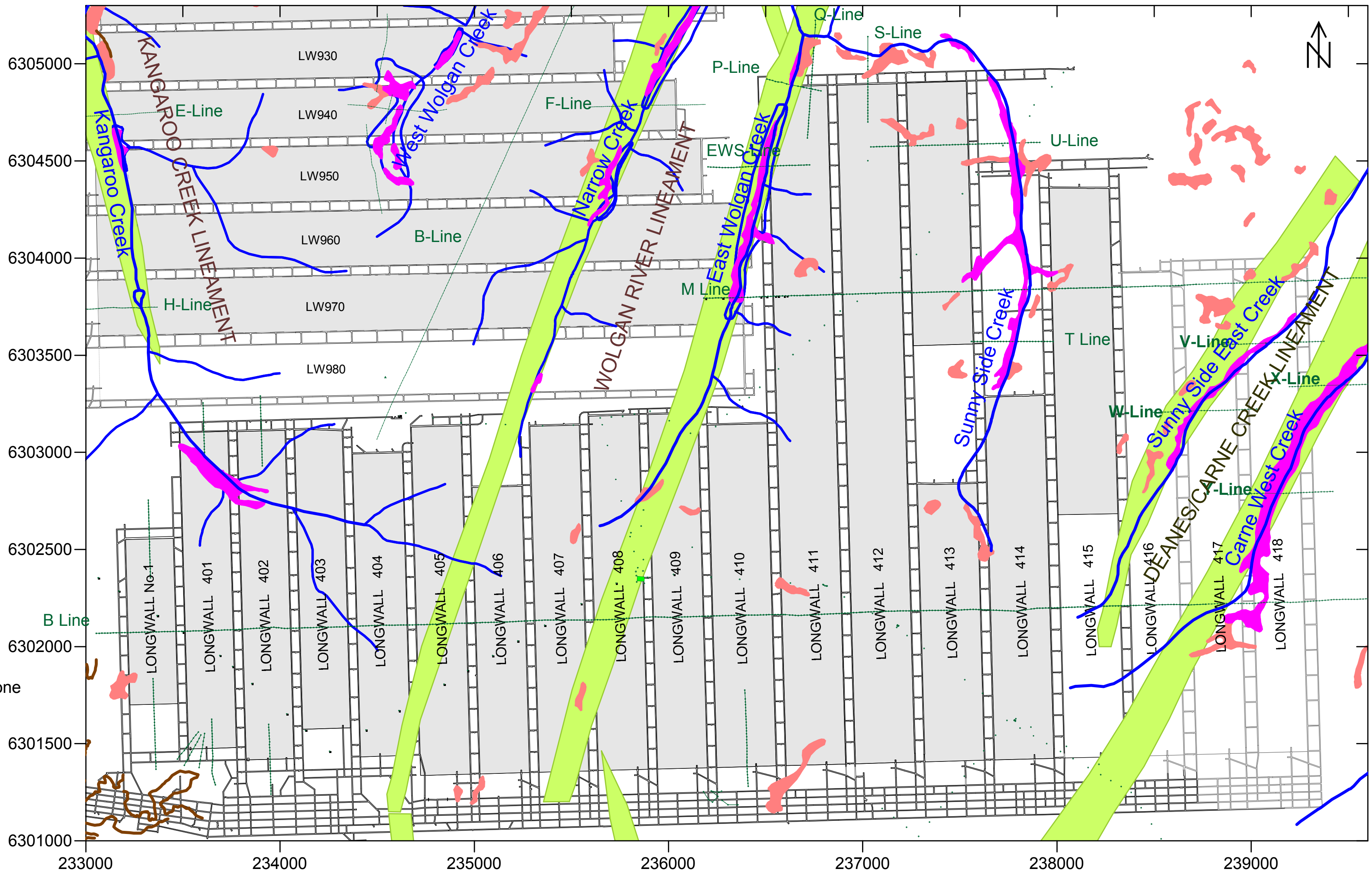
Client:	Centennial Springvale SPV-003/6
Title:	Springvale Longwalls 1 to 415 with Proposed LWs 416 to 418, Installed Subsidence Lines, Surface Features and Centennial Angus Place Longwalls
Scale:	1:30,000
Figure No:	1a



Key

- Cover Depth (m)
- Existing Subsidence Lines
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Creeks
- Rock Formations (5-20 m high)
- Existing mine workings
- Proposed mine workings
- Extracted longwall
- NSW Forests Fire Trails

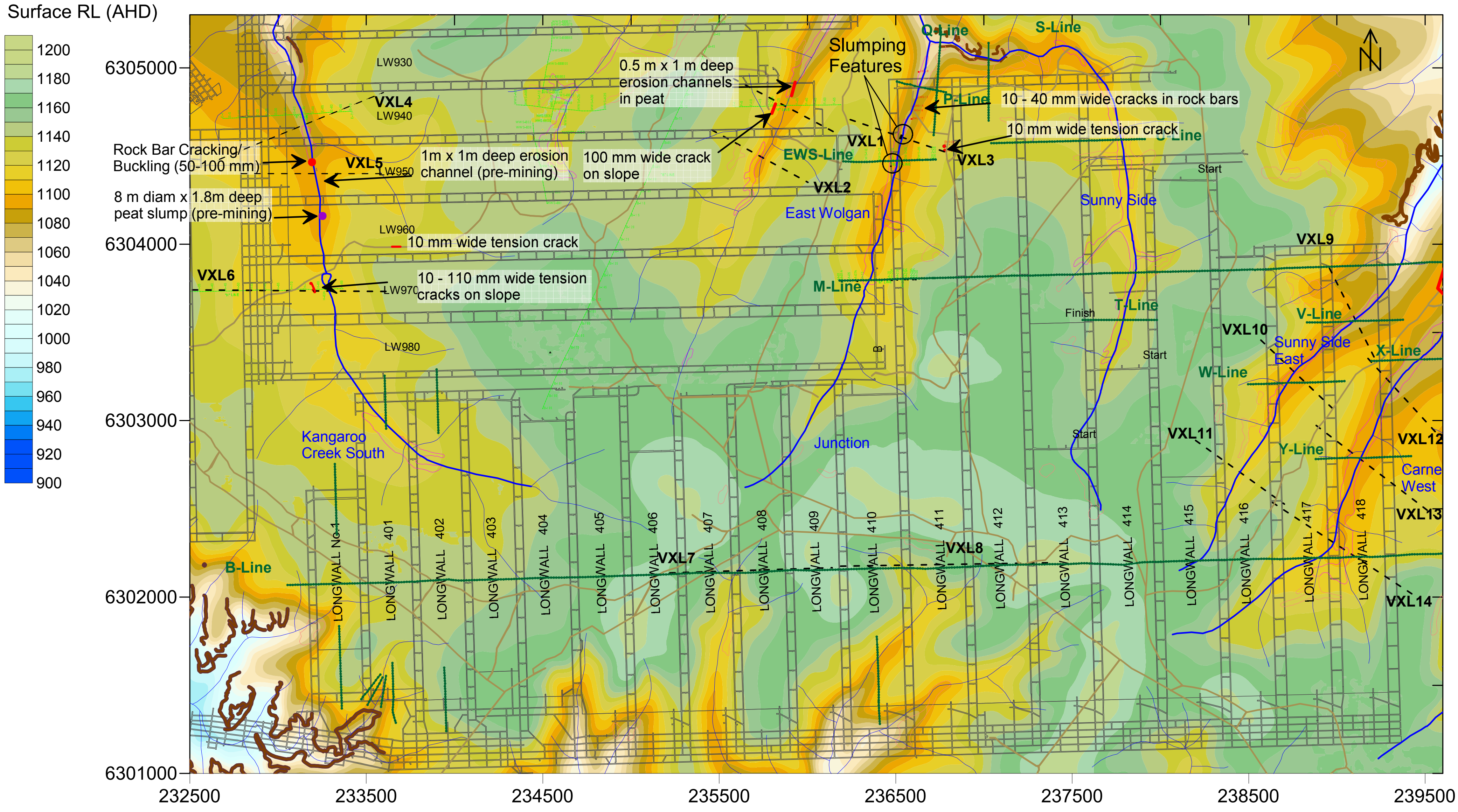
DgS	Engineer:	S.Ditton	Client:	Centennial Springvale SPV-003/6
	Drawn:	S.Ditton		
	Date:	09.05.13	Title:	Cover Depth Contours and Surface Features above Springvale Longwalls 1 to 418 and Angus Place Longwalls 920 to 980
	Ditton Geotechnical Services Pty Ltd		Scale:	1:30,000
			Figure No:	1b



Key:

- Type 1 Structure Zone (see Palaris, 2013)
- Watercourses
- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Cliff lines (>20 m high)
- Rock Formations (5 - 20 m)
- Extracted Longwall Blocks
- Proposed Longwalls
- Installed Subsidence Lines

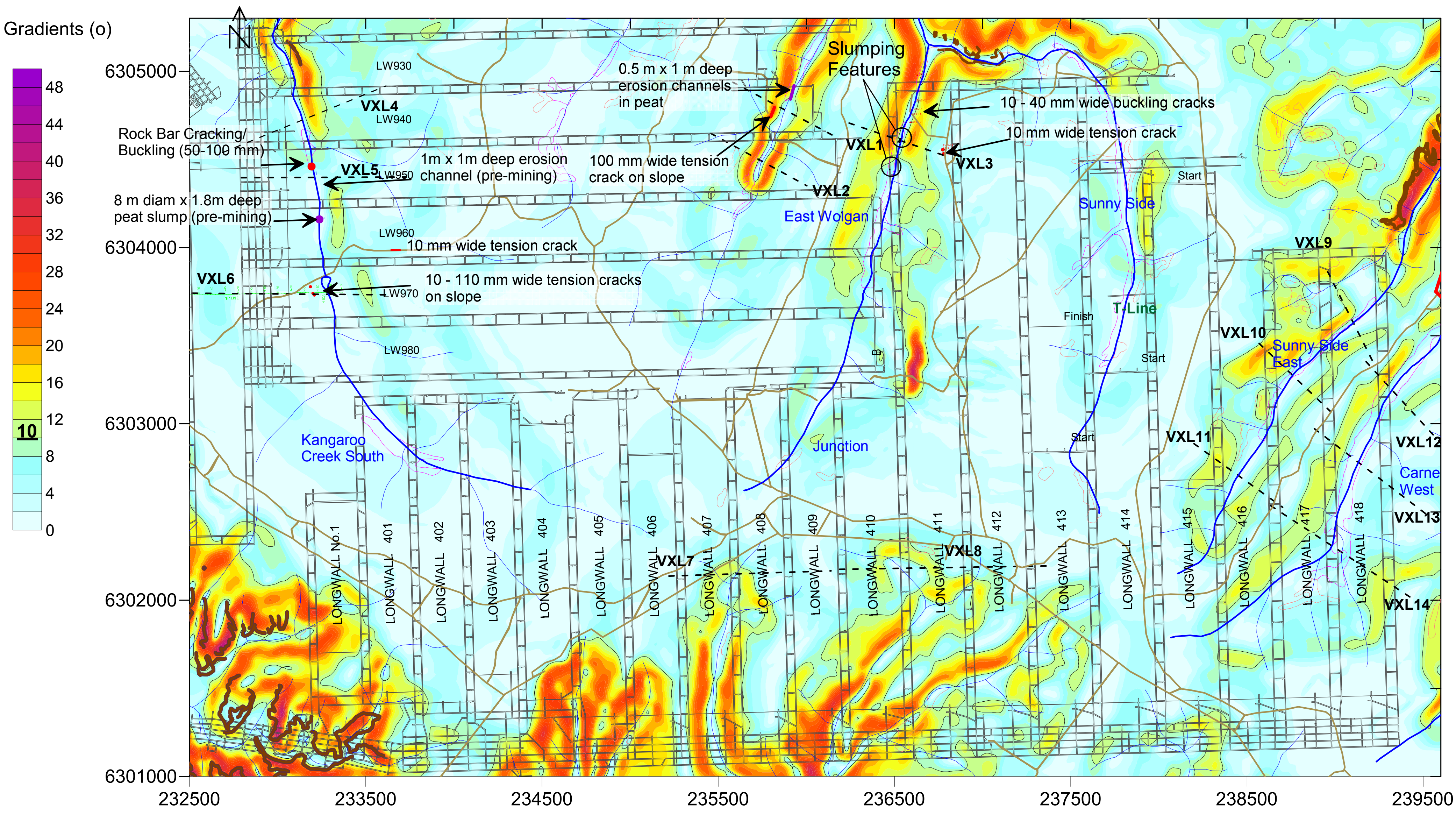
DgS	Engineer:	S.Ditton	Client:	Centennial Springvale Coal SPV-003/6
	Drawn:	S.Ditton		
	Date:	09.04.13	Title:	Interpreted/Mapped Geological Structure above the Springvale Longwalls 1 to 418
	Ditton Geotechnical Services Pty Ltd		Scale:	1:30,000
			Figure No:	1c



Key

VXL1 - - - - Valley Cross Line

DgS				
	Engineer:	S.Ditton	Client:	Centennial Springvale SPV-003/6
	Drawn:	S.Ditton		
	Date:	09.05.13	Title:	Longwalls 1 to 415 with Proposed LWs 416 to 418, Installed Subsidence Lines, Surface Impacts, Level Contours & Centennial Angus Place Longwalls
Ditton Geotechnical Services Pty Ltd			Scale:	1:30,000
			Figure No:	2a

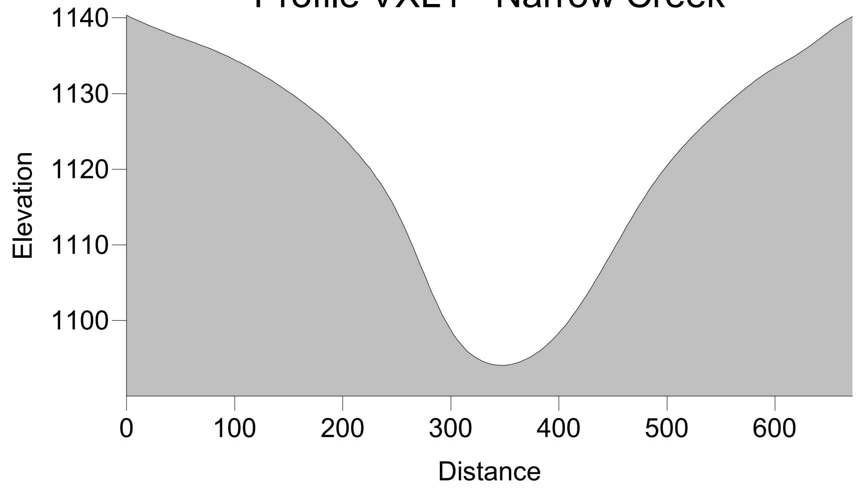


Key

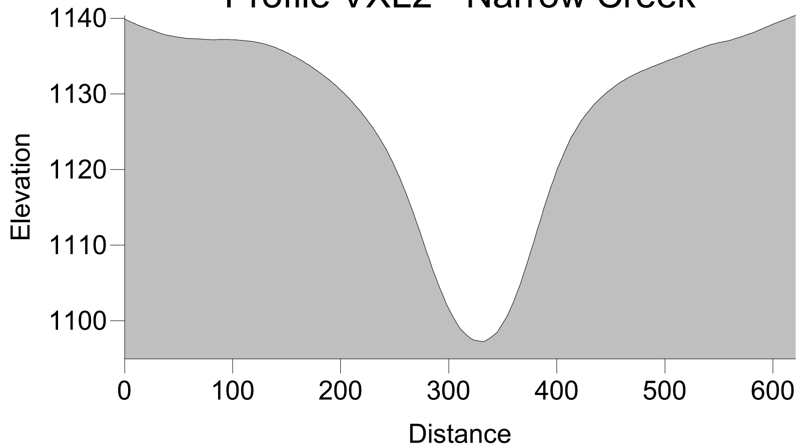
VXL1 - - - - Valley Cross Line

DgS Ditton Geotechnical Services Pty Ltd	Engineer:	S.Ditton	Client:	Centennial Springvale SPV-003/6		
	Drawn:	S.Ditton				
	Date:	09.05.13	Title:	Surface impacts and slope gradients above Springvale LWs 1 to 418 & Centennial Angus Place Longwalls 920 to 980		
			Scale:	1:30,000	Figure No:	2b

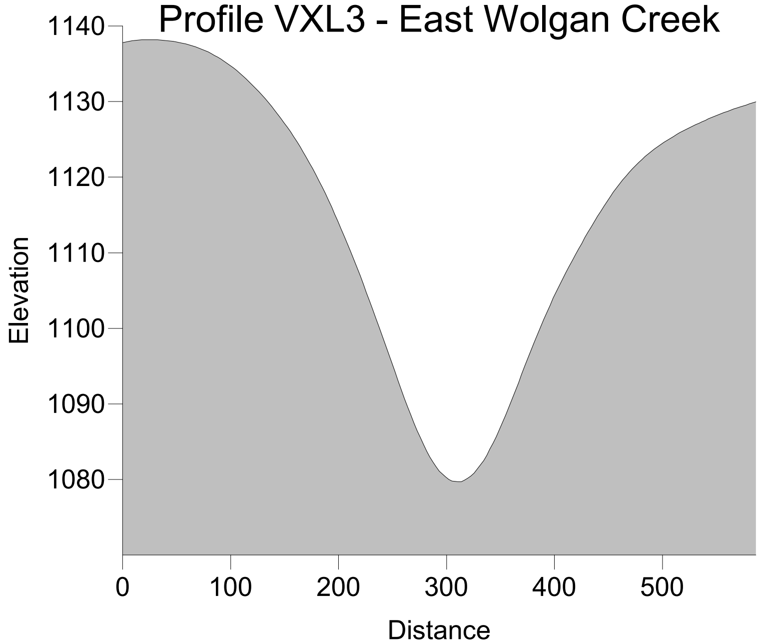
Profile VXL1 - Narrow Creek



Profile VXL2 - Narrow Creek

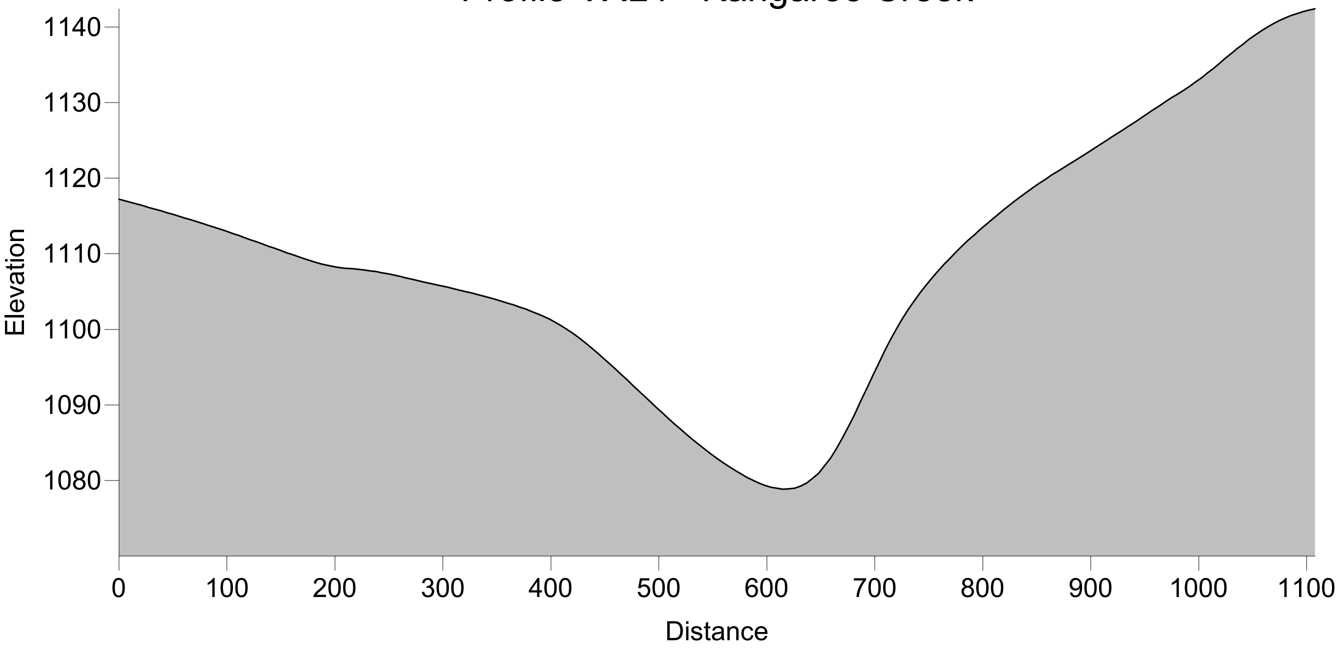


Profile VXL3 - East Wolgan Creek

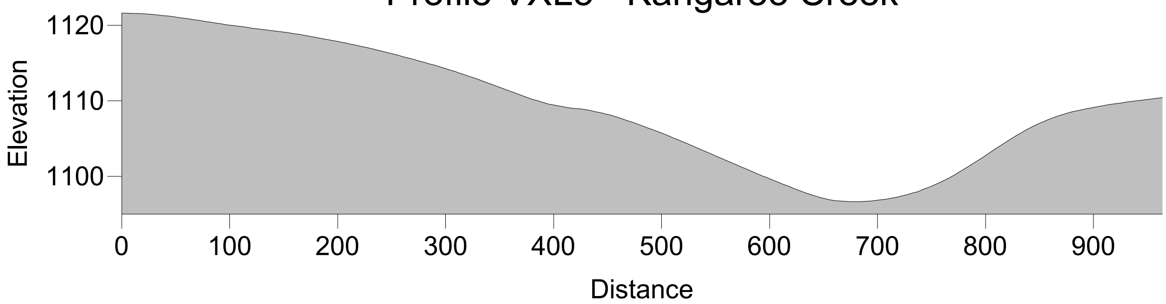


DgS	Engineer:	S.Ditton	Client:	Centennial Springvale SPR-003/6
	Drawn:	S.Ditton		
	Date:	13.05.13	Title:	Narrow Creek and East Wolgan Creek Valley Profiles (see Figure 2a for Location)
	Ditton Geotechnical Services Pty Ltd		Scale:	1:1,000 (V) 1:7,000 (H) — Figure No: 3a

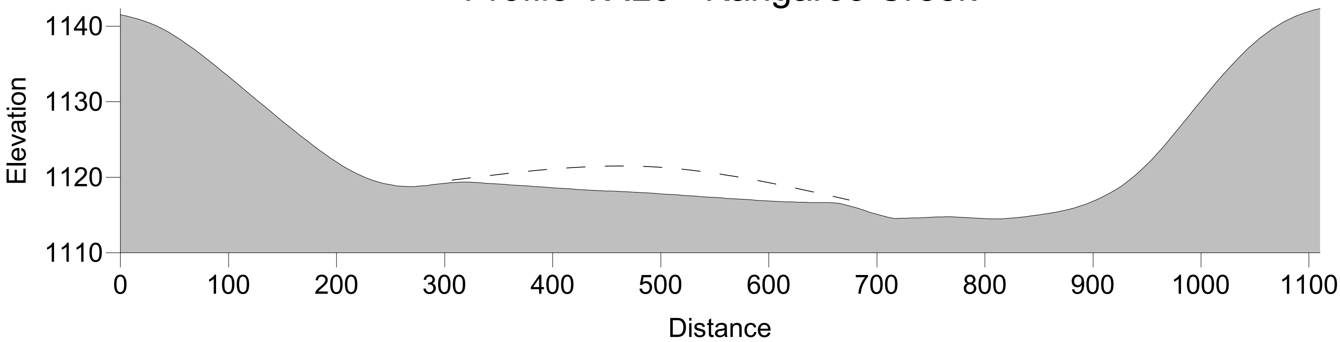
Profile VXL4 - Kangaroo Creek



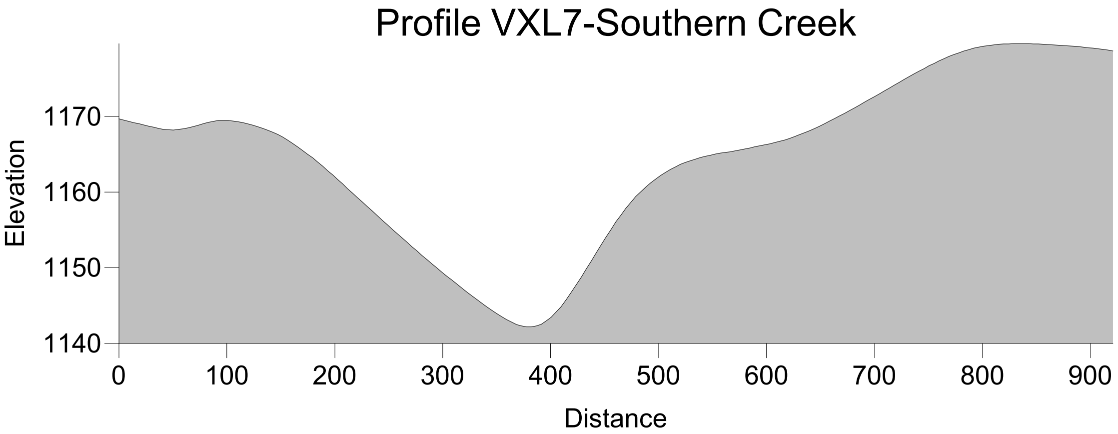
Profile VXL5 - Kangaroo Creek

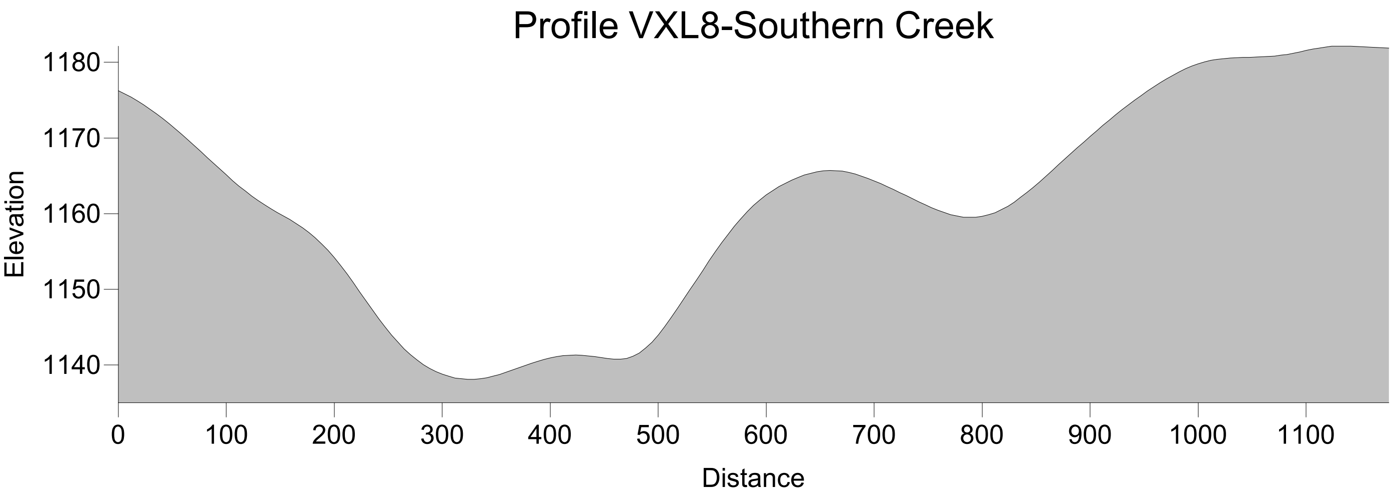


Profile VXL6 - Kangaroo Creek



Engineer:	S.Ditton	Client:	Centennial Springvale SPR-003/6
Drawn:	S.Ditton		
Date:	13.05.13	Title:	Kangaroo Creek Valley Profiles (see Figure 2a)
Ditton Geotechnical Services Pty Ltd		Scale:	1:1,000 (V) 1: 7,000 (H)
		Figure No:	3b





DgS	Engineer:	S.Ditton	Client:	Centennial Springvale
	Drawn:	S.Ditton		SPR-003/6
	Date:	13.05.13	Title:	Southern Creek Valley Profiles along B Line (see Figure 2a)
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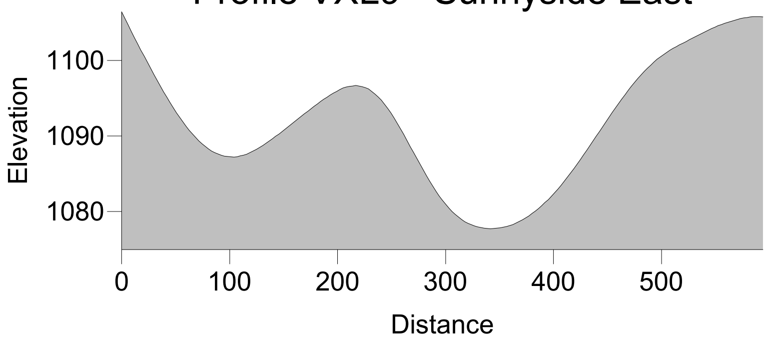
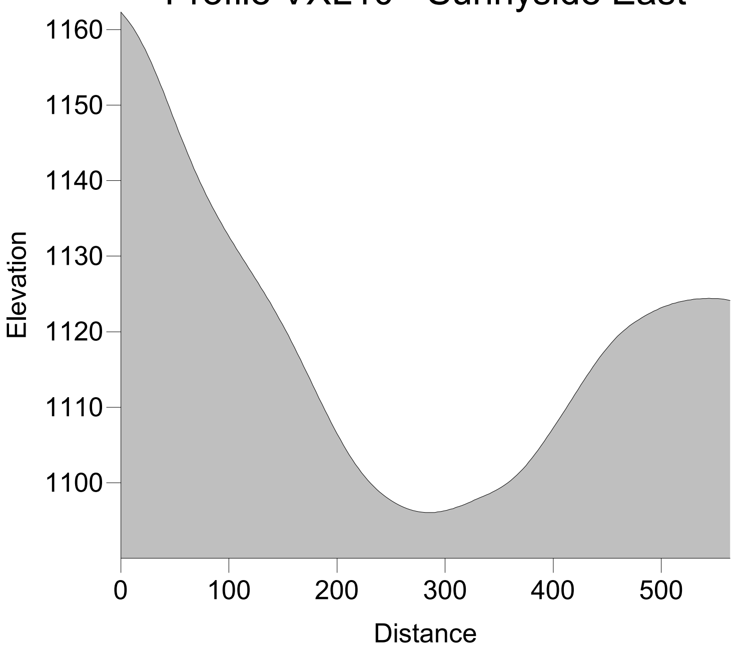
			Figure No:	3c

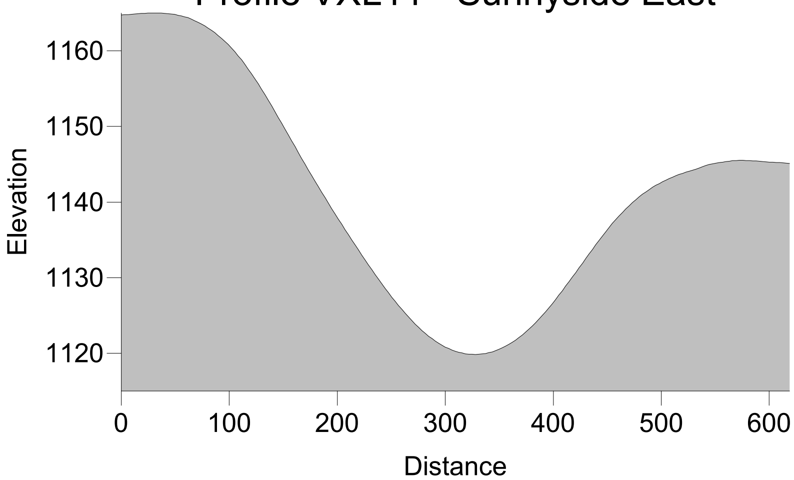
Profile VXL9 - Sunnyside East



Profile VXL10 - Sunnyside East



Profile VXL11 - Sunnyside East



DgS	Engineer: S.Ditton	Client:	Centennial Springvale SPR-003/6		
	Drawn: S.Ditton				
	Date: 13.05.13	Title:	Sunnyside East Creek Valley Profiles (see Figure 2a)		
	Ditton Geotechnical Services Pty Ltd				
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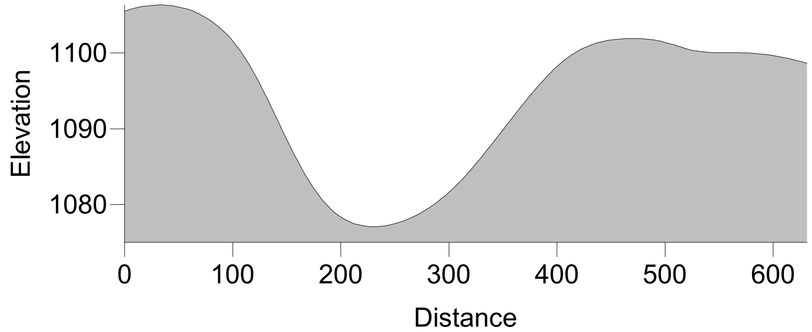
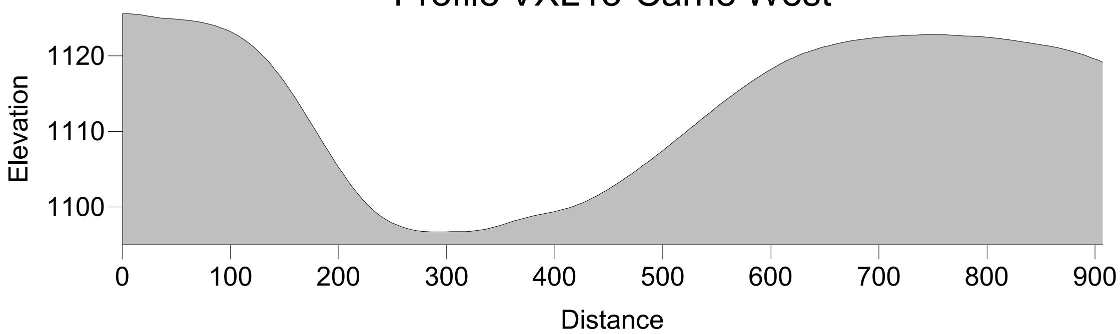
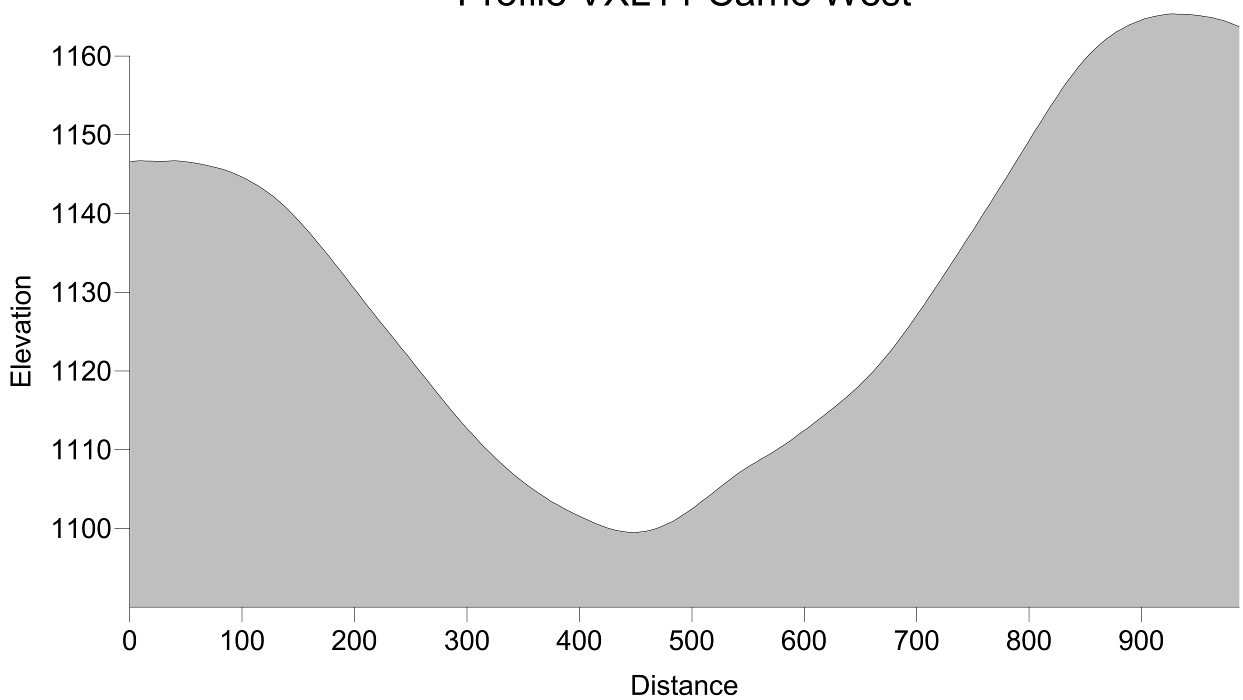
Profile VXL12-Carne West



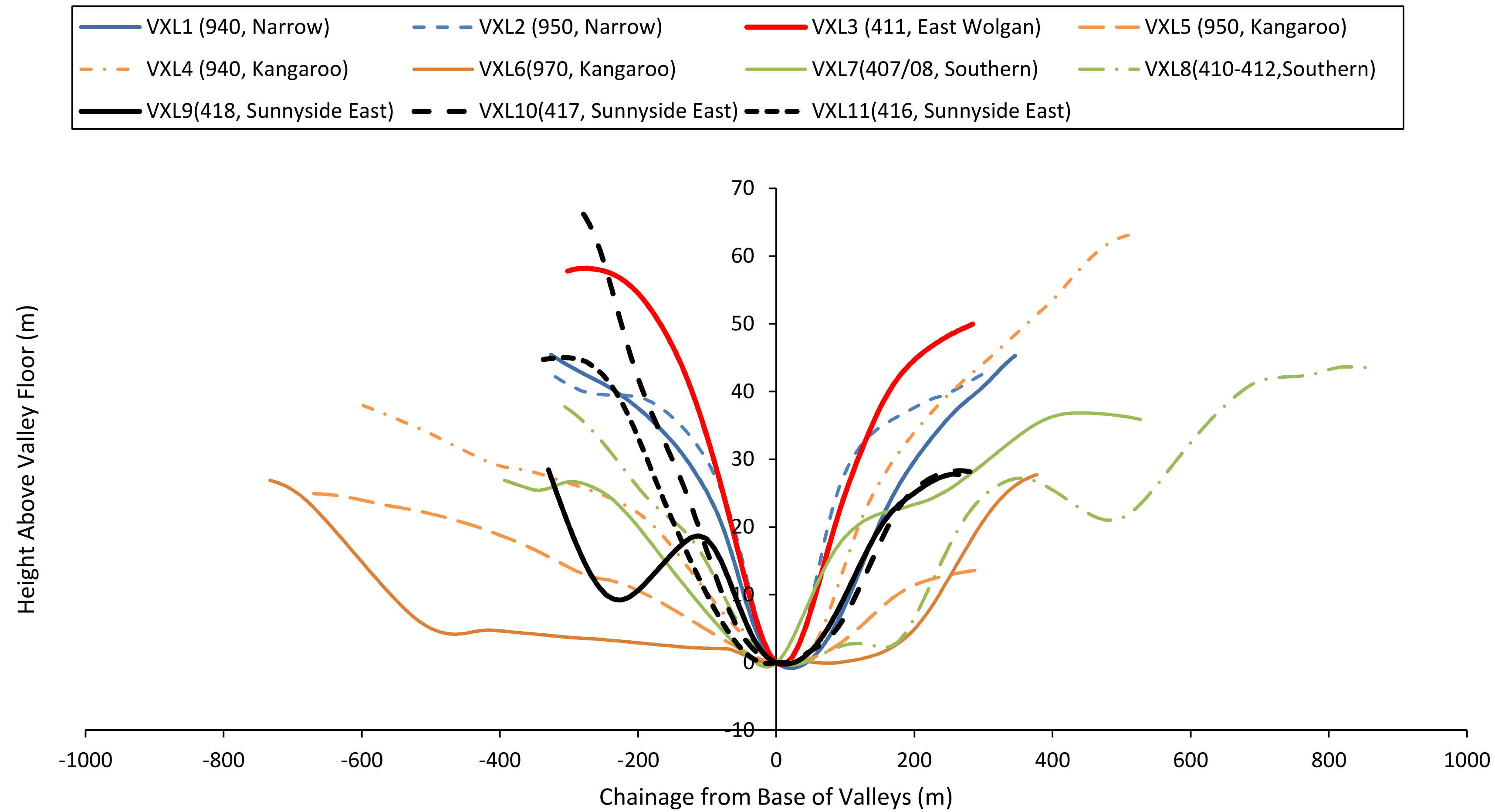
Profile VXL13-Carne West



Profile VXL14-Carne West



DgS	Engineer:	S.Ditton	Client:	Centennial Springvale SPR-003/6		
	Drawn:	S.Ditton				
	Date:	13.05.13	Title:	Carne West Creek Valley Profiles (see Figure 2a)		
	Ditton Geotechnical Services Pty Ltd					
			Scale:	1:1,000 (V): 1: 7,000 (H)	Figure No:	3e



DgS	Engineer:	S.Ditton	Client:	Centennial Springvale Colliery SPV-003/6			
	Drawn:	S.Ditton					
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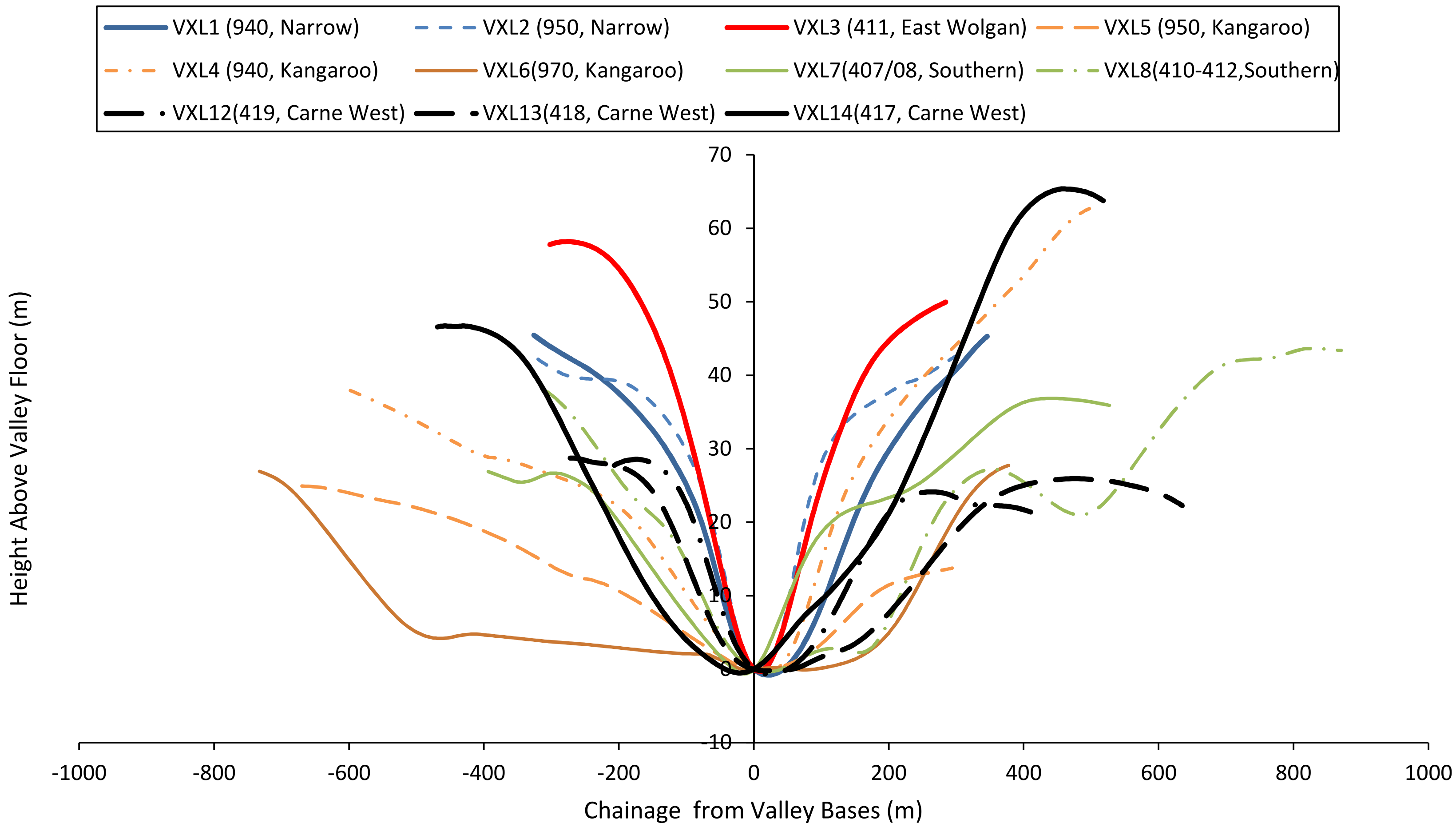
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS		Figure No:	4a



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	Drawn:	S.Ditton				
	Date:	13.05.13	Title:	Valley Shape Profile Comparison for Carne West Shrub Swamps		
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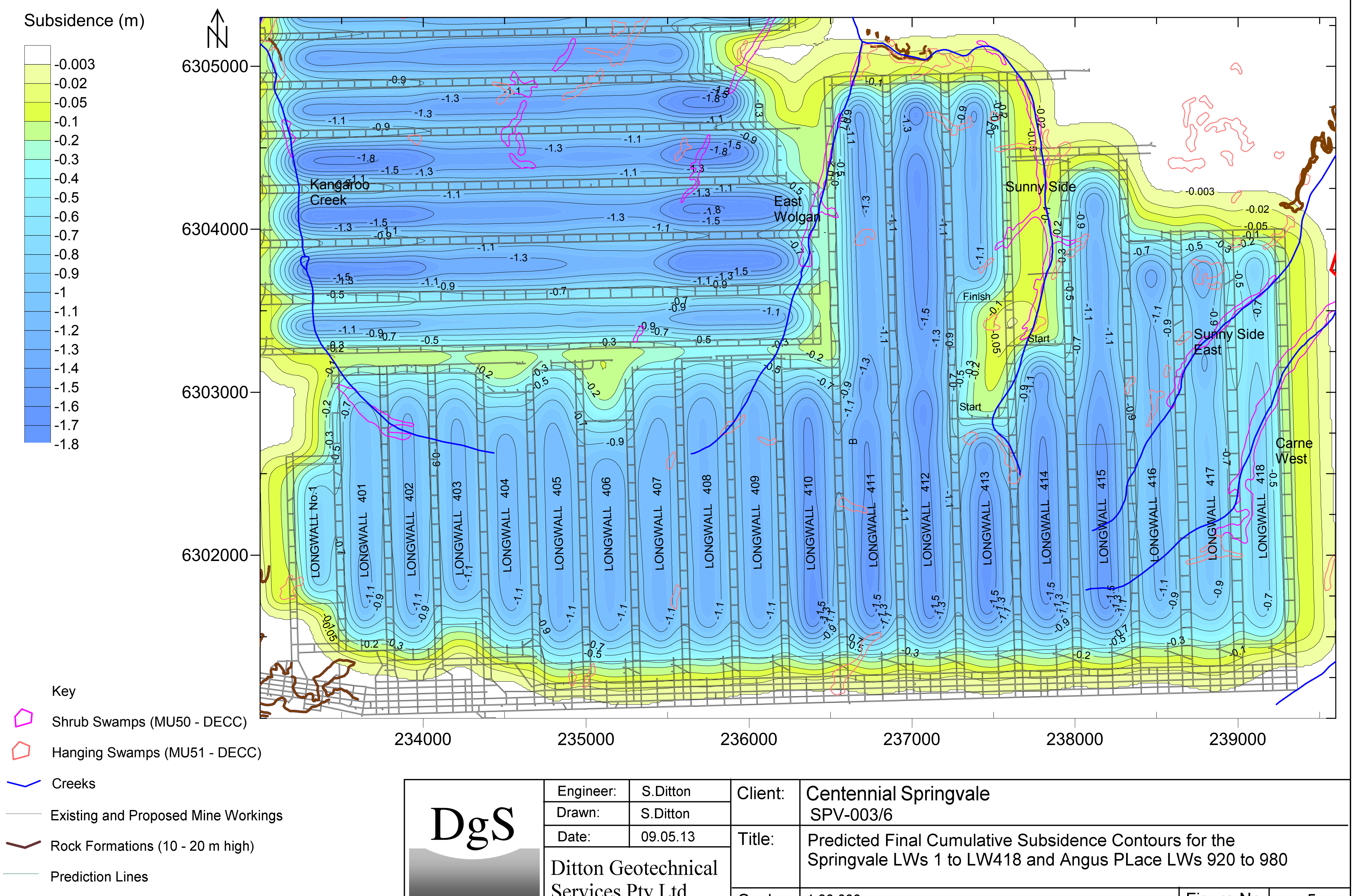
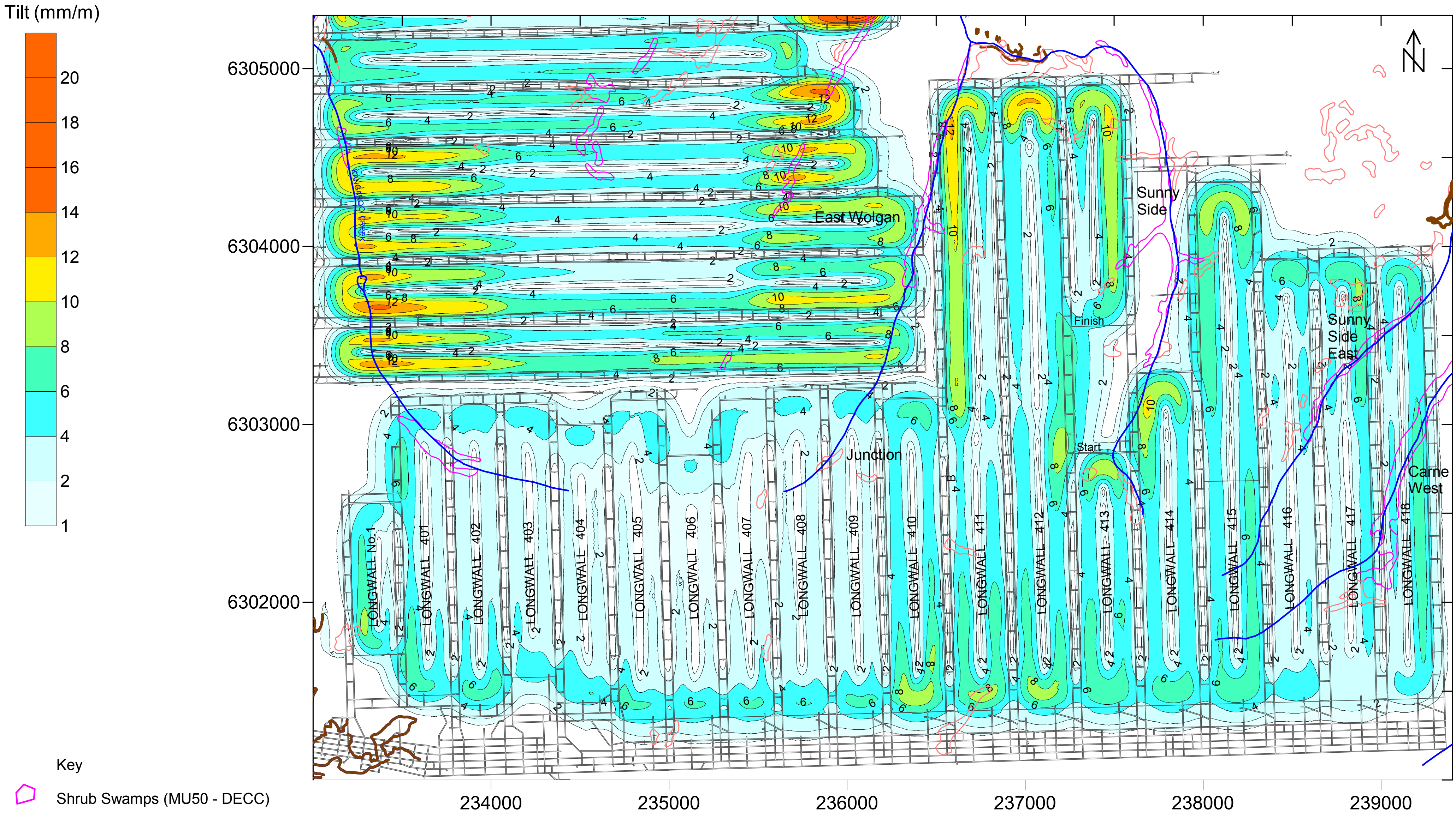


DgS	Engineer:	S.Ditton	Client:	Centennial Springvale SPV-003/6		
	Drawn:	S.Ditton				
	Date:	09.05.13	Title:	Predicted Final Cumulative Subsidence Contours for the Springvale LWs 1 to LW418 and Angus PLace LWs 920 to 980		
	Ditton Geotechnical Services Pty Ltd		Scale:	1:30,000	Figure No:	5a



Key

- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Creeks
- Existing and Proposed Mine Workings
- Rock Formations (10 - 20 m high)

DgS

Ditton Geotechnical Services Pty Ltd

Engineer:	S.Ditton
Drawn:	S.Ditton
Date:	09.05.13

Client: Centennial Springvale SPV-003/6

Title: Predicted Cumulative Tilt Contours for the Springvale LWs 1 to 418 and Angus Place Longwalls 920 to 980

Scale: 1:30,000

Figure No: 5b

Key

- Shrub Swamps (MU50 - DECC)
- Hanging Swamps (MU51 - DECC)
- Creeks
- Existing and Proposed Mine Workings
- Rock Formations (10 - 20 m high)

DgS Ditton Geotechnical Services Pty Ltd	Engineer: S.Ditton	Client:	Centennial Springvale SPV-003/6	
	Drawn: S.Ditton	Title:	Predicted Cumulative Horizontal Strain Contours for the Springvale LWs 1-418 and Angus Place Longwalls 920 to 980	
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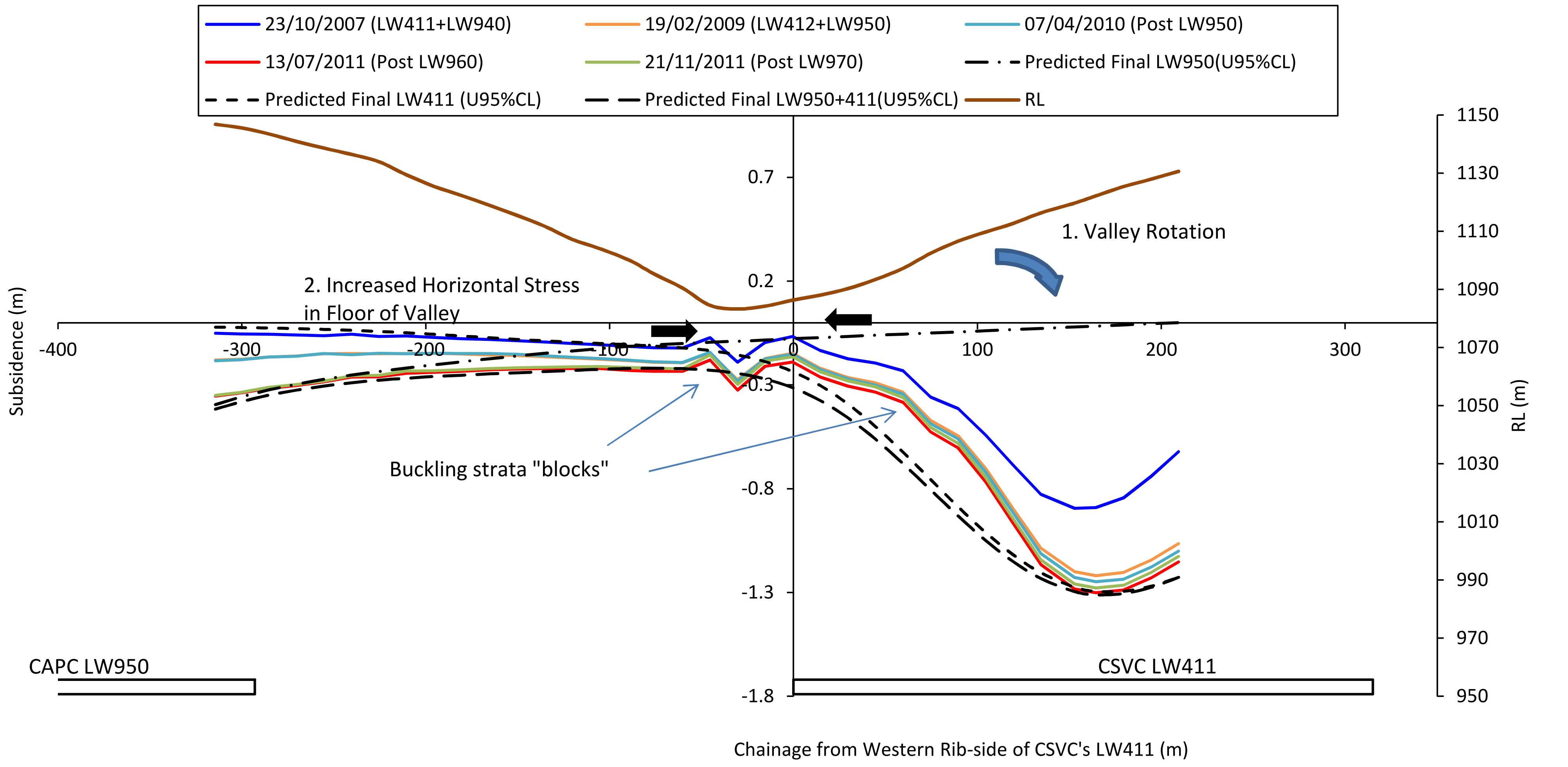
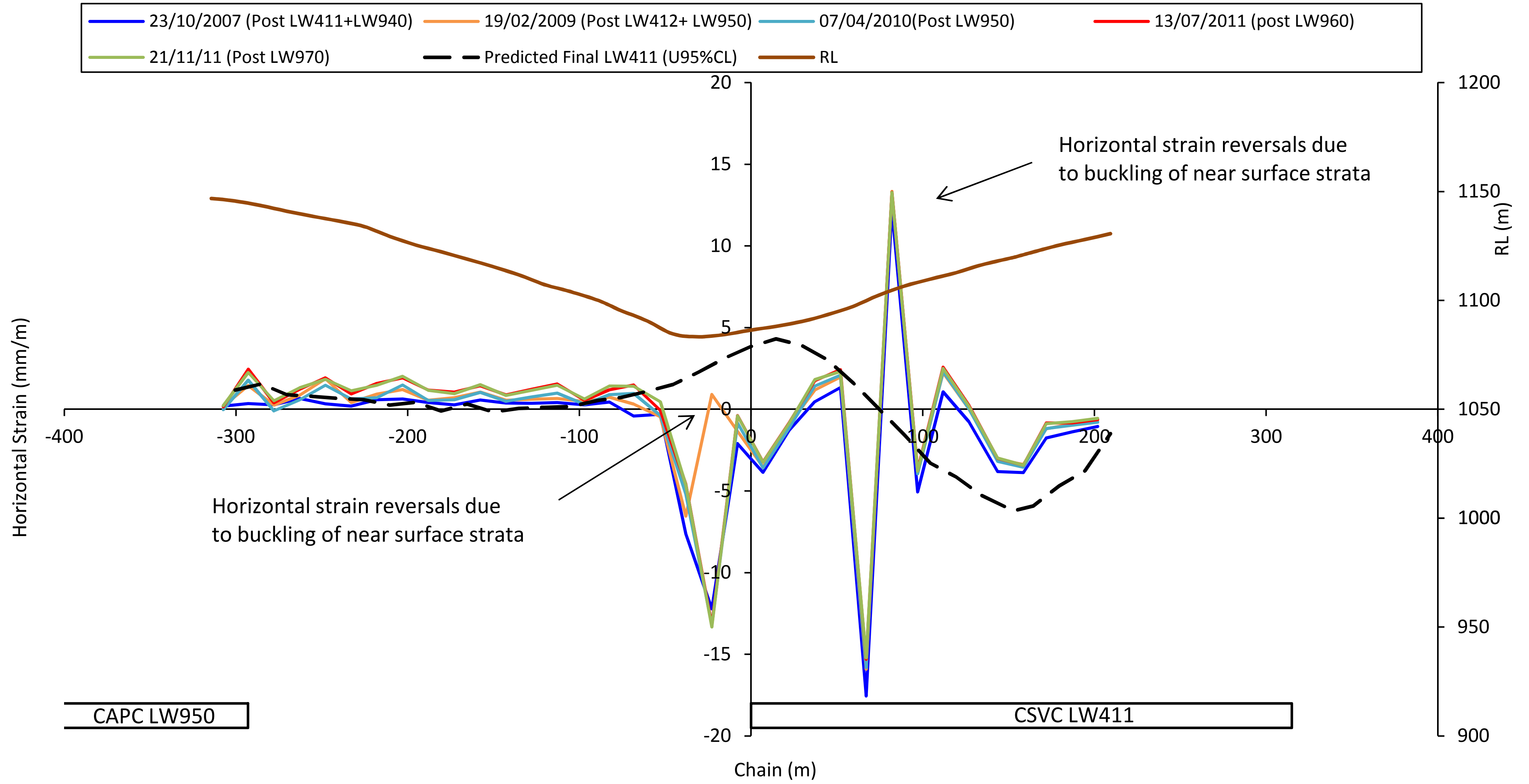
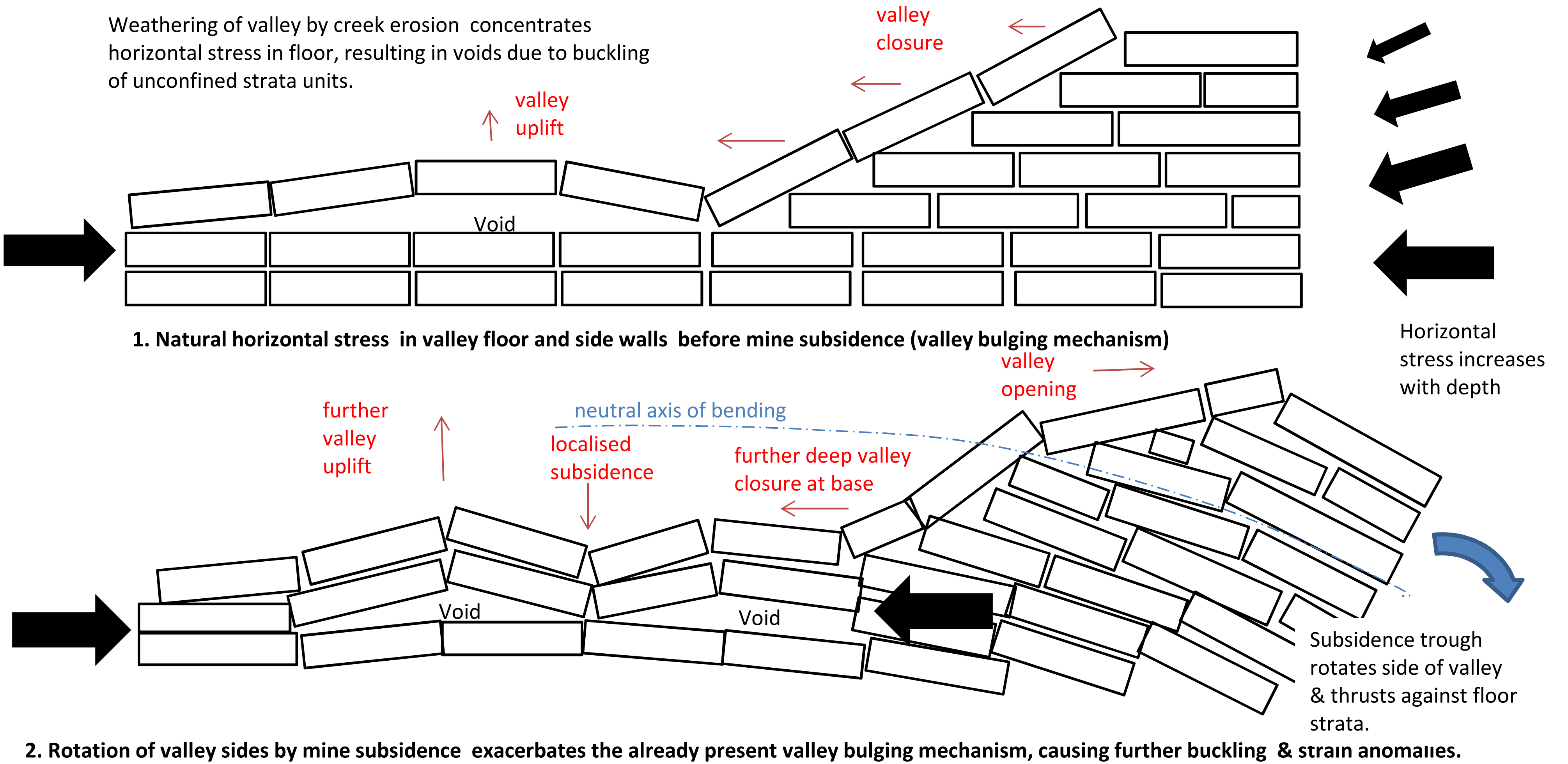


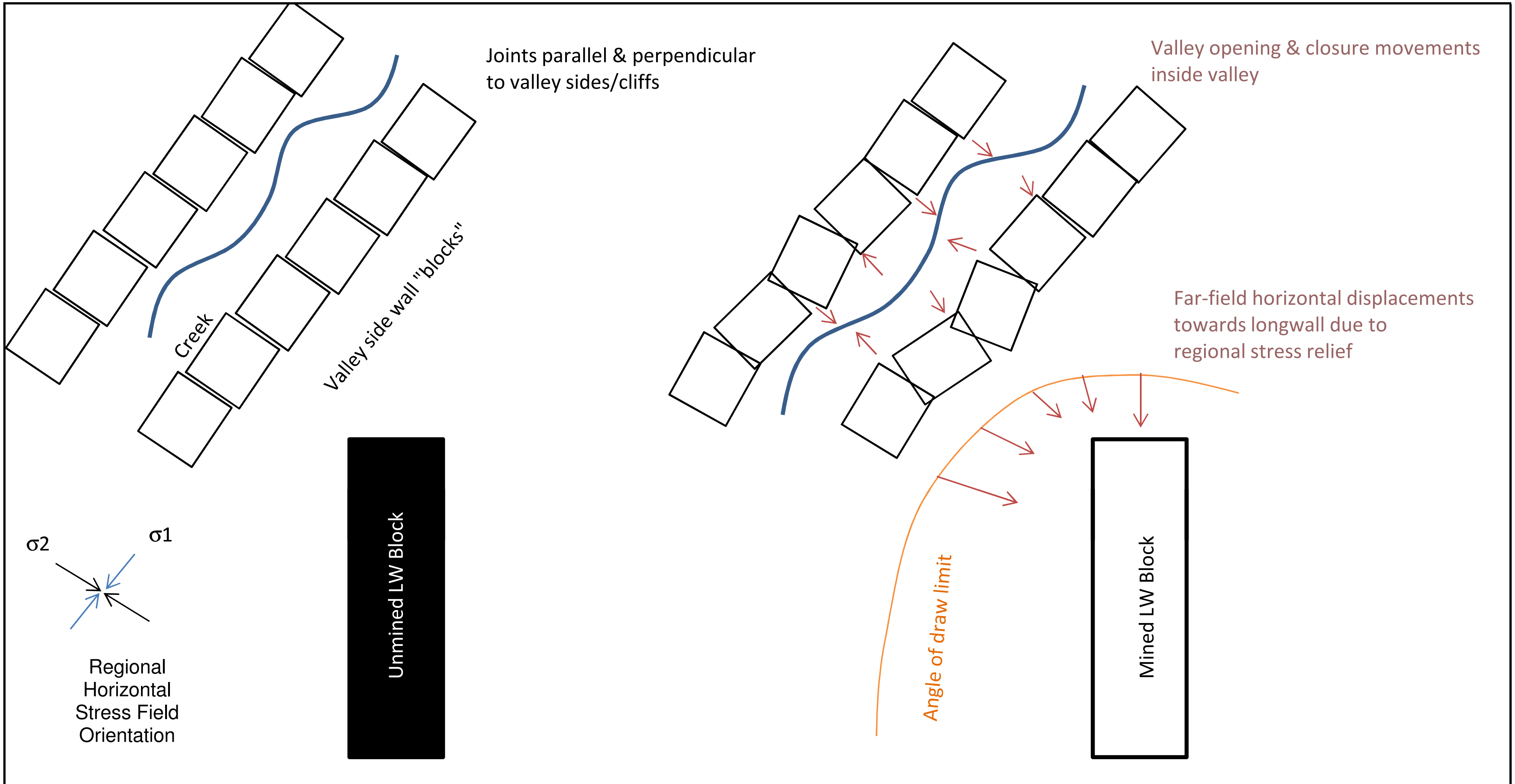
DgS	Engineer:	S.Ditton	Client:	Centennial Springvale Colliery SPV-003/6
	Drawn:	S.Ditton		
	Date:	13.05.13	Title:	Measured Subsidence Profiles along the EWS Line due to LWs 411 to 412 and LWs 940 to 970
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
			Figure No:	6a



DgS	Engineer:	S.Ditton	Client:	Centennial Springvale Colliery SPV-003/6		
	Drawn:	S.Ditton				
	Date:	13.05.13	Title:	Measured Strain Profiles along the EWS Line due to LWs 411 to 412 and LWs 940 to 970		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	6b



DgS	Engineer: S.Ditton		Client:	Centennial Springvale Colliery SPV-003/6
	Drawn: S.Ditton			
	Date: 13.05.13		Title:	Conceptual Model of Near Surface Buckling due to Valley Closure Mechanisms when Valley inside the Angle of Draw over a longwall panel
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS — Figure No: 6c



DgS	Engineer:	S.Ditton	Client:	Centennial Springvale Colliery SPV-003/6
	Drawn:	S.Ditton		
	Date:	13.05.13	Title:	Conceptual Model of Near Surface Buckling due to Valley Closure Mechanisms when Valley outside the Angle of Draw from a longwall panel
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
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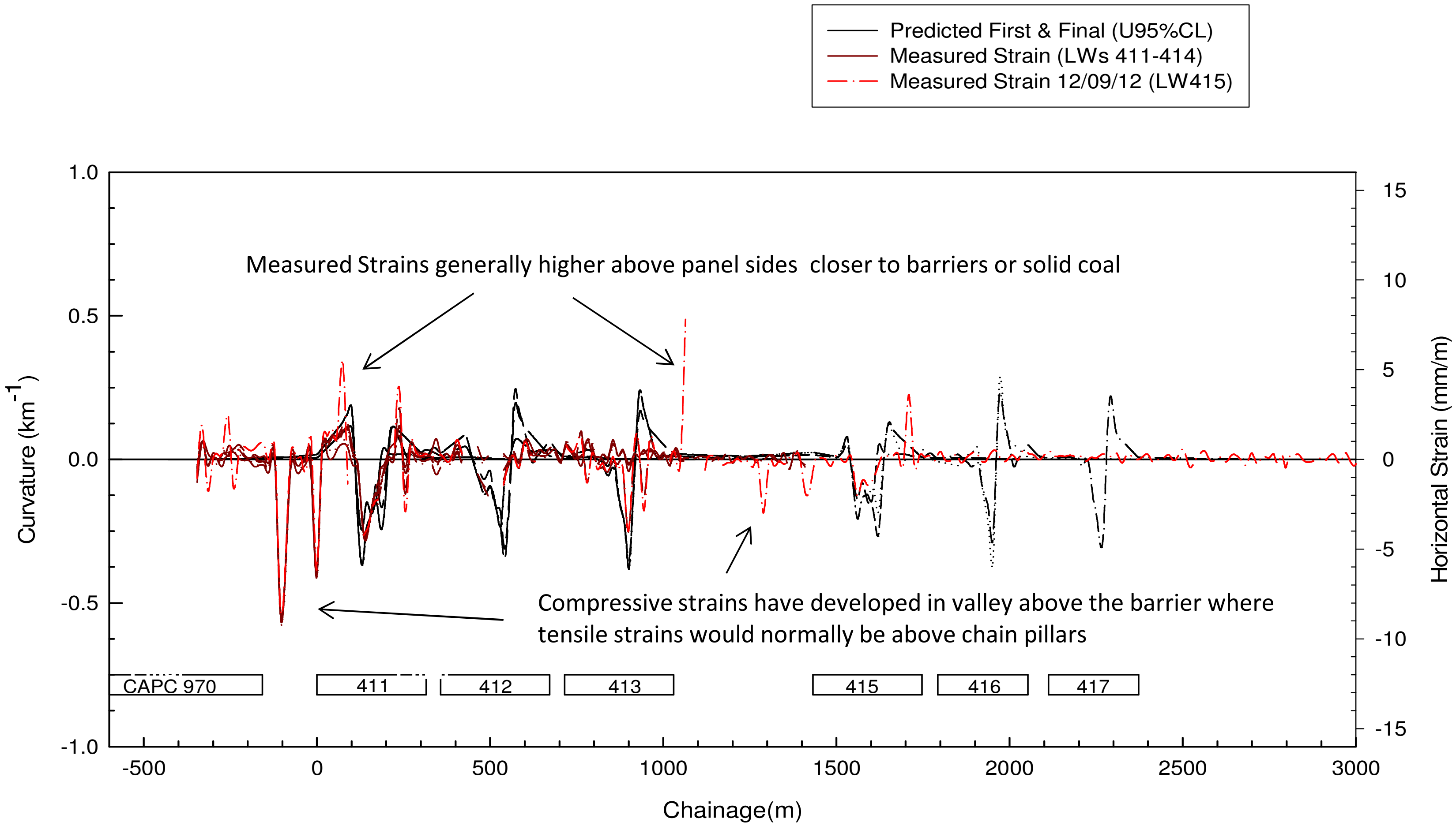
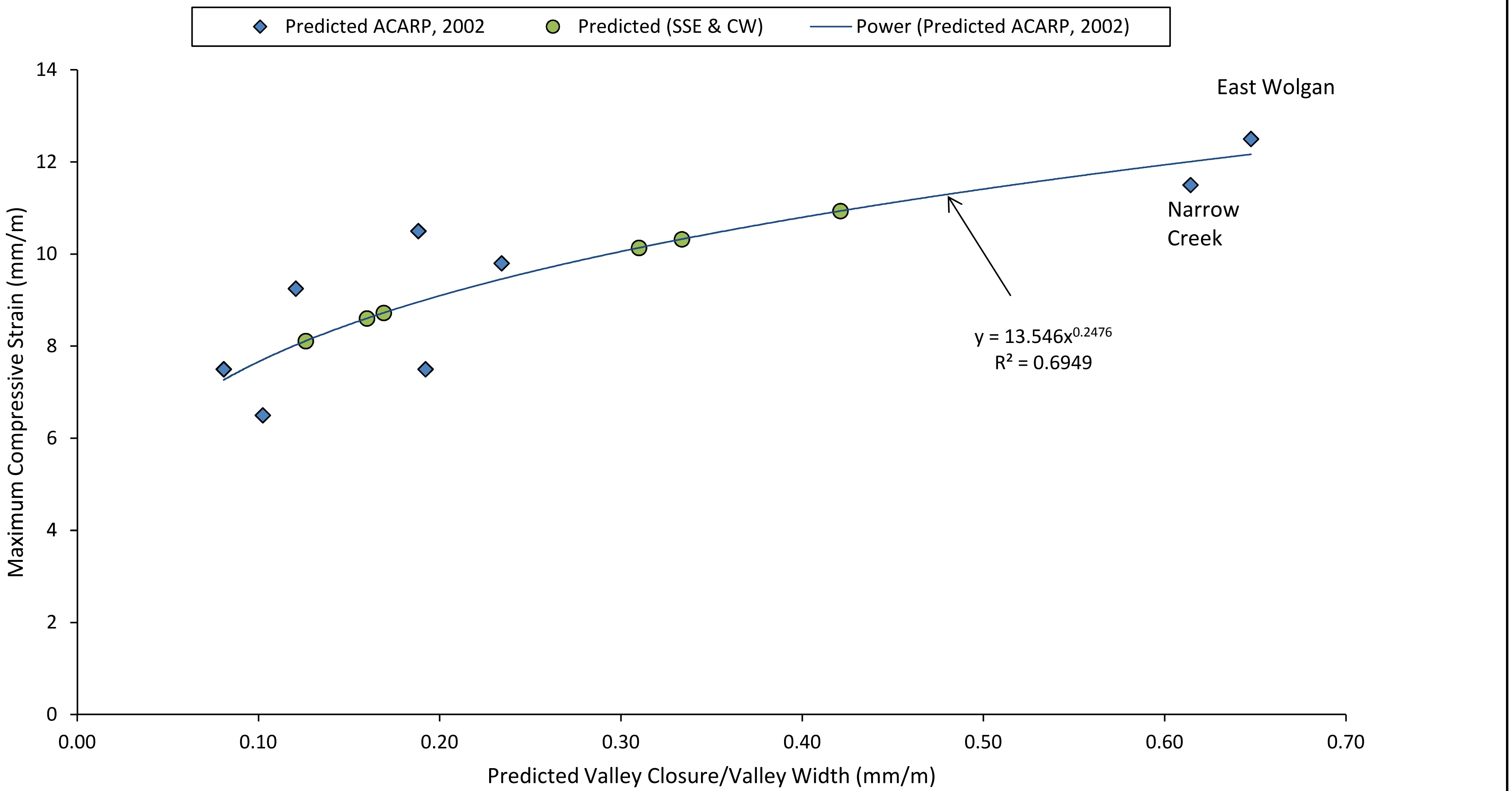
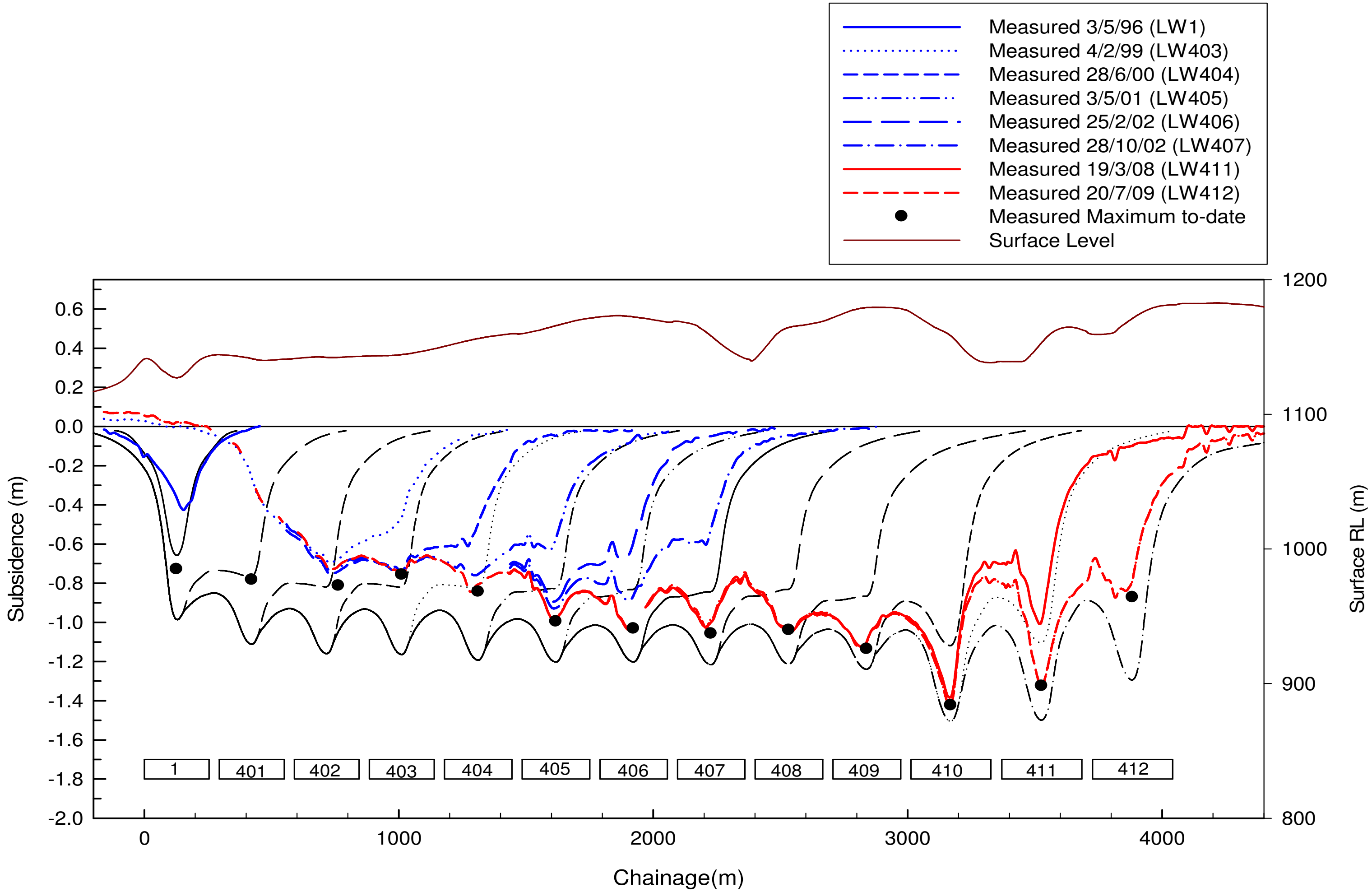


DgS	Engineer:	S.Ditton	Client:	Centennial Springvale Colliery SPV-003/6
	Drawn:	S.Ditton		
	Date:	19.06.13	Title:	Crossline M Horizontal Strain Data v. Predicted U95%CL Profiles for LWs 411-417
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
			Figure No:	7

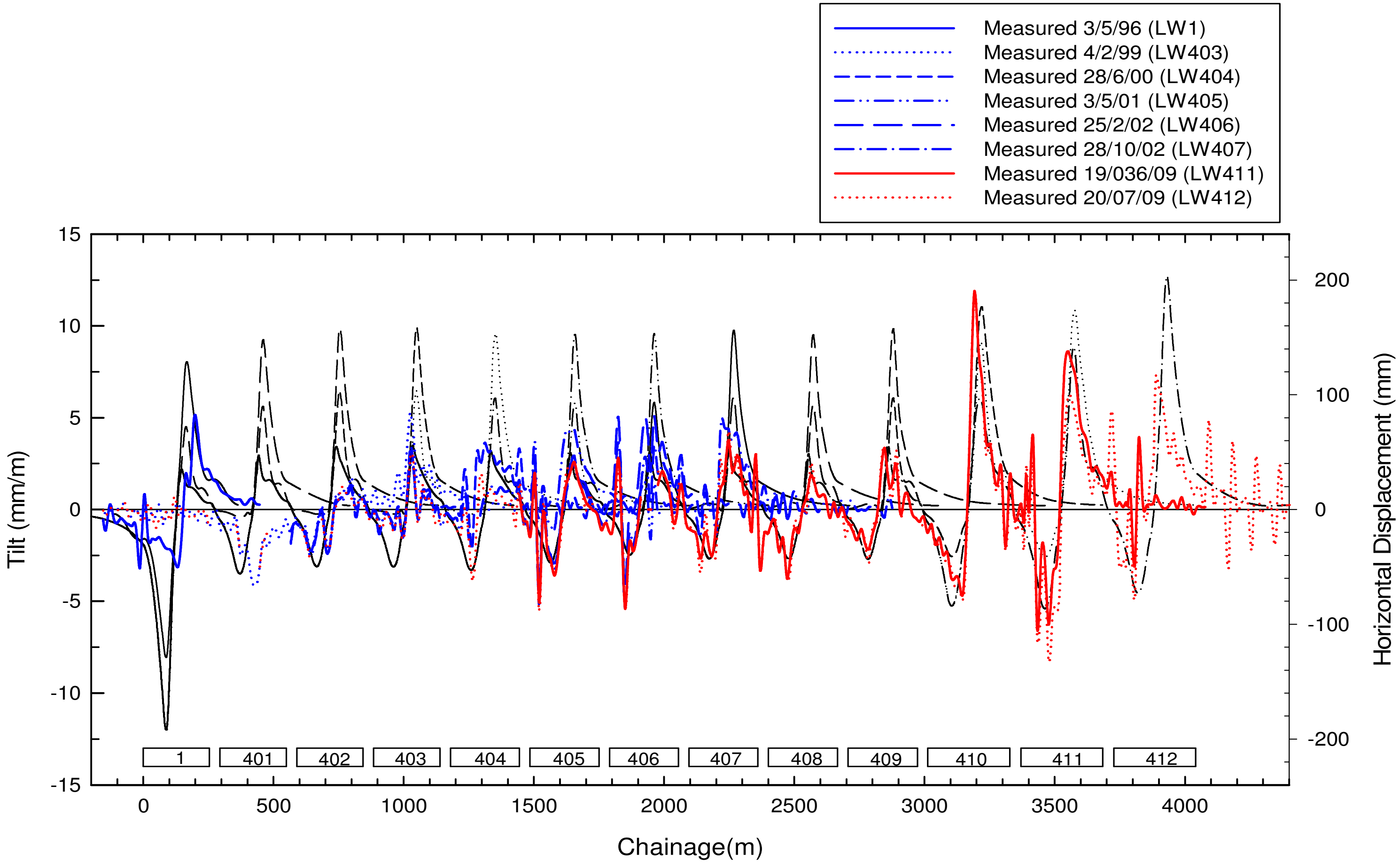


DgS	Engineer:	S.Ditton	Client:	Centennial Springvale Colliery SPV-003/6		
	Drawn:	S.Ditton				
	Date:	19.06.13	Title:	Predicted Valley Strains v. Predicted Valley Closure normalised to Valley Width		
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS	Figure No:	8

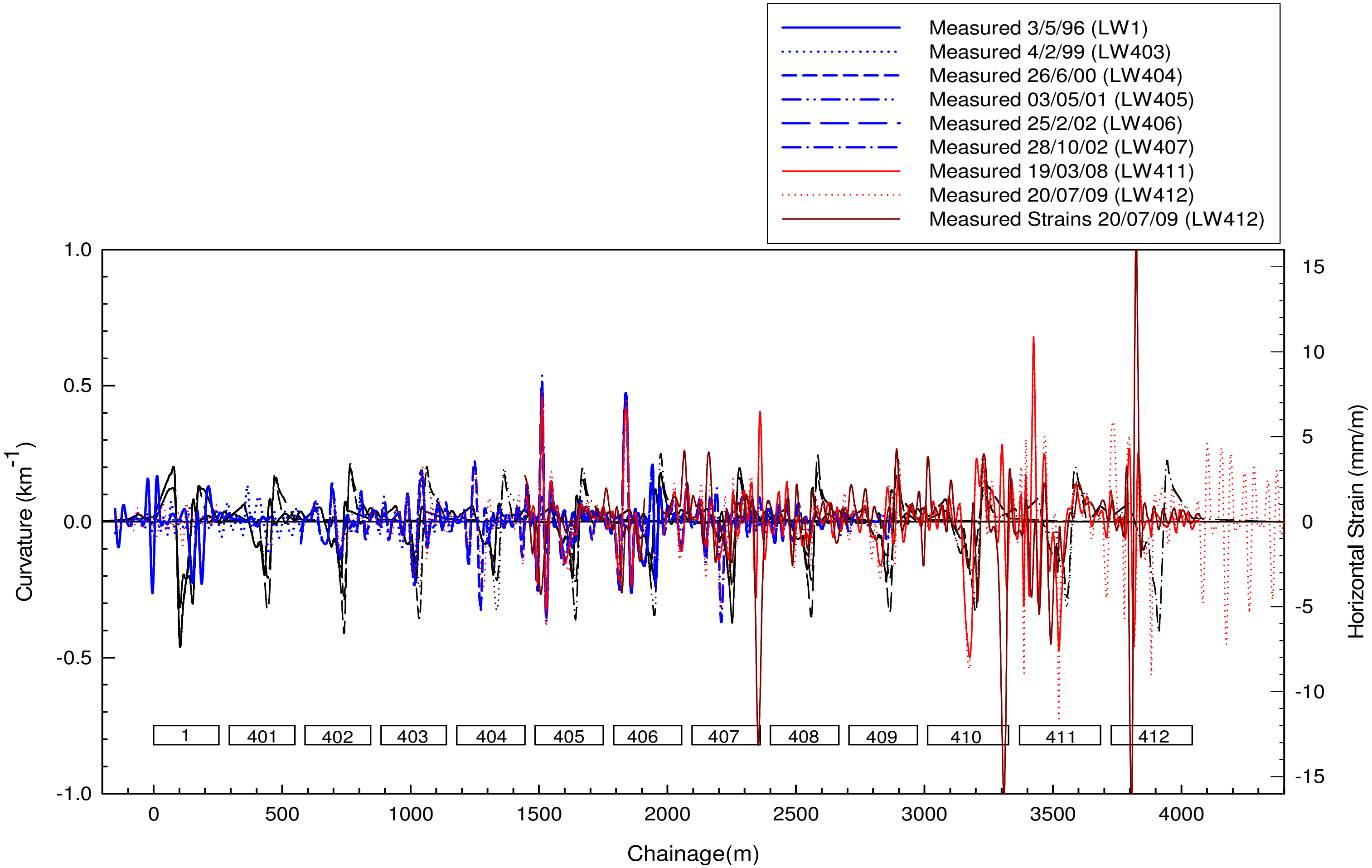
Attachment A - Subsidence Data Summary for B-Lines at Springvale and Angus Place



DgS	Engineer:	S.Ditton	Client:	Springvale Colliery SPV-003/6
	Drawn:	S.Ditton		
	Date:	13.05.13	Title:	Crossline B Subsidence Data v. Predicted U95%CL Profiles for LWs 1-412
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS — Figure No: A1.1



DgS	Engineer: S.Ditton	Client:	Springvale Colliery
	Drawn: S.Ditton		SPV-003/6
	Date: 12.12.12	Title:	Crossline B Tilt Data v. Predicted U95%CL Profiles for LWs 1-412
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS — Figure No: A1.2



DgS	Engineer:	S.Ditton	Client:	Springvale Colliery
	Drawn:	S.Ditton		SPV-003/6
	Date:	12.12.12	Title:	Crossline B Curvature and Strain Data v. Predicted U95%CL Profiles for LWs 1-412
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
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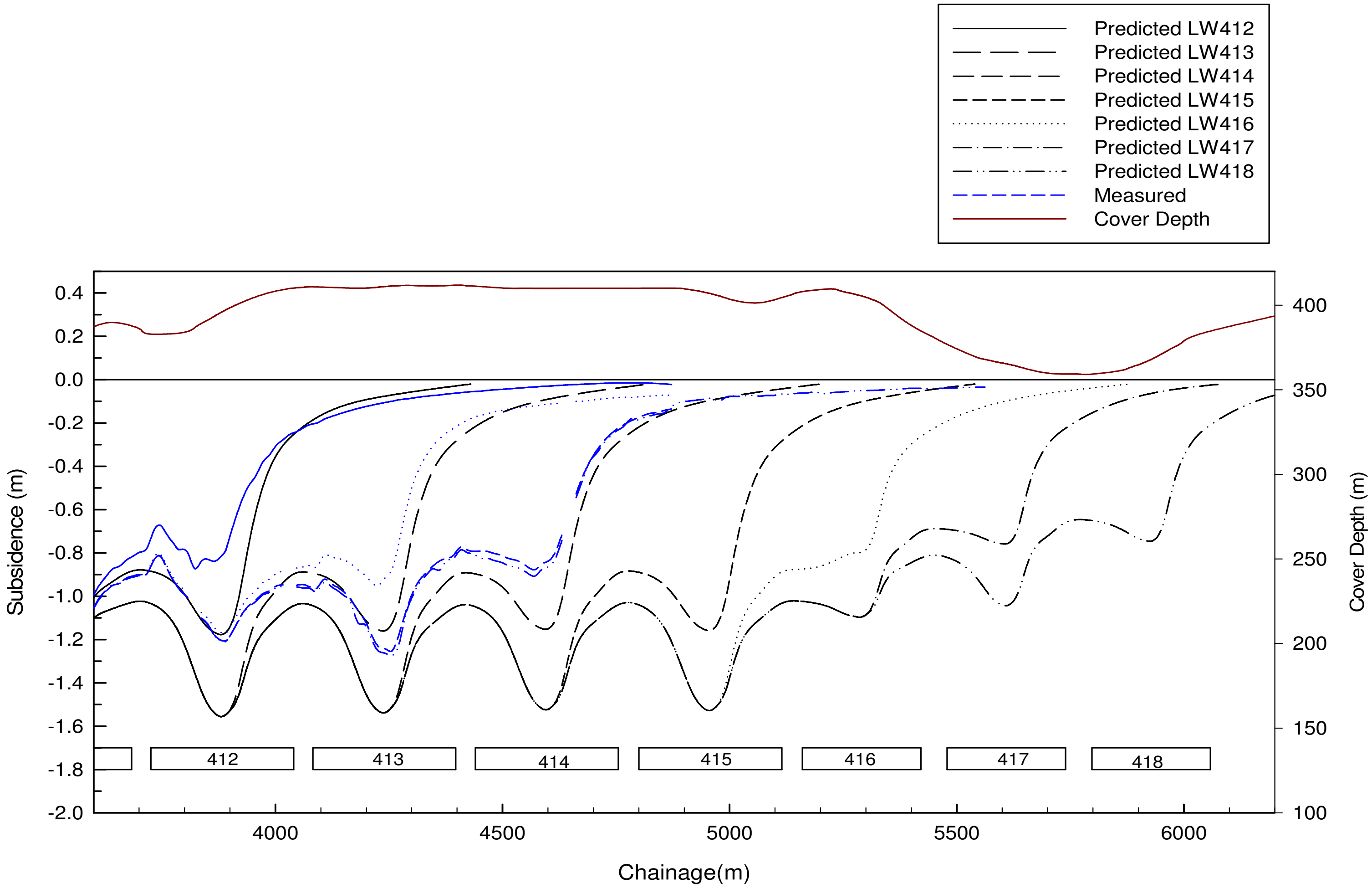
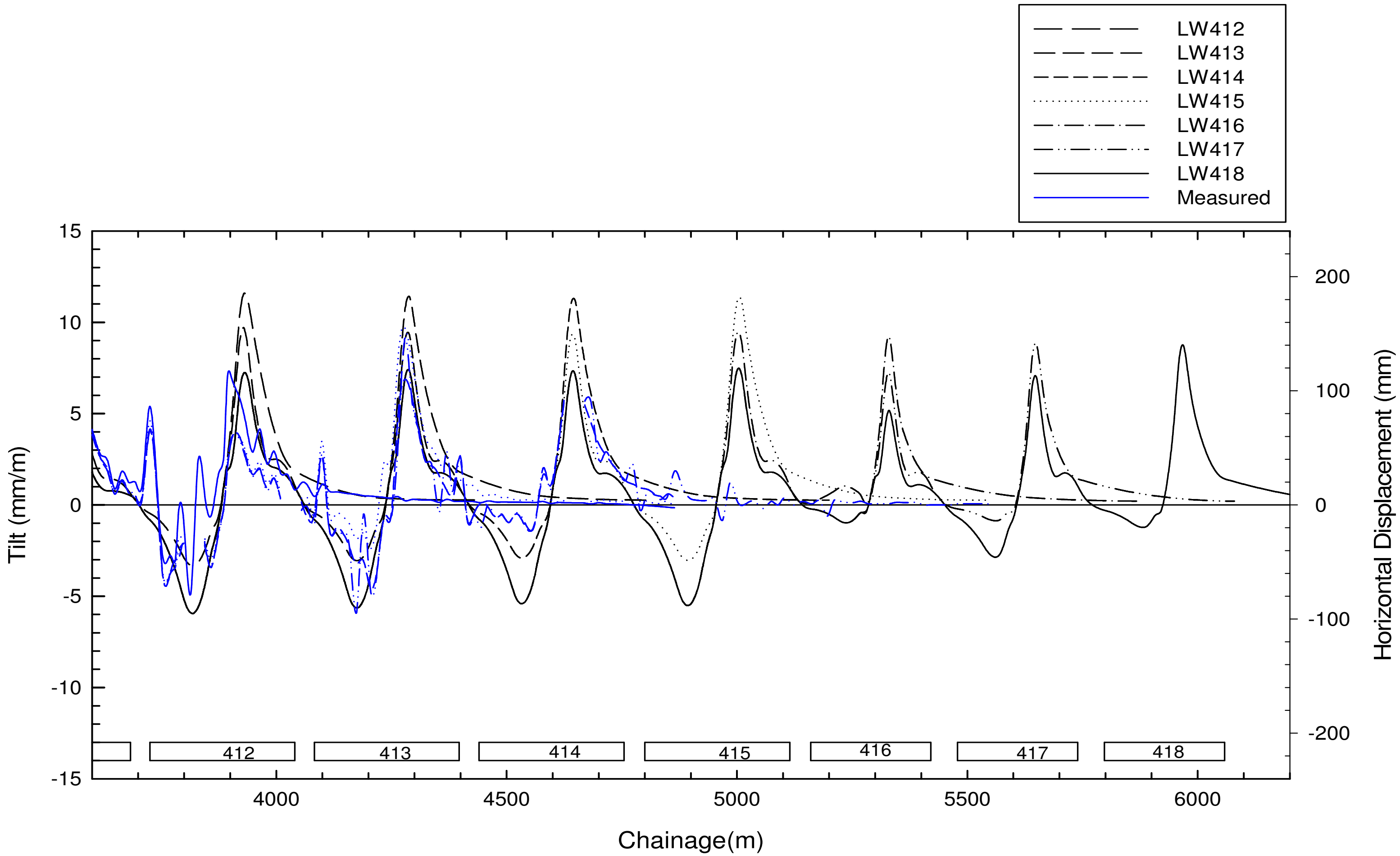


DgS	Engineer: S.Ditton	Client:	Centennial Springvale Colliery SPV-003/6
	Drawn: S.Ditton		
	Date: 10.04.13	Title:	Crossline B Predicted U95%CL Subsidence Profiles for LWs 412-418
	Ditton Geotechnical Services Pty Ltd	Scale:	NTS — Figure No: A2.1



DgS	Engineer: S.Ditton		Client:	Centennial Springvale Colliery
	Drawn: S.Ditton			SPV-003/6
	Date: 10.04.13		Title:	Crossline B Predicted U95%CL Tilt and Horizontal Displacement Profiles for LWs 412-418
	Ditton Geotechnical Services Pty Ltd		Scale:	NTS
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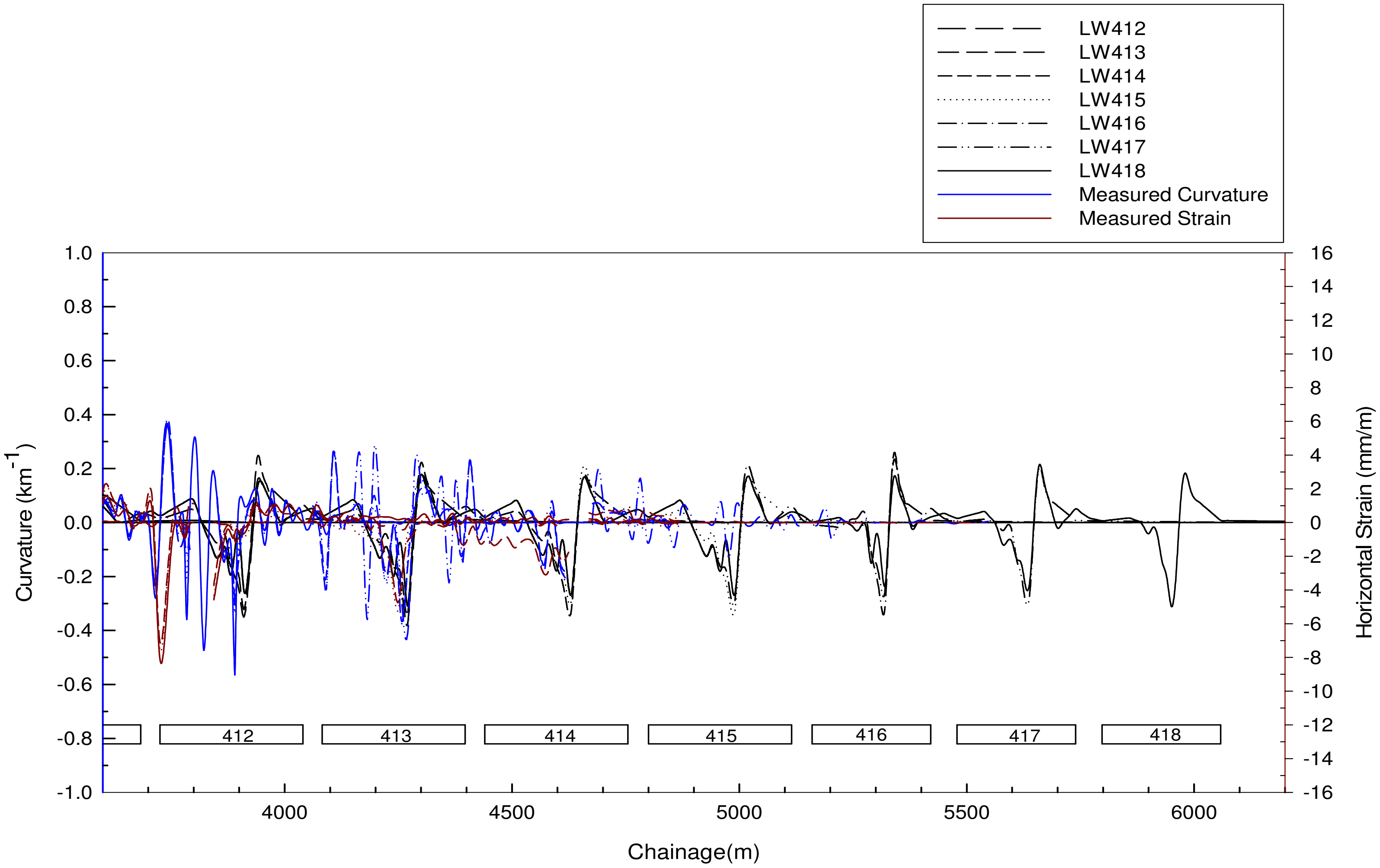
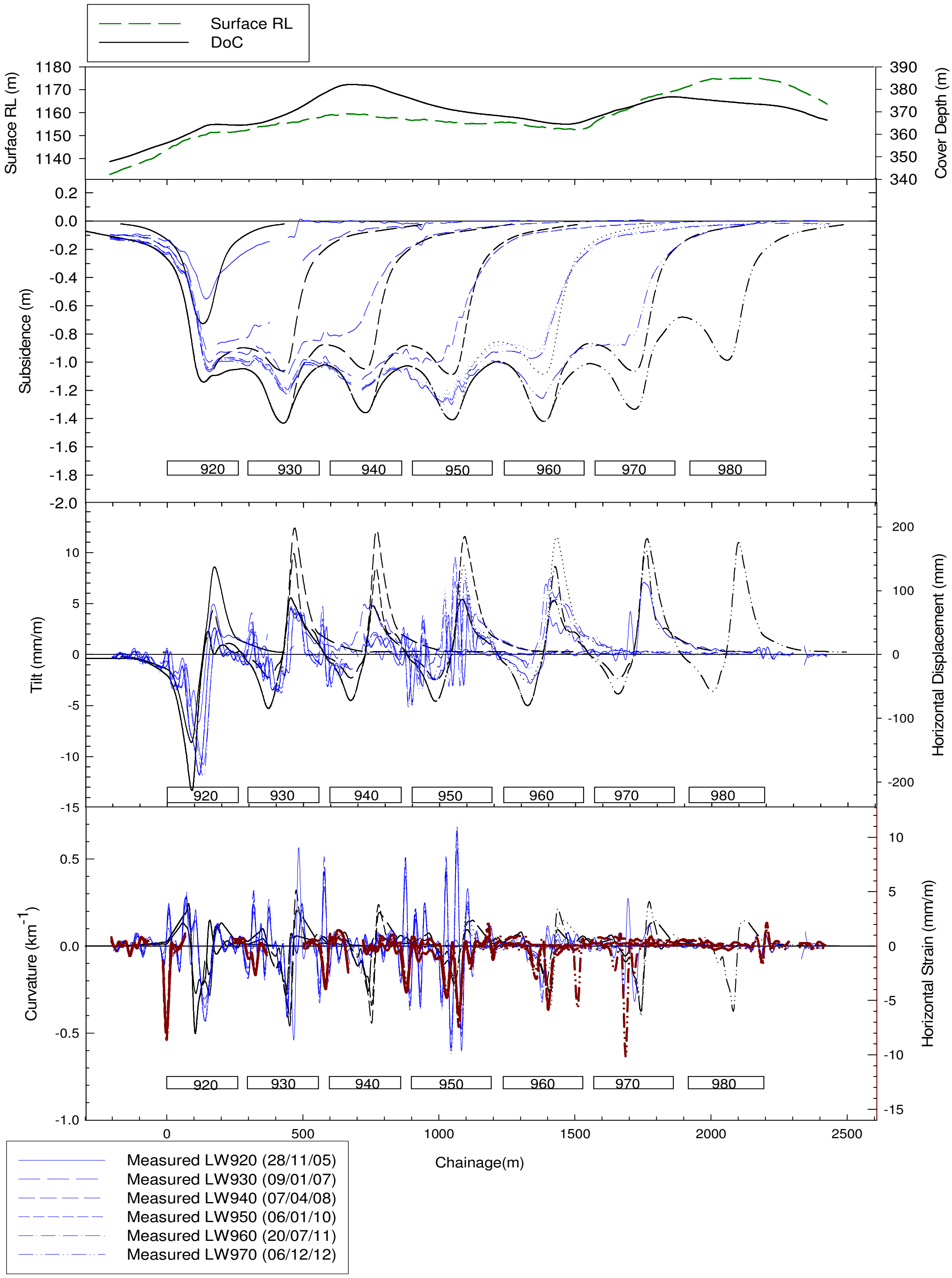


DgS	Engineer: S.Ditton	Client: Centennial Springvale Colliery SPV-003/6		
	Drawn: S.Ditton			
	Date: 10.04.13	Title: Crossline B Predicted U95%CL Curvature and Horizontal Strain Profiles for LWs 412-418		
	Ditton Geotechnical Services Pty Ltd	Scale: NTS	Figure No:	A2.3



DgS	Engineer:	S.Ditton	Client:	Springvale Colliery		
	Drawn:	S.Ditton		SPV-003/6		
	Date:	13.05.13	Title:	Crossline B Subsidence Data v. Predicted		
	Ditton Geotechnical			Profiles for LWs 920-970 at Angus Place Colliery		
	Services Pty Ltd		Scale:	NTS	Figure No:	A3