Strata Control Technology

REPORT TO:

ASHTON COAL OPERATIONS LTD

Subsidence Assessment for Upper Liddell Seam, Longwalls 1-8 Extraction Plan

ASH3657

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SUBJECT Subsidence Assessment for Upper Liddell Seam, Longwalls 1-8 Extraction Plan

REPORT NO ASH3657

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SUMMARY

Ashton Coal Operations Ltd (ACOL) is proposing to mine Longwalls 1-8 in the Upper Liddell Seam as part of their ongoing operations near Camberwell in the Hunter Valley. In accordance with the development consent DA 309-11-2001, ACOL is preparing an Extraction Plan (EP) addressing secondary extraction of these longwall panels. ACOL commissioned SCT Operations Pty Ltd (SCT) to undertake a subsidence assessment describing the impacts expected from the proposed mining suitable for submission with the EP. This report presents the results of our assessment of the subsidence impacts for the proposed mining of Longwalls 1-8 in the Upper Liddell Seam (ULD) for the Ashton Coal Project (ACP).

Longwall mining in the Pikes Gully (PG) Seam is ongoing in the area of this assessment and although subsidence associated with mining in the PG Seam is not the focus of this assessment, the cumulative effects of mining both seams has nevertheless been taken into account where relevant. Our assessment also recognises the challenges of estimating subsidence behaviour in a multi-seam environment because of the limited history of multi-seam subsidence experience in NSW and elsewhere.

ACOL propose to adopt an offset geometry whereby the longwall panels in the ULD Seam are offset to the west by 60m relative to the previously mined panels in the PG Seam. This practice is common in multi-seam longwall operations to optimise mining conditions in the second seam mined. The offset geometry also tends to reduce the magnitude of subsidence induced strains and tilts while extending the subsidence footprint of each panel mined out to the boundaries of the adjacent panels in the overlying seams.

The approach used for estimating maximum subsidence where longwall panels overlap in two seams is based on empirical experience reported by Li et al (2010). This experience indicates maximum subsidence is unlikely to exceed 85% of the combined thickness of the two seams mined. Maximum strains and tilts are estimated on the basis of the maximum subsidence using empirical experience for single seam mining (Holla 1991).

This approach is considered to be generally conservative with maximum incremental subsidence associated with mining the ULD Seam expected to be typically 2.4-2.5m but range up to 3.4m in areas where the nominal ULD extraction thickness is greater and destabilisation of the PG Seam pillars is expected to cause additional subsidence from the PG Seam.

The cumulative maximum subsidence from mining in both seams is expected to be typically less than 4.0m but up to 4.5m in the vicinity of Longwall 7B and Longwall 8 due to the thicker ULD Seam in this area.

The estimates of incremental and total cumulative subsidence are as follows:

Seam	Incremental Subsidence From Mining ULD Seam (m)	Incremental[2] Max Tilt (mm/m)	Incremental[2] Max Strain (mm/m)	Maximum Subsidence (85% of Combined Seam Thickness)(m)	Max Tilt (mm/m)	Max Strain (mm/m)
LW1	2.9	183	73	4.4	235	94
LW2	2.5	139	55	4.0	189	76
LW3	2.5	119	48	4.0	162	65
LW4A	2.4	93	37	3.9	128	51
LW4B	2.4	110	44	3.9	151	60
LW5	2.5	76	30	4.0	103	41
LW6A	2.5	73	29	4.0	100	40
LW6B	2.8	101	41	4.3	132	53
LW7A	2.5	66	26	4.0	89	36
LW7B	3.0	91	36	4.5	116	47
LW8	3.4[1]	98	39	4.4	107	43

[1] The incremental subsidence is expected to be larger in areas where narrow panels in the PG Seam are destabilised by mining in the ULD Seam.
[2] The estimates for incremental tilts and strains are regarded as only generally indicative because the empirical database of experience of mining two seams is currently very limited.

These subsidence estimates are higher than previous estimates of subsidence associated with mining the PG and ULD Seams presented in the EIS (2.7m to 3.4m) and in the 2009 SCT Report ASH3584 (3.7m). The increase is partly due to differences in geometry and an increase in the seam thickness proposed to be mined, but primarily because a more conservative approach has been taken in this current assessment to estimating the maximum subsidence for impact assessment purposes given the results presented by Li et al (2010) for multi-seam subsidence.

Based on these levels of subsidence and previous experience in single seams, maximum incremental tilts of up to 180mm/m are expected in the east and up to 100mm/m in the west. Maximum incremental strains are expected to range up to 70mm/m in the shallower eastern areas and 30-40mm/m in the deeper western areas. Maximum strains and tilts are expected to be sensitive to the relative positions of goaf edges in the two seams.

The detail of the interaction of chain pillars and longwall panels in two seams has been estimated using numerical modelling of the proposed multi-seam layout (SCT 2011). This approach does not yield subsidence values as high as empirical observations reported by Li et al (2010) consistent with the nature of empirical approaches. For the purposes of this assessment, the maximum cumulative subsidence indicated by numerical modelling has been scaled to 85% of the combined seam thickness mined to provide consistency. This approach is considered to be conservative, but has been adopted as suitable for impact assessment purposes in the absence of site specific subsidence data for multi-seam mining.

Numerical modelling indicates that, whereas in a single seam operation subsidence movements are primarily limited to within the area of the longwall panel being mined, multiple seam subsidence may extend outside the boundary of the mined ULD panel to the goaf edge of longwall panels in the overlying PG Seam.

Estimates of subsidence behaviour above panel extensions where only the ULD Seam is mined, such as above Property 130, are based on the previous subsidence monitoring at ACP in the PG Seam and general experience of subsidence behaviour for single seam extraction in the Hunter Valley and elsewhere. Maximum subsidence over the centre of the longwall panel is expected to be less than 1.6m with maximum strain of 30mm/m and maximum tilt of 70mm/m. These estimates are expected to have similar accuracy to single seam subsidence estimates previously presented for the ACP.

The proposed mining is located in an area between Glennies Creek and the western side of the Bowmans Creek flood plain. This area is predominantly open grazing land owned by ACOL. The north western corner of the area is owned by Macquarie Generation (MacGen) and the south eastern area is privately owned and operated as a dairy farm referred to as Property 130.

ACOL have approval to divert sections of Bowmans Creek to allow for more efficient resource recovery of Longwalls 6 to 8. The maximum total subsidence below the alignment of the proposed diversion of Bowmans Creek is expected to be less than 0.1m and in most areas less than 20mm.

Notwithstanding the low levels of subsidence expected at the diversion, nearby subsidence of up to an estimated 4.5m at the completion of mining in the ULD Seam is expected to leave the creek diversion elevated above parts of the original creek bed and areas of the flood plain. Rainfall runoff in the vicinity of the original creek bed and water that overtops Bowmans Creek during a flood event is expected to flow to the lowest point in the landform and pool there. The disturbance to the overburden strata caused by the subsidence may provide sufficient hydraulic connection between the surface and the mine for some of this pooled water to flow down into the mine. The potential for this inflow is addressed by Aquaterra (2009) in their Bowmans Creek Diversion: Groundwater Impact Assessment Report (and the report being prepared for submission with the EP).

Design of the creek diversion includes some provisions to assist in draining sections of the excised creek channels and SCT understands that filling of subsidence troughs and reshaping of the subsided landform is to be undertaken in some areas to maintain a free-draining landform. This work is expected to reduce inflows into the mine from the areas that are filled or reshaped.

Other natural features likely to be impacted by the proposed mining include two remnant woodlands, one a Voluntary Conservation Area located immediately north of the Property 130 boundary, and the other alongside a tributary of Bowmans Creek near the middle of Longwall 4. Both areas are understood to include sites containing Aboriginal artefacts and nesting sites for native birds, including threatened species. SCT understand that subsidence impacts associated with archaeological heritage sites and impacts on natural flora and fauna are addressed in separate reports. Except for a specific assessment of the potential for subsidence impacts on the grinding groove site, an assessment of potential impacts on archaeological and flora and fauna sites has not been included in this report. The proposed mining is not expected to perceptively impact the grinding groove site.

Surface infrastructure not owned by ACOL that is expected to be significantly impacted by the proposed mining includes an AusGrid 132kV electricity transmission line that crosses the southern end of the mining area, a proposed 11kV electricity transmission line that is yet to be constructed but follows the same alignment, a soon to be constructed section of the Lemington Road diversion around the Ravensworth North Project that follows the line of an existing section of Brunkers Lane, and a 33kV electricity line in the same area.. This infrastructure is expected to require significant monitoring, mitigation and remediation effort.

A MacGen gas pipeline easement crosses the northern end of the proposed mining area. SCT understands that there are currently no immediate plans to use this easement and if the pipeline were constructed it would be integrated with the ACP gas drainage network, which is designed to accommodate subsidence movements.

Other surface infrastructure not owned by ACOL that is expected to be impacted by subsidence or subsidence mitigation words but is more easily managed includes several local electricity transmission lines, the access road to Property No 130 used daily by a milk tanker and the property residents, farming infrastructure on Property 130 such as contour drains, fences, water troughs, buried water pipes, and tracks, buried Telstra cables used primarily for servicing Property 130 and ACOL owned houses, mining infrastructure in the northwest corner of the mining area including mine water supply and waste disposal pipes and access roads, and a gauging station on Bowmans Creek.

Ravensworth Underground Mine (RUM) owned by Xstrata is planning a multi-seam underground longwall operation that shares a lease boundary with the ACOL lease and includes the No 5 Ventilation Shaft. The stability of roadways and main heading pillars at RUM located next to this lease boundary is not expected to be affected by the proposed mining based on SCT's understanding of the proposed pillar geometries. The No 5 Ventilation Shaft is located 150m from the Longwall 8 goaf edge and may experience low level lateral shearing as a result of the proposed mining but this movement is not expected to compromise the serviceability of the shaft. There is some potential for mine water that may pond in the ACP underground mine to flow through the barrier into RUM either during operations at ACP or subsequently.

Infrastructure in the area not owned by ACOL but which is not expected to be significantly impacted by subsidence includes the New England Highway and bridge over Bowmans Creek, the 132kV and 66kV electricity transmission lines that run alongside the New England Highway, including a proposed diversion of this line around a South East Opencut (SEOC) Project, a buried fibre optic cable alongside the highway, Narama Dam, the residence and farm buildings on Property 130, and a proposed 330kV electricity line to be constructed on the barrier between RUM and ACP Longwall 8.

ACOL owned infrastructure that is expected to be impacted by the proposed mining includes access roads, 11kV electricity lines, farm dams, several residences, farm buildings, and buried water supply pipes. Potential impacts on ACOL infrastructure have not been assessed in detail in this report but existing management plans for the PG Seam are expected to be appropriate for managing the subsidence impacts on ACOL infrastructure associated with proposed mining in the ULD Seam.

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1. INTRODUCTION

Ashton Coal Operations Ltd (ACOL) is proposing to mine Longwalls 1-8 in the Upper Liddell (ULD) Seam as part of their ongoing operations near Camberwell in the Hunter Valley. In accordance with the development consent modification DA 309-11-2001, ACOL is preparing an Extraction Plan (EP) addressing secondary extraction of these longwall panels. ACOL commissioned SCT Operations Pty Ltd (SCT) to undertake a subsidence assessment describing the impacts expected from the proposed mining suitable for submission with the EP being prepared on their behalf by AECOM Australia Pty Ltd. This report presents the results of our assessment of the subsidence impacts for the proposed mining of Longwalls 1-8 in the ULD Seam for the Ashton Coal Project (ACP).

1.1 Scope of Works

The key objective of this report is to enable the EP to meet the requirements outlined in Section 3.12 (e) of the Development Consent. Specifically:

3.1.2 (e) provide revised predictions of the potential subsidence effects, subsidence impacts, and environmental consequences of the proposed second workings, incorporating any relevant information obtained since this consent.

This report is structured to provide:

1. A description of the general area including the proposed mining geometry, overburden depth and other parameters of relevance to a subsidence assessment.

2. Subsidence estimates based on the previous subsidence monitoring at the mine and reported experience of multi-seam subsidence.

3. Identification of surface features likely to be impacted by subsidence and specific assessments of the likely subsidence impacts on each of the features identified, particularly where these have not been assessed previously or the subsidence impacts from mining in the ULD Seam are significantly greater.

4. Recommendations for subsidence monitoring to take advantage of the opportunities provided by this multi-seam mining geometry.

2. EXISTING ENVIRONMENT

The proposed mining area is predominantly cattle grazing land located between Glennies Creek and the western side of the Bowmans Creek flood plain. The area is predominantly owned by ACOL and much of it has previously been subsided by mining in the Pikes Gully (PG) Seam. The southeast corner of the area includes a privately owned dairy farm (Property 130). The northwest corner of the area includes a triangle of land owned by Macquarie Generation that fringes the now completed and backfilled Ravensworth East Open Cut Mine.

The major natural features in the area include:

- Bowmans Creek which lies within the proposed mining area and directly over several panels until the Bowmans Creek diversion is completed.
- The Hunter River to the south outside the proposed mining area.
- Glennies Creek to the east of Longwall 1 and outside the mining area.

The major infrastructure within the general area includes:

- The New England Highway and associated road reserve in the north including a bridge over Bowmans Creek. Main headings extend under the highway and road reserve. The longwalls are located well outside the road reserve.
- A buried fibre optic cable alongside the highway.
- Various electricity lines:
    - A 132kV line and a combined 66kV and 11kV line alongside the New England Highway.
    - A 132kV line that traverses the southern end of the proposed mining area.
    - A 33kV line adjacent to Brunkers Lane servicing Ravensworth Operations.
- Narama Dam, a Dams Safety Committee prescribed dam, located west of the proposed mining area. The dam itself is located well outside the proposed mining area, but the DSC notification area extends into the proposed mining area.

Other infrastructure within the general area not owned by ACOL includes:

- Several local electricity transmission lines.
- Flow gauging station on Bowmans Creek operated by NSW Office of Water.
- Brunkers Lane and a private road that provides secondary access to MacGen land as well as access to Ravensworth Open Cut Mine Ravensworth Opencut.
- Private access road to Property No 130 used daily by a milk tanker and the property residents.
- Farming infrastructure on Property 130 such as contour drains, fences, water troughs, buried water pipes, and tracks.

- Buried Telstra cables servicing Property 130 and Ravensworth Operations.

- A large diameter polyline understood to carry mine water from Narama Dam to Mt Owen Mine.

- A system of MacGen sediment control dams in the northwest corner of the mining area and associated drainage paths.

Other non ACOL owned infrastructure that is yet to be constructed but is likely to be impacted by the proposed mining includes:

- The Lemington Road diversion around the Ravensworth North Project that follows the current alignment of Brunkers Lane within the proposed mining area.

- An 11kV electricity transmission line that is proposed to follow the same alignment as the 132kV line in the southern part of the mining area (to be constructed as part of the ACOL proposed South East Open Cut (SEOC) project).

- A proposed relocation for the SEOC project of the existing 66kV and 132kV electricity line located around the northern and north eastern perimeter of the proposed mining area.

- Diversion of the 330kV transmission line around the Ravensworth North Project immediately west of the proposed mining area.

- A MacGen gas pipeline that crosses Longwalls 6B, 7B and 8. The easement for this exists, but there are currently no immediate plans to construct this pipeline.

- Ravensworth Underground Mine (RUM) located west of ACP and also proposing to mine four seams. This mine development includes the No 5 Ventilation Shaft located west of the proposed mining area.

- The Void 5 Dam, a DSC prescribed dam proposed to be constructed by MacGen and located at the eastern end of Void 5. The dam is located well outside the proposed mining area, but the DSC notification area extends into the proposed mining area.

ACOL owned infrastructure within the proposed mining area includes several farm buildings and houses, farm dams, farm roads, fences, a fresh water polyline from the Hunter River, the mine pump out polyline from the southern end of the panels, four polylines (for the transfer of tailings and decant water return) that pass under the New England Highway below the bridge over Bowmans Creek, ventilation shafts, and a coal seam gas drainage network.

2.1 Existing Consents

ACOL was granted development consent on 11 October 2002 by the Minister for Planning pursuant to the provisions of the *Environmental Planning and Assessment Act 1979 (NSW)*. ACOL's consent for underground mining includes a series of longwall panels, oriented in a north-south direction. The operation is approved as a multi-seam operation although this assessment report only relates to mining in the ULD Seam.

2.2 Proposed Mining

Figure 1 shows a plan of the proposed mining area superimposed onto a 1:25,000 topographic series map (updated with a diversion to the New England Highway, the proposed Bowmans Creek diversion, and other changes to minor roads since the map was produced in 1982). The existing and proposed mining in the PG Seam is shown in red and the proposed mining in the ULD Seam is shown in black.

Figure 2 shows the proposed mining layout superimposed onto a topographic plan showing more detail of recent changes in surface infrastructure. Individual mine roadways have been omitted for clarity in the PG Seam.

Figure 3 shows more detail of existing and proposed infrastructure and contours of overburden depth.

Table 1 summarises the panel dimensions for Longwalls 1-8 in the ULD Seam and representative seam thicknesses in the two seams. Figure 4 shows the thickness of the ULD Seam ranging from 2.2m to greater than 3m. The actual mining height is expected to range from 2.5m to 3.0m.

The ULD is approximately 30m below the floor of the PG Seam (27m at the location of Borehole WMLC235 E317667, N6405619).

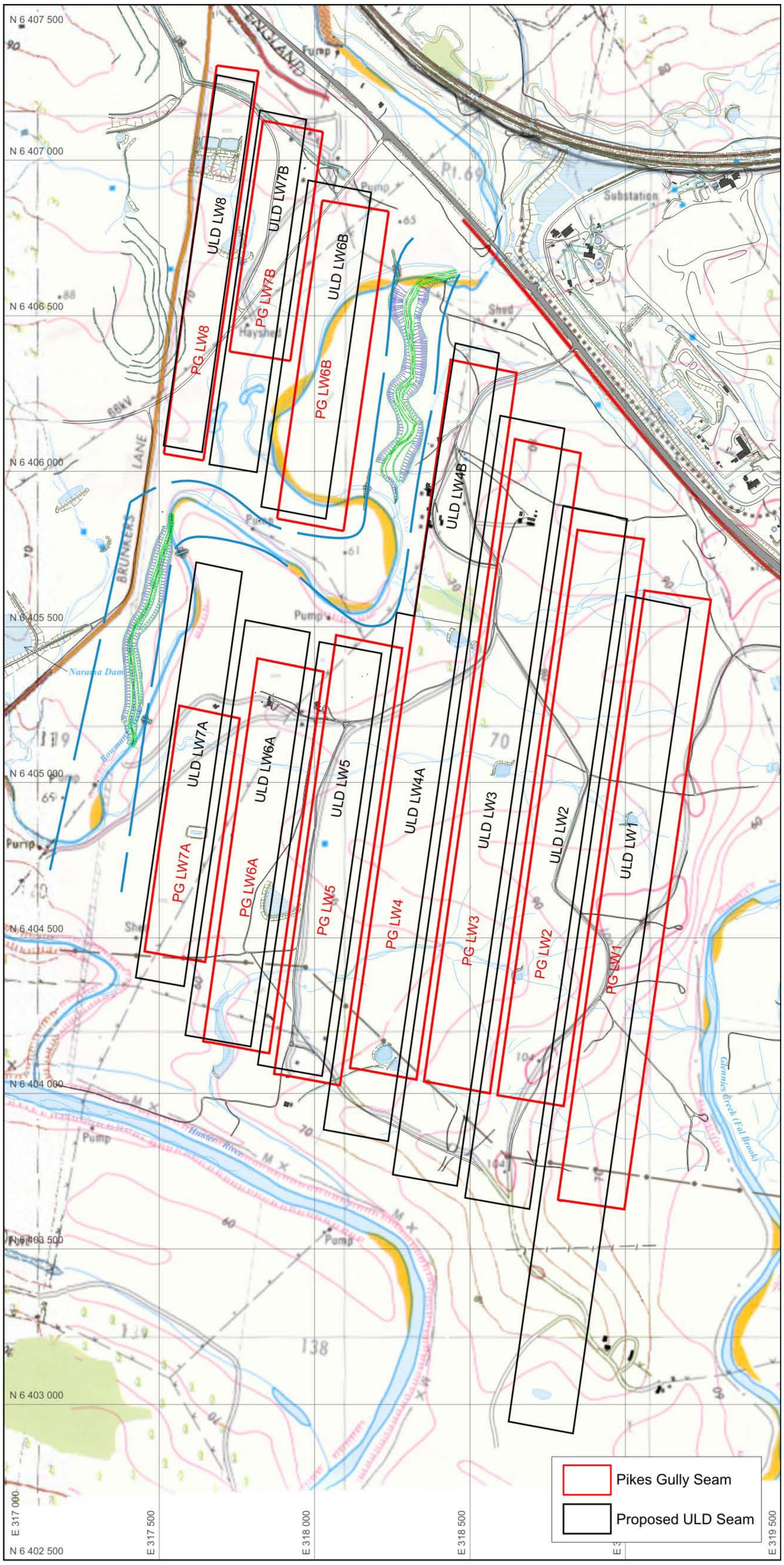

Figure 1: Mining layout in the Pikes Gully Seam and proposed mining layout in the ULD Seam superimposed onto a 1:25,000 topographic series map (1982) updated with more recent infrastructure.

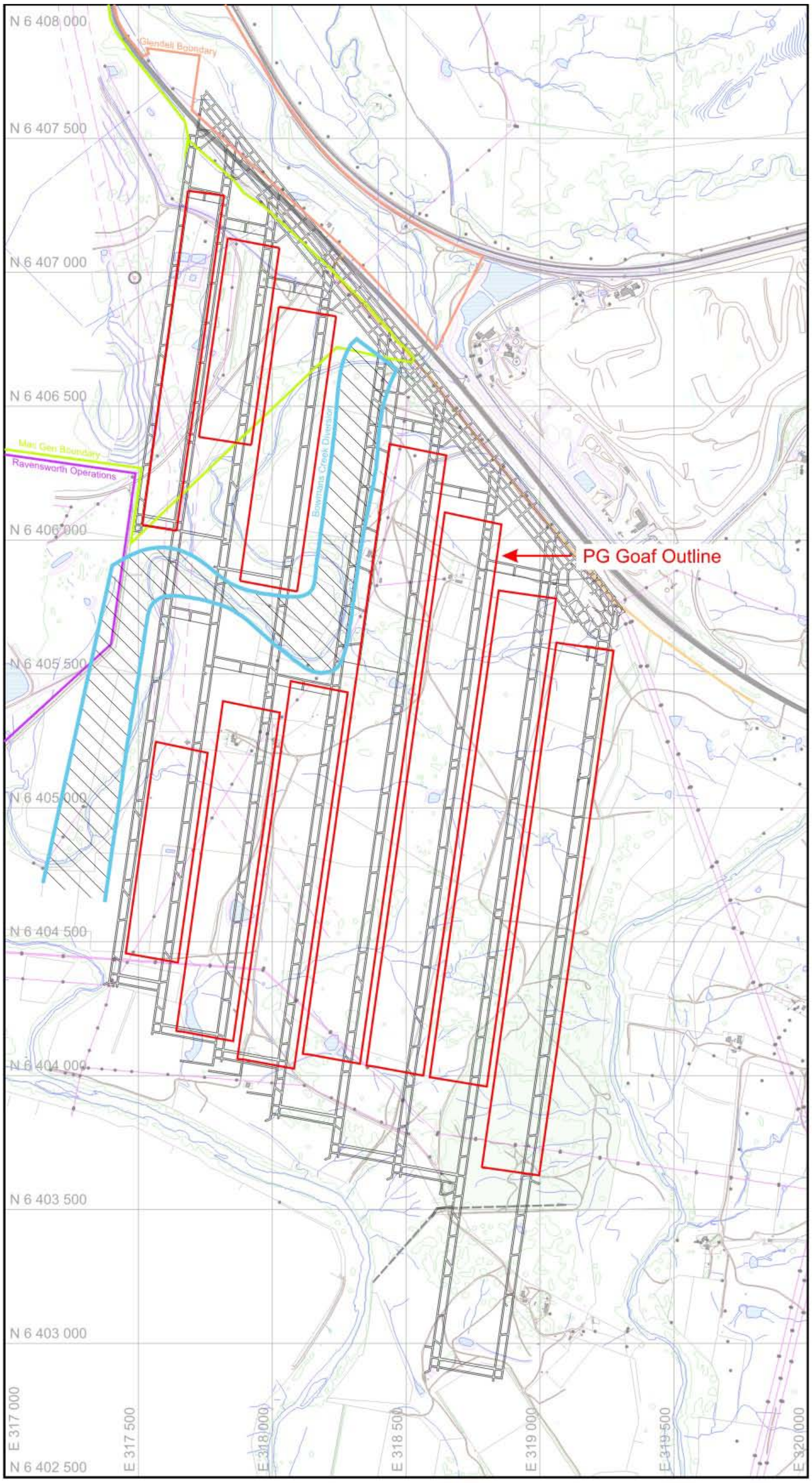

Figure 2: Proposed ULD Seam Mine Layout with Surface Infrastructure and Topographic Detail.

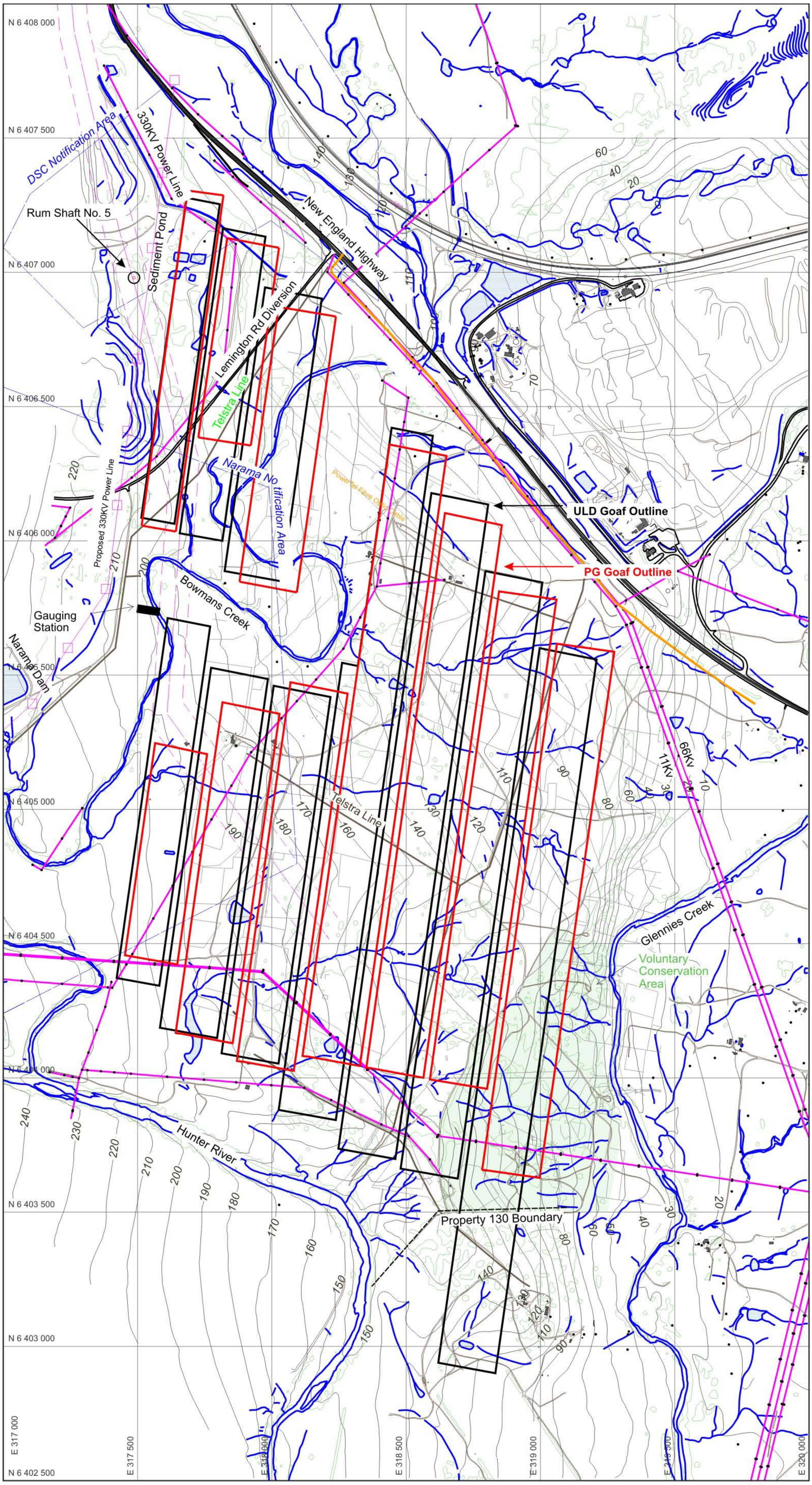

Figure 3: Detail of Surface Infrastructure and overburden depth to ULD Seam.

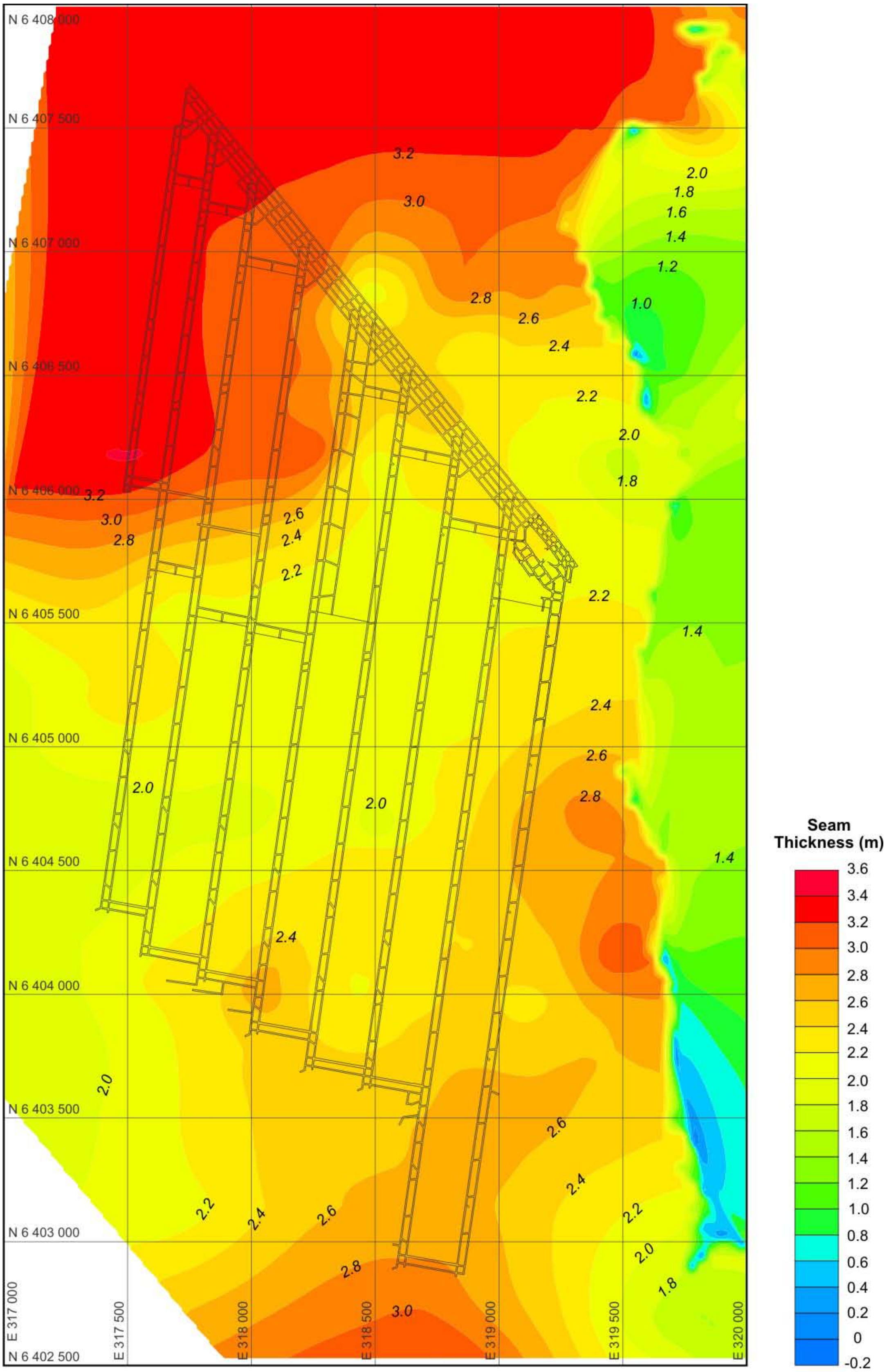

Figure 4: Upper Liddell Seam thickness.

Table 1: Proposed Geometries of Longwalls 1-8 in ULD Seam

Panel	MG Pillar Width Rib to Rib (m)	Overburden Depth to PG Seam (ULD Seam +30m) (m)	LW Void Width (outside rib to rib) (m)	Representative PG Seam Thickness (m)	Representative ULD Seam Thickness (m)
LW1	25	80-110	216	2.7	2.5
LW2	25	90-120	216	2.5	2.2
LW3	25	105-135	216	2.5	2.2
LW4A	25	130-155	216	2.4	2.2
LW4B	85	110-130	156	2.4	2.2
LW5	25	165-175	216	2.5	2.2
LW6A	25	170-185	216	2.5	2.2
LW6B	25	140-165	216	2.3	2.8
LW7A	25	190-210	161	2.5	2.2
LW7B	25	165-185	161	2.5	2.8
LW8	25	175-205	126	2.2	3.0

3. PREVIOUS SUBSIDENCE MONITORING AND PREDICTED SUBSIDENCE BEHAVIOUR

This section outlines previously observed subsidence associated with the PG Seam, as well as revised subsidence estimates for the ULD Seam based on the offset mining geometry proposed and revised estimates of the seam thickness to be mined.

Longwall mining in the PG Seam is ongoing in the area of this assessment and although subsidence associated with mining in the PG Seam is not the focus of this assessment, previous subsidence monitoring results from Longwall 1-6A in the PG Seam are presented to illustrate the subsidence behaviour that has so far been measured at the ACP. The effects of previous mining need to be considered in circumstances where impacts are cumulative.

For infrastructure that has been repaired, replaced or has yet to be constructed, only the incremental subsidence associated with mining in the ULD Seam, including any interaction effects, is relevant to the assessment of future impacts.

For most natural features and some types of infrastructure, the cumulative effect of mining in both seams is important.

In this section, both the incremental subsidence associated with mining only the ULD Seam (including any interaction effects with the PG Seam), and the cumulative subsidence associated with mining both seams are considered and presented.

The subsidence predictions presented in this report are different in some areas to those made in SCT Report ASH3584 for a stacked mining geometry. This difference is primarily a result of refinement of the seam thicknesses planned to be mined in the PG and ULD Seam and variations in subsidence associated with an offset mining geometry.

There has been no prior experience at ACP of mining two seams and the experience of mining two seams anywhere in NSW is currently limited to only a few mines. The confidence that can be placed in subsidence estimates is therefore somewhat lower than has been customary for subsidence estimates for single seam mining. However, the proposed mining at ACP will provide a strong basis for estimating surface subsidence because of the regular geometries involved in both the PG Seam and the ULD Seam.

A conservative approach has been adopted for estimating subsidence in both the stacked geometry previously and the offset geometry assessed in this report. More accurate estimates of the actual subsidence behaviour are anticipated in future, with lower values of subsidence expected, once results of subsidence monitoring become available from the first few ULD Seam longwall panels mined below existing longwall panels in the PG Seam.

3.1 Summary of Previous Subsidence Monitoring

Subsidence monitoring has been undertaken at ACP since the commencement of longwall operations in early 2007. The subsidence behaviour observed above single seam operations in the PG Seam is consistent with supercritical width subsidence and with the subsidence behaviour expected. Figure 5 shows the locations of subsidence lines that have been monitored over Longwalls 1-6. The maximum subsidence parameters are summarised in Table 2.

Figure 6 summarises the subsidence measured on the main cross line XL5 at the completion of each of the first six longwall panels. The vertical subsidence profiles shown in Figure 6 are consistent with supercritical width subsidence behaviour where full subsidence occurs in the central part of each panel and relatively low levels of subsidence are observed over the chain pillars between panels. The maximum vertical subsidence measured is less than the 1.6-1.8m predicted. Measured tilt and strain values are generally within the range predicted although there are several locations where locally higher strains and tilts have been observed. These anomalies are a consequence of ground movements that are not possible to predict using conventional subsidence estimation techniques.

Table 2: Measured Subsidence Over Longwalls 1 to 6A

	Predicted EIS	**Predicted SMP**	**Maximum Measured**			
North End of LW1			**CL2**	**XL8**		
Subsidence (mm)	1430	1800	1528	1500		
Tilt (mm/m)	122	244	100	103		
Horizontal Movement (mm)	-	>500	476	500		
Tensile Strain (mm/m)	16	73	40	15		
Compressive Strain (mm/m)	25	98	28	27		
Remainder of LW1			**CL1**	**XL5**		
Subsidence (mm)	1690	1700	1318	1436		
Tilt (mm/m)	60	141	60	75		
Horizontal Movement (mm)	-	300-500	480	503		
Tensile Strain (mm/m)	8	42	49	17		
Compressive Strain (mm/m)	12	56	23	24		
Longwall 2			**CL1**	**CL2**	**XL5**	
Subsidence (mm)	1690	1600	1296	1513	1266	
Tilt (mm/m)	91	102	40	82	78	
Horizontal Movement (mm)	-	300-500	440	298	390	
Tensile Strain (mm/m)	12	30	17	16	11	
Compressive Strain (mm/m)	18	41	16	32	28	
Longwall 3			**CL1**	**CL2**	**XL5**	
Subsidence (mm)	1500	1600	1420	1354	1429	
Tilt (mm/m)	65	78	41	48	97	
Horizontal Movement (mm)	-	300-500	463	345	394	
Tensile Strain (mm/m)	9	23	10	17	22	
Compressive Strain (mm/m)	13	31	7	18	24	
Longwall 4			**CL1**	**CL2**	**XL5**	**XL10**
Subsidence (mm)	1430	1600	1397	1194	1546	1263
Tilt (mm/m)	46	78	36	40	53	33
Horizontal Movement (mm)	-	300-500	230	560	360	258[1]
Tensile Strain (mm/m)	6	23	10	18	9	6
Compressive Strain (mm/m)	9	31	9	67	9	10
Longwall 5			**CL1**	**CL2**	**XL5**	
Subsidence (mm)	1430	1600	1266	1326	1376	
Tilt (mm/m)	29	67	23	29	35	
Horizontal Movement (mm)	-	300-500	399	339[2]	360	
Tensile Strain (mm/m)	4	20	21	6	5	
Compressive Strain (mm/m)	5	27	9	8	17	
Longwall 6A			**CL1**	**CL2**	**XL5**	
Subsidence (mm)	1430	1600	1400	1280	1360	
Tilt (mm/m)	29	57	18	25	39	
Horizontal Movement (mm)	-	300-500	0.28	0.25	0.32	
Tensile Strain (mm/m)	4	17	7	4	8	
Compressive Strain (mm/m)	5	23	7	9	9	

[1] XL10 was installed after some horizontal movement associated with the previous longwall may already have occurred so not all horizontal movements were measured.

[2] Maximum measured at end of line so actual maximum expected to be greater.

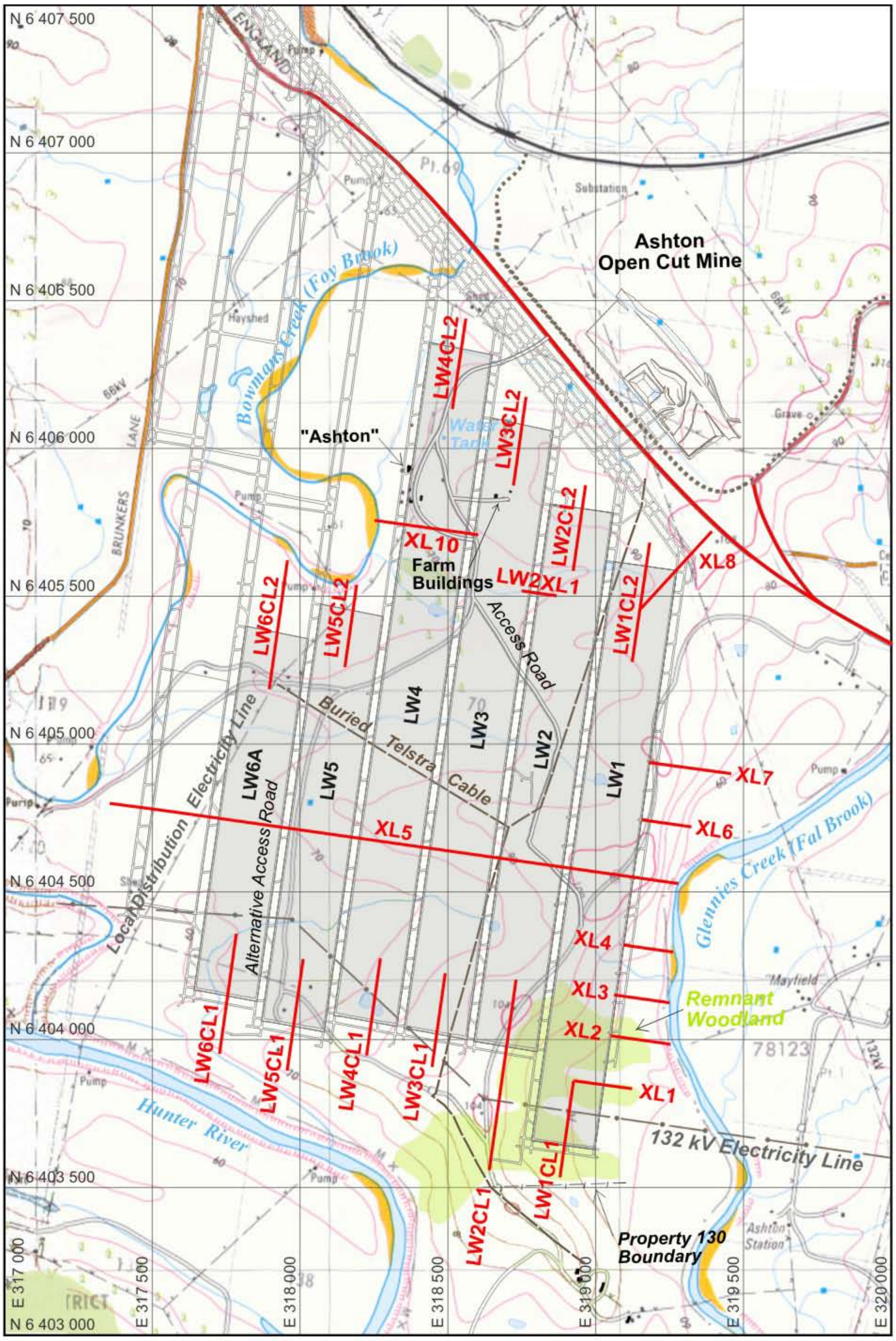

Figure 5: Site plan showing mine plan and location of the subsidence lines superimposed onto 1:25,000 topographic series map updated to reflect current infrastructure.

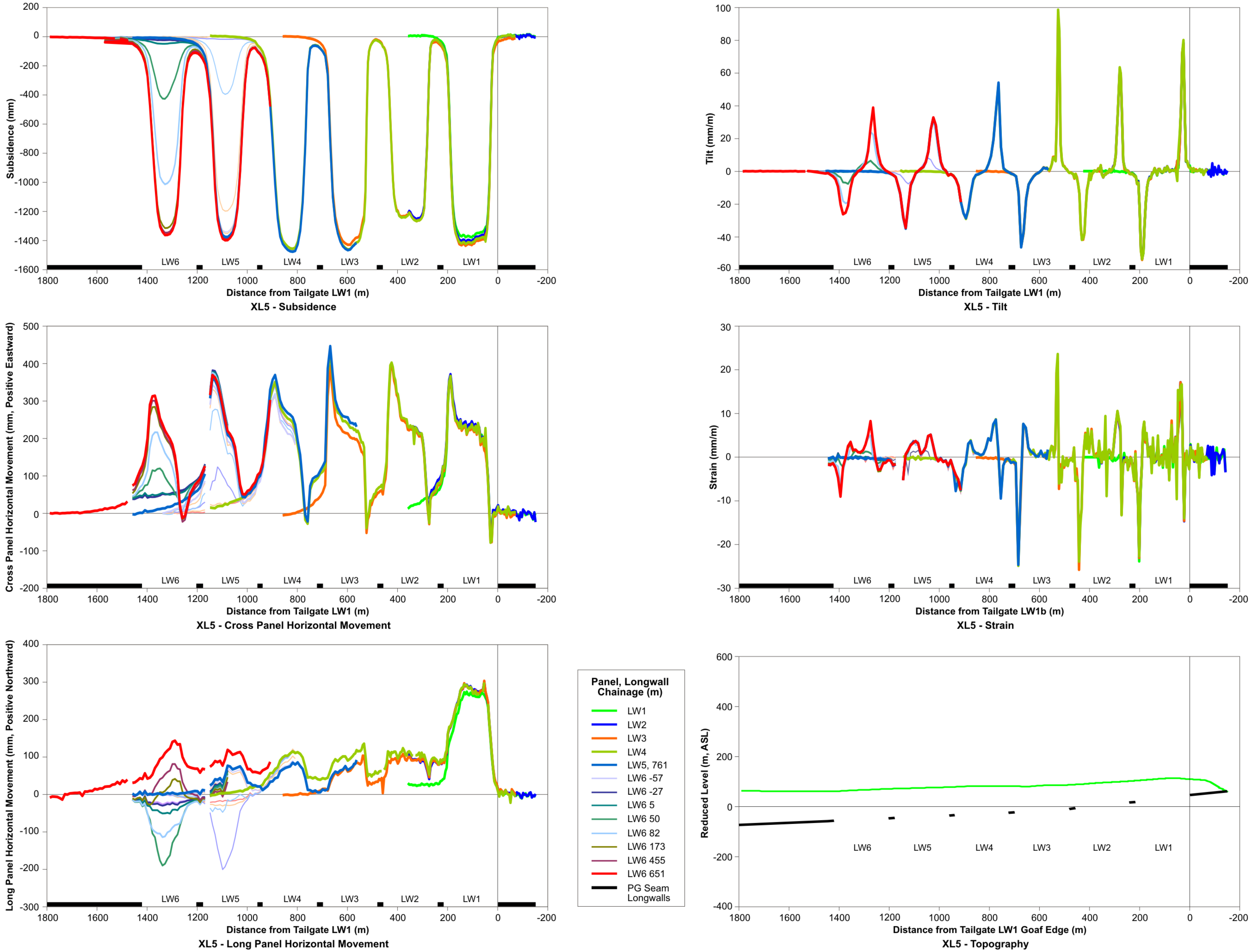

Figure 6: XL5 cross line subsidence to end of LW6A.

Approximately 200-250mm of eastward or upslope horizontal movement has been observed over all the previous longwall panels in the PG Seam. The mechanics of the processes causing horizontal movement at ACP are thought to be a result of the same lateral dilation that causes valley closure except that they are modified by the general dip of the strata to the west (SCT Report ASH3602).

Horizontal movements outside the longwall panels have been generally less than 100mm and decrease with distance from the goaf edge. Over the sides of each panel, horizontal movements are perceptible to a distance of up to 200m from the goaf edge. At the start of each of the panels, horizontal movements are observed to a distance of approximately 100m beyond the start line. At the finish of each panel, most of the ground movements occur within 50m of the goaf edge.

Maximum tilt measured to date has been 103mm/m and although there is a trend of generally decreasing tilt as the overburden depth increases, maximum tilt of 97mm/m was observed above Longwall 3 at an overburden depth of approximately 100m. In general, maximum tilts are more typically less than 70mm/m at overburden depths greater than about 70m.

Maximum strains also show a generally decreasing trend with increasing overburden depth and are generally less than 40mm/m at overburden depths greater than 70m, but a peak value of 67mm/m was observed over the finish of Longwall 4 at an overburden depth of approximately 80m and a high variability in maximum strain values is apparent.

Subsidence measurements at ACP show that the angle of draw increases with overburden depth. A 0° angle of draw is observed at about 60m overburden depth. The maximum angle of draw measured to date has been 29° over the western goaf edge of Longwall 5 where the overburden depth is approximately 145m, but this is expected to increase further with overburden depth.

Angle of draw has less significance in a multi-seam environment because of the influence of previous mining. The lateral extent of surface movements associated with mining in a lower seam is likely to be governed by the extent of the goaf in the overlying seam rather than by the characteristics of the overburden strata.

3.2 Subsidence Estimates

In this section, the subsidence estimates are presented in the form of subsidence contours, and in terms of maximum subsidence estimated for each panel. Indicative maximum strain and tilt estimates are also provided. The approach used for estimating maximum subsidence where longwall panels overlap in two seams is based on empirical experience reported by Li et al (2010). This experience indicates maximum subsidence is unlikely to exceed 85% of the combined thickness of the two seams mined. Maximum strains and tilts are estimated on the basis of the maximum subsidence using empirical experience for single seam mining (Holla 1991).

This approach is considered to be generally conservative with maximum incremental subsidence associated with mining the ULD Seam expected to by typically 2.4-2.5m but range up to 3.4m in areas where the nominal ULD extraction thickness is greater and destabilisation of the PG Seam pillars causes additional subsidence from the PG Seam. The cumulative maximum subsidence from mining in both seams is expected to be typically less than 4.0m but up to 4.5m in the vicinity of Longwall 7B and Longwall 8.

Based on these levels of subsidence and previous experience in single seams, maximum incremental tilts of up to 180mm/m are expected in the east and up to 100mm/m in the west. Maximum incremental strains are expected to range up to 70mm/m in the shallower eastern areas and 30-40mm/m in the deeper western areas. Maximum strains and tilts are expected to be sensitive to the relative positions of goaf edges in the two seams.

The detail of the interaction of chain pillars and longwall panels in two seams has been estimated using numerical modelling of the proposed multi-seam layout (SCT Report 3852). This approach does not yield subsidence values as high as empirical observations reported by Li et al (2010) consistent with the tendency for empirical approaches to provide an upper limit based on previous experience. For the purposes of this assessment, the maximum cumulative subsidence indicated by numerical modelling has been scaled to 85% of the combined seam thickness mined to provide consistency. This approach is considered to be conservative, but has been adopted as suitable for impact assessment purposes.

A significant characteristic indicated by numerical modelling is that, whereas in a single seam operation, subsidence movements are primarily limited to within the area of the longwall panel being mined, multiple seam subsidence may extend outside the boundary of the mined ULD panel to the goaf edge of longwall panels in the PG Seam.

Estimates of subsidence behaviour above panel extensions where only the ULD Seam is mined are based on the previous subsidence monitoring at ACP in the PG Seam and general experience of single seam subsidence behaviour in the Hunter Valley and elsewhere. Maximum subsidence over the centre of each longwall panel is expected to be less than 1.6m with maximum strain of 30mm/m and maximum tilt of 70mm/m. These estimates are expected to have similar accuracy to single seam subsidence estimates previously presented for the ACP.

Figure 7 shows the incremental subsidence associated with mining in the ULD Seam additional to any subsidence associated with mining the PG Seam. Figure 8 shows the cumulative subsidence associated with mining in both seams.

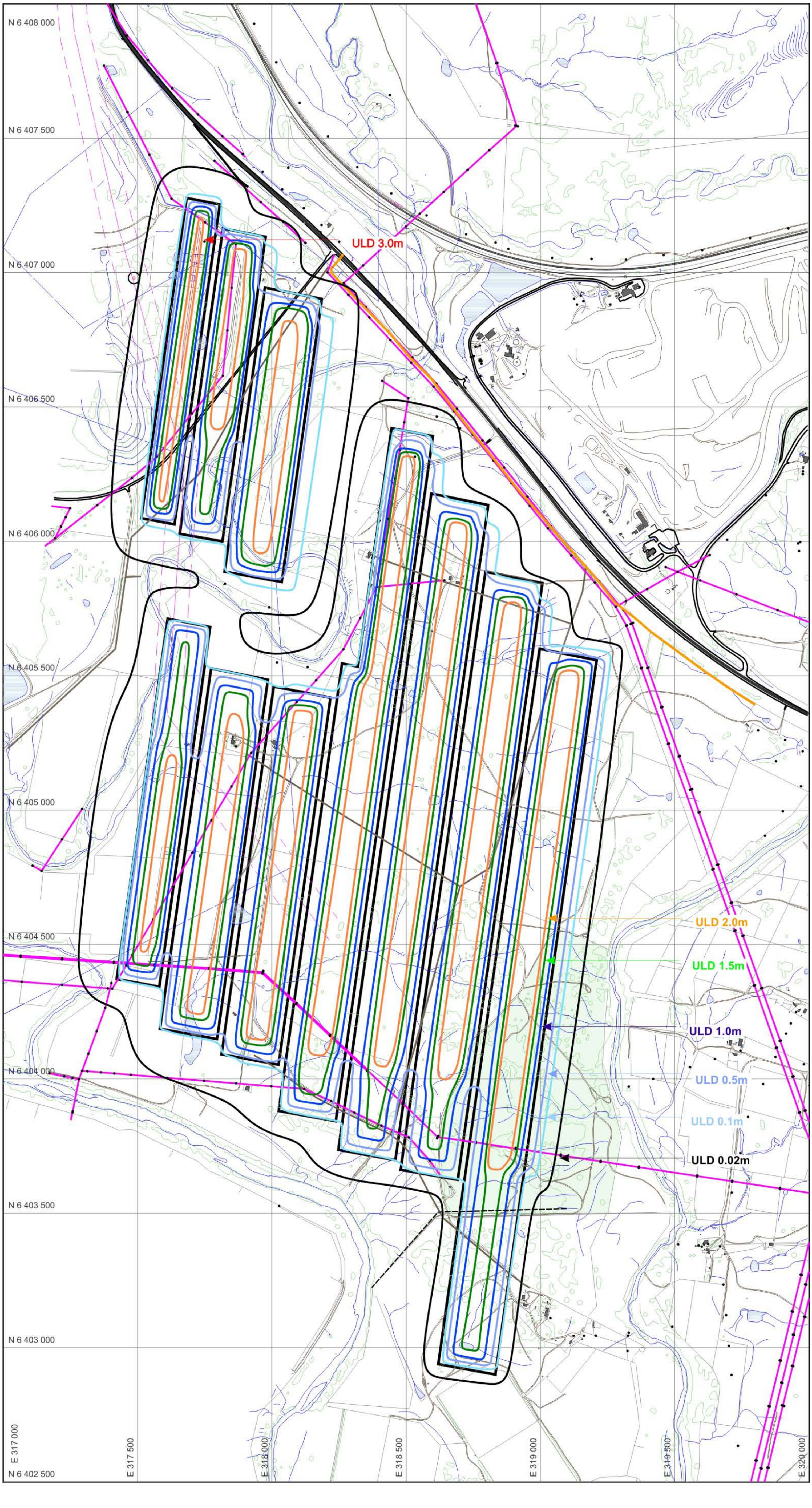

Figure 7: Incremental subsidence associated with mining ULD Seam only.

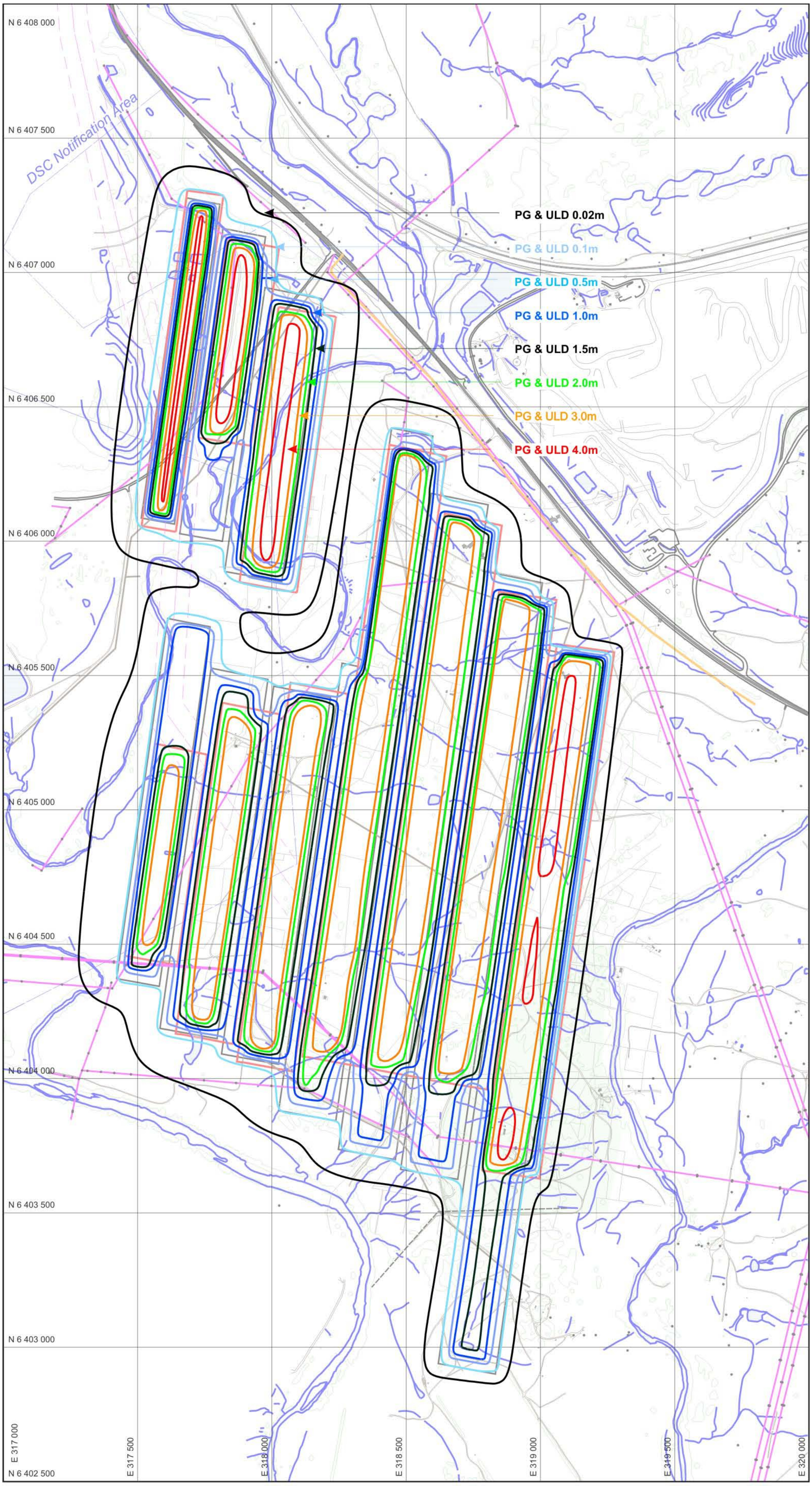

Figure 8: Cumulative subsidence associated with mining PG and ULD Seams.

It should be recognised that the maximum vertical subsidence in a single seam situation is naturally variable by about 15% for any given panel geometry and overburden depth. In a multi-seam situation, the variability is expected to be much greater so the subsidence contours shown should be regarded as indicative of the general level of subsidence that can be expected rather than as providing a high level of precision of the subsidence value at a point.

Table 3 summarises the maximum subsidence that is expected at the completion of mining each panel based on the subsidence equal to 85% of combined seam thickness mined in both seams. The maximum subsidence values are expected over the central part of the full width panels while the maximum strains and tilts are likely near the edges of the panels, particularly in areas where the goaf edges in the two seams are stacked above each other.

Table 3: Incremental and Cumulative Subsidence Parameters for Mining in the ULD Seam (reproduced in the Summary)

Seam	Incremental Subsidence From Mining ULD Seam (m)	Incremental[2] Max Tilt (mm/m)	Incremental[2] Max Strain (mm/m)	Maximum Subsidence (85% of Combined Seam Thickness)(m)	Max Tilt (mm/m)	Max Strain (mm/m)
LW1	2.9	183	73	4.4	235	94
LW2	2.5	139	55	4.0	189	76
LW3	2.5	119	48	4.0	162	65
LW4A	2.4	93	37	3.9	128	51
LW4B	2.4	110	44	3.9	151	60
LW5	2.5	76	30	4.0	103	41
LW6A	2.5	73	29	4.0	100	40
LW6B	2.8	101	41	4.3	132	53
LW7A	2.5	66	26	4.0	89	36
LW7B	3.0	91	36	4.5	116	47
LW8	3.4[1]	98	39	4.4	107	43

1 The incremental subsidence is expected to be larger in areas where narrow panels in the PG Seam are destabilised by mining in the ULD Seam.

2 There is not a strong basis to validate the process for estimating in the incremental tilts and strains so these should be regarded as only generally indicative at this stage.

These subsidence estimates are higher than previous estimates of subsidence associated with mining the PG and ULD Seams presented in the EIS (2.7m to 3.4m) and in SCT Report ASH3584 (3.7m). The increase is partly due to differences in geometry and an increase in the seam thickness proposed to be mined, but primarily because a more conservative approach has been taken in this current assessment to estimating the maximum subsidence (based on 85% of combined seam thickness) for impact assessment purposes given recent work by Li et al (2010) and the uncertainties that are now recognised to exist around predicting subsidence in a multi-seam environment.

Surface cracks associated with mining in the ULD Seam are generally expected to be up to several times greater than those observed during mining in the PG Seam. Crack widths are expected to be greatest in areas where goaf edges in the two seams are in close proximity and are likely to be greater in the eastern panels where the overburden depth is less. Maximum crack widths in the range 200-500mm are expected in shallow areas where goaf edges are stacked. Most of the cracks are likely to be transitory in nature with permanent cracks most likely to develop at the top of slopes and parallel to goaf edges.

Surface infrastructure such as roads and buildings located directly over the longwall panels are considered likely to require significant mitigation and remediation works to remain fully serviceable throughout the period of mining given the large strain and tilt levels expected.

Natural features such as trees, creek channels, and flat areas are likely to be significantly disturbed with incremental subsidence significantly greater than that already experienced from mining in the PG Seam.

3.3 Factors Influencing Reliability of Subsidence Estimates and Assumptions

In this section, the factors that influence the subsidence and the assumptions that have been made to arrive at the subsidence estimates are presented and discussed.

Subsidence estimates for the longwall panels in the PG Seam are considered to be reliable because of the previous experience of monitoring the PG Seam at ACP, and because the PG Seam is the first seam mined in undisturbed ground. Similarly, subsidence predictions in those sections of longwalls in the ULD Seam that have not been previously mined in the PG Seam are considered to be reliable because the ULD Seam is the first seam mined in undisturbed strata.

In the areas of multi-seam subsidence the confidence in the subsidence predictions is lower because of the limited experience of multi-seam mining that is available to use for predictions.

Li et al (2010) present a summary of experience of multi-seam mining in NSW and elsewhere that indicates maximum subsidence associated with supercritical width mining in two seams reaches a maximum of 83% of the combined seam thickness mined. Although Li et al suggest a maximum value of 80% of combined seam thickness, maximum subsidence of 85% of combined seam thickness has been used in this assessment.

This 85% value appears a reasonable upper limit based on the results of single seam subsidence monitoring. For single seam mining, the upper limit on subsidence is usually 65% of seam thickness mined but can range from 35% to 65% – typically 50-60% at ACP – depending on the nature of the overburden strata.

With two seams mined, there is likely to be additional settlement of the overlying goaf as it is disturbed by additional subsidence, but, similar to single seam subsidence, it is also likely that the nature of the overburden strata will reduce the actual subsidence observed to less than 85% of the combined seam thickness. Refinement of the subsidence estimates for the particular geological setting at ACP will become possible once monitoring data becomes available from the early longwall panels. In the meantime, a conservative approach to estimating the maximum subsidence has been adopted for assessment purposes.

The estimates of maximum strain and maximum tilt appear to be sensitive to the detail of the superimposed goaf edges and there is currently insufficient data available to provide these estimates with a high degree of confidence. The approach taken has been to extrapolate the empirical data reported by Holla (1991) for the maximum subsidence determined from 85% of the combined seam thickness. It is possible that strains and tilts higher than these estimates may be experienced, however, in practical terms, the strains and tilts are high enough to cause significant impacts so any inaccuracies in predicted strains and tilts are unlikely to make much difference to the management of outcomes.

Numerical modelling (SCT Report ASH3852) has been used to predict the general nature of the subsidence. This modelling takes into account the mechanical properties of the stratigraphic units that comprise the overburden strata and the interaction between chain pillars in the two seams mined. This approach has been validated successfully at several sites and is expected to provide a reasonable estimate of the general subsidence behaviour across the site after both seams have been mined.

The maximum subsidence predicted using numerical modelling for both seams is approximately 55-60% of the combined seam thickness which indicates that the 85% of combined seam thickness used for this assessment may be conservative. However, a conservative approach is considered appropriate given the lack of subsidence monitoring. In due course, once the first few longwall panels in the ULD Seam have been mined, the data set of multi-seam subsidence information will be much more comprehensive.

3.4 Comparison to Previous Predictions

Previous estimates of subsidence for each of the four seams proposed to be mined at ACP are presented in SCT Report ASH3584. These estimates are based on a stacked mining geometry and generic seam thickness information and are superseded by the estimates in this report based on the actual geometry, updated seam thickness information, and a more conservative subsidence estimation approach adopted based on the results presented by Li et al (2010).

The proposed geometry does not of itself significantly influence the estimates of maximum cumulative subsidence compared to the stacked geometry but it does influence the incremental subsidence, the nature of the subsidence, and the areas where subsidence is likely to occur.

In a stacked geometry, the chain pillars are stacked directly over each other and the pillars are designed to remain stable. Longwall 8 is close to being stacked as the western chain pillar overlie each other in the vicinity of the lease boundary. The other panels in the proposed geometry are offset so that the overlying pillars in the PG Seam become destabilised by mining in the ULD Seam. This offset arrangement has advantages for mining conditions underground as well as tending to soften the subsidence profile on the surface. Tilts and strains are likely to be reduced and the effect of mining each panel spread more broadly across several panels.

In a stacked geometry, the subsidence in each panel mined is substantially limited to within the boundary of that panel. The subsidence is cumulative within the panel, while remaining relatively low above the chain pillars. Tilts and strains at the surface tend to increase in proportion to the subsidence.

In an offset geometry, the chain pillars in the overlying seam are destabilised by mining in the lower seams. The same level of maximum subsidence occurs in the centre of both panels, but the subsidence profile is softened somewhat by the increased subsidence directly above and adjacent to the chain pillars. An outcome of this softening is that subsidence associated with mining in one panel in the ULD Seam is likely to be spread across several panels in the PG Seam once the chain pillar is destabilised. This difference in behaviour is likely to extend the timeframes associated with monitoring and remediation activities.

In the circumstance were an individual panel in the PG Seam is subcritical in width and surface subsidence has been limited by overburden bridging across the narrow panel, destabilisation of one of the chain pillars caused by mining in a lower ULD Seam has the potential to cause additional incremental subsidence at the surface because the overburden strata is no longer able to bridge across the PG Seam longwall panel and the shortfall in subsidence associated with the narrow panel is recovered as additional subsidence during mining in the ULD Seam.

Longwall 8 is a subcritical width panel in a substantially stacked geometry. There is some potential for the eastern chain pillar in the PG Seam to become destabilised by mining in the ULD Seam because of an 8m offset on this eastern side of the panel. If the chain pillar is destabilised, the surface subsidence that did not occur during mining in the PG Seam because of the subcritical panel width, is likely to occur during mining of the ULD Seam leading to greater apparent subsidence in this area.

Alternatively, if the chain pillars remain stable, overburden bridging may continue above the PG Seam with significantly lower subsidence in both seams. The predictions shown in Table 3 are based on the expectation that the chain pillars are destabilised by mining in the ULD Seam and therefore represent a conservative estimate of subsidence.

The updated seam thickness information, shown in Figure 4, influences the estimates of maximum subsidence as maximum subsidence is proportional to the seam thickness mined. In SCT Report ASH3584, the ULD seam thickness was assumed to be 2.5m across the entire mining area. Updated seam thickness information indicates the mining height is likely to vary from 2.5m to 3.0m, with the higher extraction areas being mainly in the north western and south eastern part of the mining area.

Table 4 shows a comparison of the previous estimates presented in SCT Report ASH3584 of total maximum subsidence at the completion of mining the ULD Seam compared to the maximum subsidence predicted for the revised mining geometry and updated seam thickness information.

Table 4: Incremental and Cumulative Subsidence Parameters for Mining in the ULD Seam

Panel	Previous Estimates of Total Subsidence at Completion of Mining the ULD Seam presented in SCT Report ASH3584 (m)	Estimates of Total Subsidence at Completion of Mining in the ULD Seam based on updated seam thickness information (m)
LW4	3.7	3.9
LW5	3.7	4.0
LW6A	3.7	4.0
LW6B	3.7	4.3
LW7A	3.7	4.0
LW7B	3.7	4.5
LW8	2.9[1]	4.4

[1] The lower subsidence above LW8 in the stacked geometry assessed in SCT Report ASH3584 is a consequence of the stacked pillars remaining stable.

4. ASSESSMENT OF SUBSIDENCE IMPACTS

Previous assessment of subsidence impacts have been conducted for the ACP longwall mining area as part of the EIS/EAs for all seams and SMP Approvals for Longwalls 1 to 8 in the PG Seam. The assessment presented in this report is intended to address those impacts that are significantly greater or substantially different to previously assessed impacts. Previous assessments are still relevant for those areas where the impacts are not significantly different.

4.1 Natural Features

The major natural features in the area include:

- Bowmans Creek which lies within the proposed mining area and currently directly over several panels.
- The Hunter River to the south outside the proposed mining area.
- Glennies Creek to the east of Longwall 1 and outside the mining area.

ACOL has consent to divert Bowmans Creek to allow more efficient recovery of the coal resource

Other natural features likely to be impacted by the proposed mining include two remnant woodlands, one a Voluntary Conservation Area located immediately north of the Property 130 boundary, and the other alongside a tributary of Bowmans Creek near the middle of Longwall 4. Both areas are understood to include sites containing Aboriginal artefacts and nesting sites for native birds, including threatened species.

SCT understand that subsidence impacts associated with archaeological heritage sites and impacts on natural flora and fauna are addressed in separate reports. Except for a specific assessment of the potential for subsidence impacts on the grinding groove site discussed in Section 4.1.5 in the context of the natural rock feature on which these features are located, potential impacts on archaeological and flora and fauna sites has not been included in this report as these have been considered elsewhere.

4.1.1 Bowmans Creek

ACOL has consent to divert two sections of Bowmans Creek to allow more efficient recovery of the coal resource. An assessment of the subsidence impacts from mining in the PG Seam in the vicinity of Bowmans Creek is presented in SCT Report ASH3687 (Revision 1) dated 10 February 2011.

Proposed mining in the ULD Seam will increase the magnitude of vertical subsidence over the longwall panels and is expected to increase the hydraulic conductivity of the overburden strata directly above the longwall panels. These impacts will affect the area around the original Bowmans Creek watercourse, but the subsidence impacts on the diversion channels and the undisturbed sections of Bowmans Creek are not expected to be significantly greater than those assessed previously in SCT Report ASH3687 (Revision 1).

Mining the western side of Longwall 4 in the ULD Seam directly below the edge of Longwall 4 in the PG Seam is expected to cause additional low level ground movements beyond the edge of the panel consistent with the greater level of vertical subsidence for mining in two seams. However, this additional disturbance is still of a low level and, SCT understands, has been taken into account in terms of impacts on the alluvial groundwater system.

The chain pillars in the PG Seam and the ULD seam that form the superimposed maingate of Longwall 4 are expected to remain stable in the long term, and are not expected to contribute to additional ground movements beyond those that would be expected above a solid longwall goaf edge superimposed in two seams. Mining conditions in the ULD Seam are expected to be more challenging because of the additional vertical load associated with the side abutment from the PG Seam Longwall 4, but this is a mining issue, and not one that will cause more surface subsidence or pillar instability in the overlying seam.

Notwithstanding the low levels of subsidence expected at the diversion, nearby subsidence of up to an estimated 4.5m at the completion of both the PG and ULD Seams is expected to leave the creek diversion elevated above parts of the original creek bed and areas of adjacent flood plain. Rainfall runoff and water that overtops Bowmans Creek during a flood event are expected to flow to the lowest point in the landform and pool there. Large flood events will also bypass the diversion and be directed into the excised natural channels and overbank floodplain to reduce the risk of flood damage to the constructed creek channels.

The disturbance to the overburden strata caused by ULD Seam subsidence may provide sufficient hydraulic connection between the surface and the mine for some of this pooled water to flow down into the mine. The potential for this inflow is addressed by Aquaterra (2009) in their Bowmans Creek Diversion: Groundwater Impact Assessment Report (and the report being prepared for submission with the EP).

The engineering design of the creek diversions includes methods to assist in the drainage of trapped water in subsided areas but some areas will not be able to drain naturally in the creek following subsidence.

SCT understand that filling of subsidence troughs and/or reshaping of the subsided landform is to be undertaken in some areas to maintain a free draining landform. This work is expected to reduce inflows into the mine from those areas.

4.1.2 Glennies Creek

The proposed mining in the ULD Seam is approximately 210m from Glennies Creek, some 60m further than previous mining in the PG Seam. Previous mining in the PG Seam did not cause any detectable ground movements in the vicinity of Glennies Creek, although some groundwater flow through the undisturbed section of the PG Seam that outcrops in Glennies Creek was expected and this flow was observed underground.

Mining in the ULD Seam is not expected to cause a significantly different style of ground movement in the area between the proposed mining area and Glennies Creek. The flow of groundwater through the undisturbed PG Seam is expected to continue but is not expected to increase significantly as a result of the physical disturbance caused by the proposed mining in the ULD Seam. Significant upsidence or other physical disturbance to Glennies Creek is not expected. These issues have been assessed in SCT Report ASH3990 "Subsidence and Hydraulic Conductivity Effects East of Longwall 1 in the Pikes Gully Seam" dated 26 June 2012.

With the benefit of further monitoring at Ashton and at other sites, it seems likely that at shallow depth (60-80m) there is insufficient energy available to mobilise horizontal ground movements, whereas at greater depths there is certainly data to show mobilisation of horizontal ground movements outside of mining to 1.5km at 250m and up to about 3km at 500m.

Mining in the ULD Seam, offset as it is 60m to the west, is not likely to significantly change the situation, except to increase the amount of vertical subsidence over the superimposed area of the longwall panels. There is a slight possibility that this additional vertical subsidence may provide sufficient energy to mobilise horizontal movements up dip, but on balance, this seems unlikely based on current understanding of these mechanisms.

4.1.3 Hunter River

Proposed mining in the ULD Seam is nominally 160m from the Hunter River at the closest point adjacent to the corner of Longwall 3. The overburden depth to the ULD Seam in this area is approximately 160m, so the Hunter River is protected by a barrier of half depth plus 80m. Longwalls 5, 6 and 7 are located beyond 200m from the Hunter River alluvium consistent with Development Consent Condition commitments (Commitment per schedule C item 3.2 for Development Consent Modification No. 6). No perceptible physical disturbance of the Hunter River channel is expected as a result of the proposed mining.

4.1.4 Remnant Woodlands

The two remnant woodlands, one a Voluntary Conservation Area located immediately north of the Property 130 boundary, and the other a woodland area alongside a tributary of Bowmans Creek near the middle of Longwall 4 are understood to include sites containing Aboriginal artefacts and nesting sites for native birds (including threatened species). SCT understand that subsidence impacts on archaeological heritage sites generally and impacts on natural flora and fauna are addressed in separate reports commissioned by ACOL.

4.1.5 Rock Outcrop Containing Aboriginal Grinding Groove Site

A rock outcrop alongside Bowmans Creek is the site of several Aboriginal grinding grooves. The site is located approximately 190m from the nearest longwall panel in the ULD Seam at an overburden depth of 110m. There is considered to be no potential for any ground movements associated with the proposed mining to cause perceptible impacts at this site.

4.2 Existing Major Infrastructure

Existing major infrastructure within the general area includes:

- The New England Highway and associated road reserve in the north including a bridge over Bowmans Creek. Main headings extend under the highway and road reserve. The longwalls are located well outside the road reserve.

- A buried fibre optic cable alongside the highway.

- Various electricity lines:
    - A 132kV line and a combined 66kV and 11kV line alongside the New England Highway.
    - A 132kV line that traverses the southern end of the proposed mining area.
    - A 33kV line adjacent to Brunkers Lane servicing Ravensworth Operations.
    - Narama Dam, a Dams Safety Committee prescribed dam, located west of the proposed mining area.

The potential subsidence impacts on existing major infrastructure are discussed in this section.

4.2.1 New England Highway and Bowmans Creek Bridge

The New England Highway is located some 50m north of the southern edge of the road reserve. At its closest point to the proposed mining in the ULD Seam, the road reserve is 82m from the northeast corner of Longwall 7B. The overburden depth at this location is approximately 168m, so the proposed mining just encroaches within half depth of the southern edge of the road reserve at this location. Elsewhere, the road reserve is beyond half depth from the proposed mining.

There is not expected to be any perceptible impact on the road reserve, the New England Highway itself, or the cutting at the northern end of Longwall 1 from the proposed mining.

The slight encroachment off the corner of Longwall 7B is not expected to be significant because the area is located at the finish end of the panel where ground movements are not observed to extend much beyond the goaf edge, and the area is located off the corner of the panel where ground movements are less because of corner effects.

The New England Highway passes through a cutting at the northern end of the first few longwall panels. Experience from mining the PG Seam longwall panels indicates that horizontal movements were imperceptible beyond about 60m from the northern ends of the panels even at overburden depths as great as 140m. The overburden depth to the ULD Seam in the vicinity of the cutting is less than 100m and the cutting is in excess of 250m from the northern corner of Longwall 1. No impact on the cutting is expected as a result of the proposed mining the ULD Seam, but a program of monitoring similar to that used for the PG Seam longwalls is recommended to provide confirmation.

The bridge on the New England Highway over Bowmans Creek is located approximately 290m from the end of Longwall 4B and approximately 380m from the end of Longwall 6B. An estimate of the maximum valley closure movements expected from the existing mining in the PG Seam and the proposed mining in the ULD Seam using the 2002 ACARP method was 10mm and 11mm respectively (Kay 2011). Kay noted that although the method does not include multi-seam cases, the predictions are not considered additive. SCT is not aware of any impacts on the Bowmans Creek Bridge from mining in the PG Seam and no significant impacts are expected as a result of proposed mining in the ULD Seam.

4.2.2 PowerTel Fibre Optic Cable

A buried PowerTel fibre optic cable is located 93m from the corner of Longwall 6B at its closest point to the proposed mining. An overburden depth to the ULD Seam in this area is 138m. The fibre optic cable is protected by a barrier of half depth plus 24m. No significant ground movements are expected at this distance from the finishing ends of the proposed longwall panels and the fibre optic cable is expected to be fully protected from any impacts associated with the proposed mining.

4.2.3 Electricity Transmission Lines

4.2.3.1 132kV Line and 66kV/11kV Line Adjacent to Highway

A 132kV electricity line and a 66kv electricity line (also carrying an 11kV line) are located alongside the highway just outside the road reserve. At their closest, these lines are located at distances from the end of Longwalls 6B and 7B of 83m and 85m respectively. The overburden depth at these locations is 138m and 168m respectively, so the pole structures supporting these lines are protected by barriers to the proposed mining in excess of half depth. No significant movements are expected.

The potential for subsidence impacts associated with the relocation of these lines for the SEOC Project is discussed in Section 4.4.3.

4.2.3.2 132kV Line Across Southern Part of Mining Area

A 132kV electricity line located across the southern part of the proposed longwall mining area is expected to be subject to the full range of ground movements. Sections of this line have already experienced subsidence from mining in the PG Seam. Table 5 presents a summary of the incremental subsidence expected from mining the ULD Seam and the total subsidence expected at the completion of mining both the PG and ULD Seams at each of the pole locations. The poles are numbered from the east with Pole 1 located immediately to the east of Longwall 1. The AusGrid poles numbers are also provided.

Where both seams have been mined, the maximum subsidence is expected to reach 4.0m in the centre of both panels, be reduced to about 2.4m over the chain pillars in the PG Seam, and be less than 0.3m at the solid goaf edge of the outermost panel edge of any overlapping panels. Maximum tilts and strains are likely to vary up to 200mm/m and 80mm/m respectively with the actual values sensitive to position relative to individual panels.

The 132kV electricity line is likely to be affected by movements at the top of poles, relative movement of adjacent poles, relative movement of poles and stays, and ground clearance on conductors. In general, the movements are likely to occur only for a period of a few weeks while the longwall passes through the area (100m before to 200m after each longwall goes through), but there may be greater levels of residual movement with multi-seam mining. A program of monitoring of ground movements will allow better definition of the period of ground movements.

Poles 2 and 3, the first poles affected by mining in two seams, are located in the first area where mining will have occurred in two seams. There will be no opportunity for monitoring to confirm the magnitudes of any movement prior to the movements affecting the poles. We understand that Pole 2 is planned to be replaced by poles located over the adjacent chain pillars where generally lower subsidence movements are expected. Pole 3 is located adjacent to chain pillar in an area where most of the subsidence is associated with single seam mining and therefore the movements are likely to be of lower magnitude similar to those which have previously occurred along other sections of the line. Poles 4, 5 and 6 are located in areas where mining will be single seam only. Special provisions are required at Pole 4 to accommodate the change of direction and the changes in tension on the stay wires.

Subsidence monitoring data from Longwalls 1 and 2 will be available to better inform management strategies for the remainder of the line where poles are located in areas of two seam mining.

Table 5: Estimated Subsidence Movements on 132kV Electricity Line

Pole Number	AusGrid Pole Number	Depth to ULD (m)	Max Subs		Tilt				Horizontal Movement				Strain
			ULD+PG (m)	ULD Only (m)	Max Tilt (mm/m)	Direction Toward	Perm Tilt	Direction Toward	Initial Movement (m)	Direction Toward	Horz Offset (m)	Direction Toward	Maximum Strain (mm/m)
1	STR193	60	0	0	0	N/A	N/A	N/A	0.1	E	0.1	E	0
2	STR192	100	4	2.5	200	S	60	W	0.6	SE	0.8	NE	80
3	STR191	130	1	1	60	S	10	E	0.4	SE	0.6	NE	24
4	STR190	160	1.6	1.6	50	S	<5	N/A	0.2	S	0.2	N	20
5	STR189	160	0.3	0.3	10	W	10	W	0.1	W	0.2	NW	4
6	STR188	160	2	1.8	150	S	60	E	0.3	SE	0.5	NE	60
7	STR187	170	4	2.5	120	S	10	W	0.8	S	0.8	N	48
8	STR186	180	1	0.8	60	E	10	E	0.4	S	0.6	NE	24
9	STR185	185	4	2.5	110	S	10	E	0.8	S	0.8	N	44
10	STR184	190	4	2.5	110	S	10	W	0.8	S	0.8	N	44
11	STR183	200	2	1.8	60	SW	20	W	0.2	SW	0.3	NW	24
12	STR182	205	0.1	0.1	5	W	5	W	0.2	E	0.2	NE	2

4.2.3.3 33kV Line Adjacent to Brunkers Lane

A 33kV electricity line skirts the edge of the opencut spoil dump located on the MacGen owned land alongside Brunkers Lane above Longwalls 7B and 8. The single concrete pole structures are stayed at changes of direction. A decision on how best to manage the additional subsidence associated with mining in the ULD Seam will be informed by the experience of mining similar structures in earlier panels. There may be an opportunity to relocate this line onto the barrier between ACP and RUM where subsidence impacts are likely to be insignificant.

4.2.4 Narama Dam

Narama Dam is an earth embankment water storage reservoir owned and operated by Xstrata Coal. The dam is also known as the Ravensworth In-Pit Storage Dam in DCS reports, the Ravensworth Operations 1000 ML Dam in Ravensworth Reports, and has been approved by the DSC at Ravensworth-1.

The toe of the dam wall is located approximately 400m west of Longwall 7A. The dam is prescribed by the DSC. The DSC Notification Zone extends over Longwalls 5 to 8.

No significant ground movements associated with the proposed mining in the ULD Seam are expected at this distance from the goaf edge. The subsidence monitoring program and management plan currently in place for PG Seam mining is expected to be appropriate for confirming the nature and extent of any low level ground movements in the area.

4.3 Other Infrastructure Not Owned by ACOL

Other infrastructure within the general area not owned by ACOL includes:

- Farming infrastructure on Property 130 such as fences, water troughs, buried water pipes, and tracks.
- Several local electricity transmission lines.
- Flow gauging station on Bowmans Creek operated by NSW Office of Water.
- Brunkers Lane and a private road that provides secondary access to MacGen land as well as access to Ravensworth Open Cut Mine Ravensworth Opencut.
- Private access road to Property No 130 used daily by a milk tanker and the property residents.
- Buried Telstra cables servicing Property 130 and Ravensworth Operations.
- A large diameter polyline understood to carry mine water from Narama Dam to Mt Owen Mine.

- A system of MacGen sediment control dams in the northwest corner of the mining area and associated drainage paths.

Subsidence impacts on most of these infrastructure items have been discussed in previous assessments for the ACP. As per the requirements of Section 3.1.2 (e) of the Development Consent to provide revised predictions of the potential subsidence effects, subsidence impacts, and environmental consequences of the proposed second workings, it is not intended to repeat full assessments for the minor infrastructure located within the proposed ULD mining area because the subsidence impacts are likely to be consistent with previous assessments for the PG Seam and for the multi-seam project as a whole. There are existing management plans that relate to this infrastructure for mining in the PG Seam. These management plans are being reviewed and updated as part of the EP for the ULD Seam. These management plans are expected to be suitable to manage the impacts from proposed mining in the ULD Seam.

The subsidence impacts of the extension of Longwall 1 into Property 130 is reviewed and presented, because the ULD Seam mining area extends well beyond the previous extent of mining in the PG Seam.

There is a low subsidence corridor along the alignment of Bowmans Creek that would provide an alignment for some infrastructure such as the 11kV electricity lines servicing ACOL infrastructure and other customers south of the Hunter River, Telstra line to Ravensworth Operations, and the Narama-Mt Owen polypipes. Relocation of some infrastructure into this corridor may obviate the need for ongoing management of subsidence impacts.

4.3.1 Property 130

Property 130 is located at the southern end of Longwall 1 and will only be affected by mining in the ULD Seam in Longwall 1. Previous mining in the PG Seam did not occur below Property 130. The subsidence estimates are based on the previous subsidence monitoring at ACP in the PG Seam and general experience of subsidence behaviour for single seam extraction in the Hunter Valley and elsewhere. The overburden depth to the ULD Seam ranges from approximately 105m to 150m in this area.

Maximum subsidence over the centre of the longwall panel is expected to be less than 1.6m with maximum strain of 30mm/m and maximum tilt of 70mm/m. These estimates are expected to have similar accuracy to single seam subsidence estimates previously presented for the ACP.

Impacts on roads, fences, dams, and other farming infrastructure is likely to be similar to that experienced over Longwalls 3-5 in the PG Seam. Some impacts are likely to be perceptible, but in general, these impacts should be able to be managed without undue difficulty and with only relative minor works such as regrading tracks, re-tensioning fences, and closing any open cracks that may develop in dam walls.

Contour drains are likely to require regrading once the subsidence has been completed to allow continued operation. Permanent surface cracks may need to be filled by ripping and re-compaction. Flat lying areas where pools may develop, may need some minor earthworks to return the landform to a free draining state.

4.4 Future Major Infrastructure Planned Within the Timeframe of ULD Seam Mining

Other non ACOL owned infrastructure that is yet to be constructed but is likely to be impacted by the proposed mining includes:

- The Lemington Road diversion around the Ravensworth North Project that follows the current alignment of Brunkers Lane within the proposed mining area.

- An 11kV electricity transmission line that is proposed to follow the same alignment as the 132kV line in the southern part of the mining area (to be constructed as part of the proposed SEOC Project).

- A proposed relocation for the SEOC Project of the existing 66kV and 132kV lines that skirt around the northern perimeter of the proposed mining area.

- Diversion of the 330kV transmission line around the Ravensworth North Project immediately west of the proposed mining area.

- A MacGen gas pipeline that crosses Longwalls 6B, 7B and 8. The easement for this pipeline exists, but we understand that there are currently no immediate plans to construct this pipeline and the pipeline may be integrated with ACOL's gas drainage network.

- Ravensworth Underground Mine (RUM) located west of ACP is proposing to mine four seams. This mine development includes the No 5 Ventilation Shaft located some 150m west of the proposed mining area.

- The Void 5 Dam, a DSC prescribed dam located at the eastern end of Void 5. The dam is located well outside the proposed mining area, but the DSC notification area extends into the proposed mining area.

In this section, the potential impacts of mining in the ULD on this proposed infrastructure is discussed. Given the detail of some of this infrastructure and the relative timing of construction relative to mining may change depending on circumstances, the assessment of future impacts is necessarily somewhat general in nature. An assessment closer to the time of construction may be appropriate when timing and other details become clearer.

4.4.1 Lemington Road Diversion

The Lemington Road diversion around the Ravensworth North Opencut Project is currently under construction. Within the proposed mining area, the new alignment follows the existing alignment of Brunkers Lane and crosses Longwalls 6B, 7B and 8. Mining in the PG Seam in this area has not yet been completed and may not be completed before the road is constructed. If the road is completed before mining in the PG Seam, there is potential for sections of the road to subside up to 4.5m if the ULD Seam is mined at a full extraction height of 3.0m. The proposed mining and mining related subsidence has been recognised in the design of the road.

The subsidence movements at any given location are expected to develop in two main stages as each seam is mined. However, unlike single seam operations where subsidence movements are mainly limited to within the boundary of the current panel, there is potential for adjacent panels to cause significant additional ground movement if overlying chain pillars are destabilised.

Total maximum tilts of 80-120mm/m and total maximum horizontal strains of 35-50mm/m are expected, but in some areas these maxima may be reduced if mining in the PG Seam is completed prior to the road diversion being constructed.

The road surface is likely to require significant monitoring and progressive remediation effort to keep it serviceable during the periods of mining in the ULD Seam. However, similar levels of ground movement have been successfully managed at another site in the Hunter Valley, so maintaining the road as serviceable, for the second seam of extraction, is considered both possible and practical. The period over which intensive monitoring and progressive remediation is required is likely to extend for several weeks during the period of mining each adjacent longwall panel.

Vertical lowering of the road surface is expected to make the road more vulnerable to flooding of Bowmans Creek. The 100 year Average Recurrence Interval (ARI) flood level for the Hunter River is nominally RL64.1m (Bowmans Creek Diversion Flood Study 2009). The finished level of the lowest point on Lemington Road is understood to be RL68.8m. With an estimated maximum 4.5m of total subsidence due to mining the PG and ULD Seams, there is potential for Lemington Road to drop to RL64.3m and become vulnerable to inundation in floods with a lower probability than 1 in 100 in any given year.

Some readjustment of the road level is considered likely to be necessary once mining is complete to recover the vertical alignment of the road and reduce the road's vulnerability to flood inundation.

Culverts, roadside barriers, and other roadside furniture are likely to be impacted by mining subsidence. Total maximum tilts of 80-120mm/m and strains of 35-50mm/m are expected on a 10m bay length. The serviceability or otherwise of these structures will depend on timing of mining and construction detail.

4.4.2 11kV Electricity Line Crossing Southern Part of Proposed Mining Area

ACOL propose to construct an 11kV electricity transmission line that follows the same alignment as the 132kV line in the southern part of the mining area. This line is required to supply electricity to the SEOC Project currently being developed by ACOL. The line is expected to experience the full range of subsidence movements similar to the existing 132kV line (presented in Table 5).

We understand that there are few options for alternative alignments that are not subject to subsidence, but that the supply is primarily for the SEOC Project. A high level of monitoring with associated potential requirement for intervention to maintain ground clearances and pole stability is anticipated to maintain the serviceability of this line throughout the period of mining.

4.4.3 132kV and 66kV Electricity Line Diversions Around SEOC Project

Two electricity lines that follow the New England Highway to the north of the proposed mining area are to be diverted around the proposed SEOC Project where they cross open land to the east of ACP.

All poles on the 132kV line (CN60007 to CN60136 and all poles south of this) will be outside of half depth from the edge of Longwall 1 in the ULD and PG Seams, so subsidence movements are expected to be less than 20mm with negligible tilt. Horizontal movements are expected to be less than 50mm and likely to be mainly in an east-west direction. Horizontal strains are likely to be negligible.

Poles on the 66kV line from CN60139 to CN60143 are inside of half depth and are expected to experience low level subsidence ranging from 20-40mm vertical subsidence with tilts less than 1mm/m. Horizontal movements are likely to be generally less than 50mm and likely to be mainly in an east-west direction.

No significant subsidence impacts or requirement for remediation is anticipated on either of these two lines from the proposed mining in the ULD Seam.

4.4.4 330kV Electricity Transmission Line

As part of the Ravensworth North Opencut Project, Xstrata are planning to redirect a 330kV transmission line onto the barrier between ACP Longwall 8 and the main headings of RUM. While the barrier between the two mines is expected to experience only low levels of ground movements from proposed mining of up to four seams at both RUM and ACP, there is considered to be some potential for lateral spreading of the pylon legs as a result of differential horizontal movements. We understand that the pylons are being designed to accommodate these low level ground movements. These structures are expected to be able to tolerate the ground movements associated with proposed mining in the ULD Seam at ACP.

4.4.5 MacGen Gas Pipeline Easement

We understand that MacGen have a gas pipeline easement that extends across Longwalls 6B, 7B and 8 (Department of Planning and Infrastructure (DP&I) 2009). DP&I approval indicates that the easement ceases just east of Bowmans Creek. We understand that there are no immediate plans to construct a pipeline along this easement and if the pipeline were to be constructed, its primary purpose appears to be to capture coal seam gas from the ACP coal seam gas drainage network. The levels of subsidence anticipated across the proposed mining area for the PG and ULD seams is likely to be greater than conventional gas pipelines would be able to accommodate without significant work, but given the purpose of the pipeline, a flexible construction suitable for accommodating mining subsidence is expected.

4.4.6 Ravensworth Underground Mine

RUM is an Xstrata owned longwall operation that proposes to eventually mine four seams including the PG Seam, the Lemington Seam, the Middle Liddell Seam, and the Barrett Seam. There is a 40m wide barrier (20m either side of the lease boundary) that separates RUM from ACP. The RUM main headings are located immediately west of the barrier.

Plans available for the PG Seam indicate the RUM main heading pillars are to be formed at nominal centres of 30m by 65m. The overburden depth in the area adjacent to the lease boundary ranges from 150m to 200m. For a nominal roadway height of 2.7m, the width to height ratio of these pillars is approximately 9, and their nominal strength is estimated to be 31MPa using Bieniawski's pillar design formula:

$$Qp = K (0.64 + 0.36 W/H)$$

where Qp is nominal pillar strength, K is a factor representing coal strength and pillar geometry (a value of K=8 is used for this assessment), W is pillar width (measured rib to rib) and H is pillar height.

The tributary area loading on the RUM main heading pillars in the PG Seam is 6.5MPa.

The main heading roadways at RUM are 67m from the goaf edge of Longwall 8 in the north and 70m in the south. Proposed mining in the PG and ULD Seam at ACP is expected to increase the vertical load on the RUM main heading pillars by an estimated 1-2MPa, based on the side abutment loading expected from Longwall 8. Tributary area loading and this additional vertical loading are relatively insignificant compared to the 31MPa nominal strength of the RUM main heading pillars and no perceptible impact is expected.

The No 5 Ventilation Shaft proposed at RUM is located some 150m from the goaf edge of Longwall 8. The shaft will be lined with a steel tube and integrated precast concrete lining.

The overburden depth at the goaf edge is approximately 180m, so the shaft will be protected by a distance equal to half depth plus 60m or 0.7 times depth (35° angle of draw equivalent) plus 20m. This level of protection is greater than the level of protection that would generally be accepted as adequate for protection of shafts.

There is not expected to be any potential for vertical subsidence at the location of the shaft, but some horizontal shearing may occur at horizons close to the base of the Bayswater Seam – some 20m below the surface – and at the horizon of the PG Seam during mining of the PG and ULD Seams at ACP.

Horizontal movements to the west of the PG Seam longwall panels are routinely observed to extend to about 200m beyond the goaf edge. At 150m distance, low level horizontal movements of the order of 20-30mm are routinely observed. These movements are likely to be accommodated within the strata as shear on a single bedding plane horizon at about the level of the coal seam being mined. Any such shear movements from proposed mining in the ULD Seam are likely to have occurred prior to the ventilation shaft extending to below the ULD Seam.

Any shear movement that occurs above the level of the mining horizon is not expected to significantly impact on the operation of the ventilation shaft.

There is some potential for mine water that may pool in the ACP underground mine to flow through the barrier into RUM either during operations at ACP or subsequently.

4.4.7 Void 5 Dam

The Void 5 Dam is an ash dam that has yet to be constructed. The dam is a DSC prescribed dam that is to be located at the eastern end of Void 5 approximately 260m from the goaf edge of Longwall 8. The overburden depth to the PG Seam is approximately 180m in this area.

The dam is located well outside the proposed mining area, but the DSC notification area extends into the proposed mining area. The dam is expected to be constructed from backfilled spoil material and is expected to be able to tolerate any of the low level ground movements that are anticipated from the proposed mining.

4.5 ACOL Owned Infrastructure

ACOL owned infrastructure over the underground mine includes several farm buildings and houses, farm dams, farm roads, fences, a fresh water polyline from the Hunter River, the mine pump out polyline from the southern end of the panels, four polylines that pass under the New England Highway below the bridge over Bowmans Creek, and a proposed coal seam gas drainage network.

Although these items of infrastructure are not assessed in detail in this report because they are owned by the mine, a general assessment indicates that the subsidence movements expected from mining in the ULD Seam are likely to cause perceptible damage to the houses and other buildings located above the longwall panels. The farm dams, farm roads, fences are likely to be perceptibly impacted. Polylines laid on the surface are expected to be able to accommodate any ground movements. Buried polylines may be damaged in areas where ground movements become concentrated either as large tension cracks or compression humps.

The existing management plans for all the ACOL owned infrastructure are likely to be adequate to manage the additional subsidence movements expected from proposed mining in the ULD Seam.

Two ACOL shafts are located in the main headings north of the proposed mining area. One shaft is 5.5m in diameter and extends from the surface to the ULD Seam. The second shaft is 4m in diameter and joins the PG Seam and the ULD Seam. These two shafts are located beyond the northern end of the proposed ULD Seam mining area. Ground movements observed ahead of the longwall panels are of generally low magnitude and no significant impacts are expected in either shaft.

5. SUMMARY OF RECOMMENDATIONS FOR SUBSIDENCE MONITORING AND MANAGEMENT

The proposed longwall mining of two seams in close vertical proximity to each other and in a parallel overlapping geometry provides a unique opportunity to develop a better understanding of multi-seam subsidence.

We recommend that additional subsidence lines or subsidence monitoring strategies are used to monitor ground movements in three dimensions at all the locations where the panel geometries provide a variety of different overlaps and where there are existing lines. These sites include:

- The tailgate (eastern) goaf edge of Longwall 1 where there are already numerous cross-lines that will provide measurement of the variability in behaviour for essentially similar geometry. Most of these lines will need to be extended west across the panel as far as the western side of Longwall 1.
- The start lines of Longwalls 5 and 6 where the goaf edges are stacked.
- The western edge of Longwall 4 where the goaf edges are stacked.
- The finish line of Longwall 5 where the ULD Seam panels extend beyond the PG Seam goaf.

In general the existing subsidence lines will be suitable to cover the start areas of panels in the PG Seam. These current lines are offset 60m from the centreline of the longwall panels in the ULD Seam, but in the first few panels, the overburden depth is shallow enough that this offset will not be significant. There may be a need to replicate the existing lines along the centreline of the ULD Seam longwall panels from about Longwall 4 onwards in order to measure the full subsidence that develops, but the requirement for this should be assessed once the first few panels have been mined.

The start of Longwall 6A is currently planned to have the ULD start line directly under the PG Seam start line. The hard edge that will be formed in two seams with this geometry will be an opportunity to observe the maximum tilts, horizontal movements and strains that develop in such a situation.

Single seam mining in the ULD Seam is unlikely to be significantly different to the single seam mining in the PG Seam so there is limited value in intensively monitoring subsidence in areas where only the ULD Seam has been mined. Unless there is considered to be benefit in doing so, the disruption caused to Property 130 of having a subsidence line installed and surveyed at regular intervals does not seem to be justified for the start area of Longwall 1. It may be preferable to survey specific items of infrastructure located both inside and outside the mining area to confirm the levels of ground movement as a basis for implementing remediation strategies.

We recommend that infrastructure such as electricity lines that may be significantly affected by the proposed mining is specifically monitored with a view to better understanding the actual movements and the correlation between any damage that is observed and the movements that cause it.

There may be an opportunity to relocate some infrastructure onto the barrier between ACP and RUM where subsidence impacts are likely to be insignificant.

There is also a low subsidence corridor along the alignment of Bowmans Creek that would provide an alignment for some infrastructure such as the 11kV electricity lines servicing ACOL infrastructure and other customers south of the Hunter River, Telstra line to Ravensworth Operations, and the Narama-Mt Owen polypipes. Relocation of some infrastructure into this corridor may reduce the need for ongoing management of subsidence impacts.

The stability of RUM main heading roadways and pillars is not expected to be affected by the proposed mining, but an assessment of the potential interaction is recommended once the geometries are known.

To provide a general overview of the subsidence that develops in the relatively regular geometry that is proposed, we recommend that an airborne LiDAR survey is run at the completion of mining in each of the PG and ULD Seams. LiDAR provides an additional tool to assist in targeting industry best practice for subsidence monitoring. The accuracy of this type of monitoring is typically in the range 0.1-0.3m. With subsidence of up to 4.5m expected, useful information on the nature of the subsidence that develops will be able to be determined across the full area of the mine in the one survey. This technique may also be useful for confirming the extent of any filling work that is undertaken to achieve a free draining landform post-mining.

Horizontal ground movements associated with mining are being recognised to extend further than was previously understood. This improved understanding is coming as a result of well controlled GPS survey techniques based on a widely distributed network of remote control points on all sides of the mining area. The state survey network is now being managed as a base to provide far field control and again provides an additional tool to assist in targeting industry best practice. We recommend that a survey control network is established at ACP based on this network so that the extent of far field movements can be established with a high degree of confidence in a multi-seam environment.

6. CONCLUSIONS

The database of experience available in NSW to estimate the magnitude and nature of subsidence for the multi-seam mining proposed in the ULD Seam at ACP is limited to only a few sites where multi-seam mining has been practiced. The approach used for this assessment is based on empirical estimation of maximum subsidence using data presented by Li et al (2010) and maximum subsidence of 85% of the total seam thickness mined.

The distribution of subsidence is based on the results of numerical modelling that takes into account the interaction of offset chain pillars. Tilts and strains are estimated using maximum subsidence and the approach outlined by Holla (1991) for single seam operations in the Western Coalfield. The approach used is intended to be conservative so as to provide a generally upper bound estimate of subsidence parameters for assessment purposes. The results of subsidence monitoring over early panels will provide a strong basis to refine subsidence estimates in later panels.

Maximum incremental subsidence associated with mining the ULD Seam is expected to by typically 2.4-2.5m but range up to 3.4m in areas where the nominal ULD extraction thickness is greater and destabilisation of the PG Seam pillars may cause additional subsidence. The cumulative maximum subsidence from mining in both seams is expected to be typically less than 4.0m but up to 4.5m in the vicinity of Longwall 7B and Longwall 8.

Based on these levels of subsidence and previous experience in single seams, maximum incremental tilts of up to 180mm/m are expected in the eastern part of the proposed ULD Seam mining area and up to 100mm/m in the western part where the overburden depth is greater. Maximum incremental strains are expected to range up to 70mm/m in the shallower eastern areas and 30-40mm/m in the deeper western areas. Maximum strains and tilts are expected to be sensitive to the relative positions of goaf edges in the two seams.

Numerical modelling indicates that whereas in a single seam operation, subsidence movements are primarily limited to within the area of the longwall panel being mined, multiple seam subsidence may extend outside the boundary of the mined ULD panel to the goaf edge of overlying longwall panels in the PG Seam.

Estimates of subsidence behaviour above panel extensions where only the ULD Seam is mined are based on the previous subsidence monitoring at ACP in the PG Seam and general experience of subsidence behaviour in the Hunter Valley and elsewhere. Maximum subsidence over the centre of each of these panels longwall panel is expected to be less than 1.6m with maximum strain of 30mm/m and maximum tilt of 70mm/m. These estimates are expected to have similar accuracy to single seam subsidence estimates previously presented for the ACP.

The ULD Seam longwall panel layout has been designed so that the maximum total subsidence below the alignment of the proposed diversion of Bowmans Creek is less than 0.1m and in most areas less than 20mm.

Notwithstanding the low levels of subsidence expected at the diversion, nearby subsidence of up to an estimated 4.5m at the completion of both the PG and ULD Seams is expected to leave the creek diversion elevated above parts of the original creek bed. Rainfall runoff in the vicinity of the original creek bed and water that overtops Bowmans Creek during a flood event is expected to flow to the lowest point in the landform and pool there. The disturbance to the overburden strata caused by the subsidence may provide sufficient hydraulic connection between the surface and the mine for some of this pooled water to flow down into the mine. The potential for this inflow is addressed by Aquaterra (2009) in their Bowmans Creek Diversion: Groundwater Impact Assessment Report (and the report being prepared for submission with this EP).

SCT understand that filling of subsidence troughs and reshaping of the subsided landform is to be undertaken in some areas to maintain a free draining landform where practicable. This work is expected to also be effective in reducing inflow into the mine.

Other natural features likely to be impacted by the proposed mining include subsidence movements within two remnant woodlands, one a Voluntary Conservation Area located immediately north of the Property 130 boundary, and the other alongside a tributary of Bowmans Creek near the middle of Longwall 4. Both areas are understood to include sites containing Aboriginal artefacts and nesting sites for native birds. SCT understand that subsidence impacts associated with archaeological heritage sites and impacts on natural flora and fauna are addressed in separate reports prepared as part of this EP.

Surface infrastructure not owned by ACOL that is expected to be significantly impacted by the proposed mining includes an Ausgrid 132kV electricity transmission line that crosses the southern end of the mining area, a proposed 11kV electricity transmission line that is yet to be constructed but follows the same alignment, and a soon to be constructed section of the Lemington Road diversion around the Ravensworth North

Project that follows the line of an existing section of Brunkers Lane. This infrastructure is expected to require significant monitoring, mitigation and remediation effort.

A MacGen gas pipeline easement crosses the northern end of the proposed mining area. SCT understands that there are currently no immediate plans to use this easement and if a gas pipeline were constructed, it would be integrated with the ACP gas drainage network to accommodate subsidence movements. Other surface infrastructure not owned by ACOL that is expected to be impacted by subsidence or subsidence mitigation words includes several local electricity transmission lines, the access road to Property No 130 used daily by a milk tanker and the property residents, farming infrastructure on Property 130 such as contour drains, fences, water troughs, buried water pipes, and tracks, and buried Telstra cables used primarily for servicing Property 130 and ACOL owned houses, mining infrastructure in the northwest corner of the mining area including mine water supply and waste disposal pipes and access roads, and a gauging station on Bowmans Creek.

RUM is currently developing a multi-seam underground longwall operation that shares a lease boundary with the ACOL lease and includes RUM's No 5 Ventilation Shaft. Main heading pillars at RUM are located next to the ACP lease boundary. The stability of the main heading roadways and pillars is not expected to be affected by the proposed mining, but a more detailed assessment of the potential interaction is recommended once the geometries are known.

The No 5 Ventilation Shaft is located 150m from the goaf edge of Longwall 8 and is protected by a horizontal offset from mining greater than 0.7 times depth (equivalent to 35° angle of draw). The shaft may experience low level lateral shearing as a result of the proposed mining in the ULD Seam but these movements are not expected to affect its serviceability.

There is some potential for mine water that may pond in the ACP underground mine to flow through the barrier into RUM either during operations at ACP or subsequently.

Infrastructure in the area not owned by ACOL but not expected to be significantly impacted by subsidence includes the New England Highway and bridge over Bowmans Creek, the 132kV and 66kV electricity transmission lines that run alongside the New England Highway, a buried fibre optic cable alongside the highway, Narama Dam, the residence and farm buildings on Property 130, a proposed 330kV electricity line to be constructed on the barrier between RUM and ACP Longwall 8.

ACOL owned infrastructure that is expected to be impacted by the proposed mining includes access roads, farm dams, several residences, farm buildings, and buried water supply pipes. Potential impacts on two ACOL shafts are considered unlikely to be significant. Existing management plans for the PG Seam are expected to be appropriate for managing the subsidence impacts on ACOL infrastructure associated with proposed mining in the ULD Seam.

Additional subsidence monitoring is recommended during mining of the ULD Seam because of the unique opportunity afforded by the proposed mining layouts in the PG and ULD Seams.

7. REFERENCES

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8. GLOSSARY OF TERMS

The coal mining and subsidence terminologies used in this report have specific meanings that are explained in this glossary.

Angle of Draw — The angle between a vertical line from the goaf edge to the surface and a line drawn from the goaf edge at seam level to a point on the surface where surface subsidence decreases below 20mm subsidence. An angle of 26.5° is equivalent to a distance from the goaf edge of half the overburden depth.

Barrier Pillar — A block of unmined coal adjacent to a longwall panel large enough to limit surface subsidence to low levels.

Chain Pillar — The block of coal left unmined between two longwall panels. The surface above a chain pillar experiences subsidence effects from both adjacent longwall panels.

Critical Width — The longwall panel width where a further increase in panel width does not increase the maximum subsidence in the centre of the panel.

Cumulative Subsidence — The total subsidence caused by mining more than one seam.

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. This height affects the magnitude of surface subsidence but may be more or less than the seam height.

Goaf — The void left once all the coal has been mined.

Goaf Edge — The edge of the goaf and a point that defines the transition from solid coal to fully extracted coal.

Incremental Subsidence — The increment of subsidence caused by the extraction of each successive seam mined.

Longwall Panel — A block of coal that is fully extracted by longwall mining techniques. The panel is usually defined by the installation road at the start of the panel, chain pillars on either side, and a finish line at the end of the panel.

Maximum Subsidence	The greatest subsidence observed or predicted within a longwall panel.
Overburden Depth	The thickness of strata between the surface and the seam being mined.
Panel Width	The shortest distance across a longwall panel
Pillar Subsidence	The minimum subsidence over a chain pillar.
Subcritical Subsidence	Characteristic subsidence behaviour of the overburden strata when the panel width is less than critical width. Subcritical panel width is characterised by some degree of overburden bridging across the panel and maximum subsidence less than the subsidence that would occur for the same depth and seam thickness if the panel were of supercritical width.
Subsidence Profile	The subsidence along a cross section or long section of the surface above a longwall panel
Supercritical Subsidence	Characteristic subsidence behaviour of the overburden strata when the panel width is greater than critical width. Maximum subsidence is reached in the central part of supercritical width panels.