Strata Control Technology

REPORT TO:

ASHTON COAL OPERATIONS PTY LTD

Subsidence Assessment for the Extraction Plan for Longwalls 201-204 in the Upper Lower Liddell Seam

ASH4552_REV3

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REPORT TO James Barben
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SUBJECT Subsidence Assessment for the Extraction Plan for Longwalls 201-204 in the Upper Lower Liddell Seam

REPORT NO ASH4552_REV3

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SUMMARY

Ashton Coal Operations Pty Ltd (ACOL) is proposing to mine Longwalls 201-204 in the Upper Lower Liddell (ULLD) Seam as part of their ongoing operations near Camberwell in the Hunter Valley of NSW. In accordance with the development consent DA 309-11-2001i, 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 subsidence and predicted 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 201-204 in the ULLD Seam for the Ashton Coal Project (ACP).

The surface impacts from mining the ULLD seam are not expected to be significantly different compared to the impacts that were successfully managed during mining in the previous two seams. The subsidence impacts are expected to remain within the Subsidence Performance Measures of development consent DA 309-11-2001i.

Longwalls 201-204 are located substantially on ACOL owned land and substantially within the existing footprint of previous mining in the Pikes Gully (PG) and Upper Liddell (ULD) Seams. The start of Longwall 201 in the far southeast of the EP Application Area (EP area) is located on privately owned land known as Property 130. Longwall mining in the overlying PG and ULD Seams has already been completed over much of the EP area. Although mining in the PG and ULD Seams is not the focus of this assessment, the cumulative effects of mining all three seams is nevertheless taken into account where relevant.

There are challenges for estimating subsidence parameters in a multi-seam environment because of the limited subsidence monitoring data available for multi-seam subsidence in NSW and elsewhere around the world. However, the previous experience of subsidence monitoring in the PG and ULD Seams at the ACP site provides a strong basis to identify the various components that contribute to the subsidence movements observed to date.

This previous monitoring indicates two distinct types of behaviour, the behaviour that occurs generally over the offset panels and the behaviour that occurs over stacked goaf edges where the goaf edges in two seams are located directly above each other. Subsidence movements observed generally over the offset geometries show incremental increases in maximum subsidence but the strains and tilts are of a similar magnitude to single seam mining. By contrast, tilts and strains observed over stacked goaf edges are significantly higher than the general background levels of tilt and strain. The assessments of surface features and infrastructure affected by stacked goaf edges are relatively limited in extent and are considered separately as special cases.

The following table details the estimated incremental and cumulative subsidence parameters for both general background subsidence and for stacked goaf edges.

ULLD Seam Longwall Panels And Depth (m) and Depth Range (in brackets)	Longwall 201-204 ULLD Seam Predictions				
	ULLD Subs (m)	ULLD Tilt (mm/m)		ULLD Strain (mm/m)	
	General and Stacked Edges	General	Stacked Edges	General	Stacked Edges
Incremental Subsidence Parameters					
LW201 115 (105-175)	2.5	76	150	43	76
LW202 135 (125-190)	2.7	70	140	40	70
LW203 155 (145-210)	2.7	61	120	35	61
LW204 165 (150-230)	2.7	57	120	33	57
Cumulative Subsidence Parameters					
LW201 115 (105-175)	5.7	120	350	74	170
LW202 135 (125-190)	5.7	110	300	63	150
LW203 155 (145-210)	5.8	94	260	56	130
LW204 165 (150-230)	5.7	86	240	52	120

Predicted maximum cumulative subsidence for the ULLD Seam in the Bowmans Creek Diversion Environmental Assessment was 5.8m, maximum tilt was 240mm/m and maximum strain was 110mm/m. The maximum tilt is increased for stacked edges in this EP for stacked edges above Longwalls 201-203 consistent with Condition 32 (e) of Schedule 3 - Environmental Performance Conditions of the modified development consent (DA 309-11-2001i)

Unconventional subsidence movements associated with ripples, steps, and far field horizontal movements are expected to be similar or less than they were during previous mining in the PG and ULD Seams. Any such movements are expected to be generally insignificant by comparison with the general ground movements associated with mining three seams, particularly ground movements above stacked goaf edges.

Bowmans Creek, the Hunter River and Glennies Creek and associated alluvium are sufficiently remote from Longwalls 201-204 in the ULLD Seam for there to be no significant additional impacts from the proposed panels.

Changes to the natural landform over Longwalls 201-204, are expected to cause some ponding in the natural drainage lines that generally flow down to the Bowmans Creek floodplain including increased ponding within a series of farm dams.

A small portion of Property 130 that was previously mined under in the ULD Seam is proposed to be mined under at the start of Longwall 201. A small farm dam is the only additional farm infrastructure not previously mined under. Mining in the ULLD Seam is estimated to cause incremental subsidence to give a maximum cumulative subsidence below Property 130 of about 3.0 m. No stacked goaf edges are created in this area so tilts and strains are expected to be similar to the general background levels which were experienced previously during mining in the ULD Seam. Re-grading of the access road, re-tensioning of fences, and back filling any open surface cracks that may develop is expected to be required to manage the surface impacts.

The access road to Property 130 crosses stacked goaf edges at the northern end of Longwall 204 and the southern end of Longwall 202. Both of these crossings are in areas where there is no practical alternative route available to be used for daily access to Property 130. Incremental subsidence of 2.7 m is expected during the mining of Longwalls 201-204 with maximum tilts and strains expected at locations of the stacked goaf edges, most likely in areas that were remediated previously during mining in the PG and ULD Seams. The access roads are expected to require mitigation and remediation works on an ongoing basis during the period of active mining in order for daily access to be maintained. The access road is expected to be impacted by inundation as a result of changes to the landform. This ponding is likely to affect both the primary and alternative access roads at their northern junction.

The buried telecommunications line (Telstra cable) to Property 130 is considered to be susceptible to damage from the proposed mining of Longwalls 201-203. Although this cable has been undermined by both the PG and ULD Seam longwalls with no damage or impacts to serviceability reported, the mining of the ULLD seam is expected to increase the ground strain levels, especially at the stacked goaf edges, to levels that may cause an interruption to service. Options to avoid loss of service include relocating the cable sections likely to be impacted away from stacked goaf edges, uncovering these sections of the cable, repairing as necessary, or replacing the fixed land line with a mobile service.

The only significant major infrastructure in the area of the EP area likely to be impacted by mining subsidence is the 132 kV electricity transmission line owned by Ausgrid that crosses the southern ends of all the panels. A specific assessment for these poles has been carried out separately and the poles on the line have been upgraded to better accommodate subsidence movements. The program of upgrading and structural assessment allowed the subsidence movements from the PG and ULD Seam mining to be successfully managed in the past. This previous work and continuing assessment is expected to allow successful management of the subsidence movements expected from the mining of Longwalls 201-204 in the ULLD Seam. Ponding has potential to cause inundation at one pole. Filling or local regrading of the landform is likely to be effective for managing this ponding.

A local area 11 kV electricity line owned by Ausgrid crosses the north-west section of the EP area above Longwall 204. The single pole structures on this line have tolerated the subsidence movements experienced from mining in the PG and ULD Seams. Subsidence effects on this line are expected to be nearly double at two stacked goaf edges. Sheaving of the conductors on poles located in areas of high tilt particularly at the stacked goaf edges is recommended to ensure that insulators and supporting cross members do not become overloaded by changes in conductor tension. In areas of high tilt, the line may need to be temporarily supported during the period of active mining and some poles may need to be replaced once mining is complete. An option to re-route approximately 650 m of the line onto the solid coal barrier to the west of Longwall 204 may also be cost effective.

Other major infrastructure in the general vicinity but outside the EP area includes the New England Highway, Lemington Road, Ausgrid electricity lines (132 kV electricity line and a combined 66 kV/11kV electricity line), a Ravensworth Operations 33 kV electricity line and a Transgrid 330 kV electricity line alongside Lemington Road, an AAPT fibre optic cable, a Ravensworth Operations fibre optic cable, and a Telstra cable corridor. These infrastructure are all well outside the EP area in locations where no subsidence movements are expected from the mining of Longwalls 201-204. Impacts to farm infrastructure by proposed mining in the ULLD Seam are expected to be similar to the types of impacts that occurred during mining in the PG and ULD Seams. Farm buildings constructed with brick and masonry walls or large floor slabs may be perceptibly impacted during the period of active mining depending on their location relative to the panel. Other infrastructure such as farm dams, water reticulation systems, fences, gates, cattle grids, and stockyards may also be impacted depending on their specific location. In general, these impacts can most easily be managed as and when they occur. A program of regular visual inspection and appropriate remediation if required is considered suitable to manage these impacts.

Most of the surface infrastructure located within the EP area is owned by ACOL. Buried water pipelines are the only infrastructure that has potential to have impact beyond operational issues. These pipelines could pose an environmental risk if they were to rupture. Strategies to manage this potential include, uncovering a section of the pipeline, monitoring performance with emergency shutdown provisions or isolating the line during the period of active mining and testing prior to returning to service may also provide a satisfactory management option.

Other ACOL owned operational infrastructure includes ventilation shafts, fan installations, a central methane gas drainage plant and associated infrastructure, BOC nitrogen gas plant, associated boreholes with collar hardware and surface pipeline networks, and mine dewatering system equipment as well as 11kV electricity line to supply this infrastructure. Some minor impacts are expected however these are expected to be able to be effectively managed by existing ACOL subsidence management systems.

The existing program of subsidence monitoring has proven to be suitable to assess the nature of subsidence related ground movements in a multi-seam environment and to manage the associated impacts. It is recommended that this program continues for the proposed ULLD Seam mining area to enhance the existing double seam database and take advantage of the unique opportunity to capture high confidence subsidence measurements over regular triple seam longwall panels for the first time.

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1. INTRODUCTION

Ashton Coal Operations Pty Ltd (ACOL) is proposing to mine Longwalls 201-204 in the Upper Lower Liddell (ULLD) Seam as part of their ongoing operations near Camberwell in the Hunter Valley of NSW. In accordance with the development consent DA 309-11-2001i, 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 subsidence and predicted 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 201-204 in the ULLD Seam for the Ashton Coal Project (ACP).

Longwall mining in the EP Application Area (EP area) has already been completed in the overlying Pikes Gully (PG) and Upper Liddell (ULD) Seams over much of the area of proposed mining. Although mining in the PG and ULD Seams is not the focus of this assessment, the cumulative effects of mining all three seams has nevertheless been taken into account where relevant.

It should be recognised that there are challenges for estimating subsidence behaviour in a multi-seam environment because of the limited subsidence monitoring data available for multi-seam subsidence in NSW and elsewhere around the world. However, the previous experience of subsidence monitoring in the PG and ULD Seams at the ACP site provides a strong basis to identify the various components that contribute to the subsidence movements observed to date.

The expected subsidence in the ULLD Seam has been estimated from these components with what is considered to be reasonable confidence. Notwithstanding the likelihood of the predications being less accurate than might be possible for single seam mining, the consequences of any variations in the actual incremental subsidence are not expected to significantly influence the cumulative impacts given the subsidence movements that have already occurred across the site.

This report is structured to provide a brief overview of the site, a review of the subsidence experience to date, estimates of the subsidence expected as a result of the proposed mining in the ULLD Seam, and a description of the subsidence impacts that are expected as a result of these movements on the various surface features and surface infrastructure located across the area.

2. SITE DESCRIPTION

This section presents a description of the general area of the ACP including the proposed mining geometry, overburden depth, and other parameters of relevance to a subsidence assessment. A general overview of surface features likely to be impacted by mining is also included.

2.1 Proposed Mining Geometry

Figure 1 shows a plan of the proposed mining geometry for Longwalls 201 to 204 superimposed onto a 1:25,000 series topographic series map of the area. This map is updated to reflect recent changes in surface features and infrastructure and shows previous mining in the PG and ULD Seams.

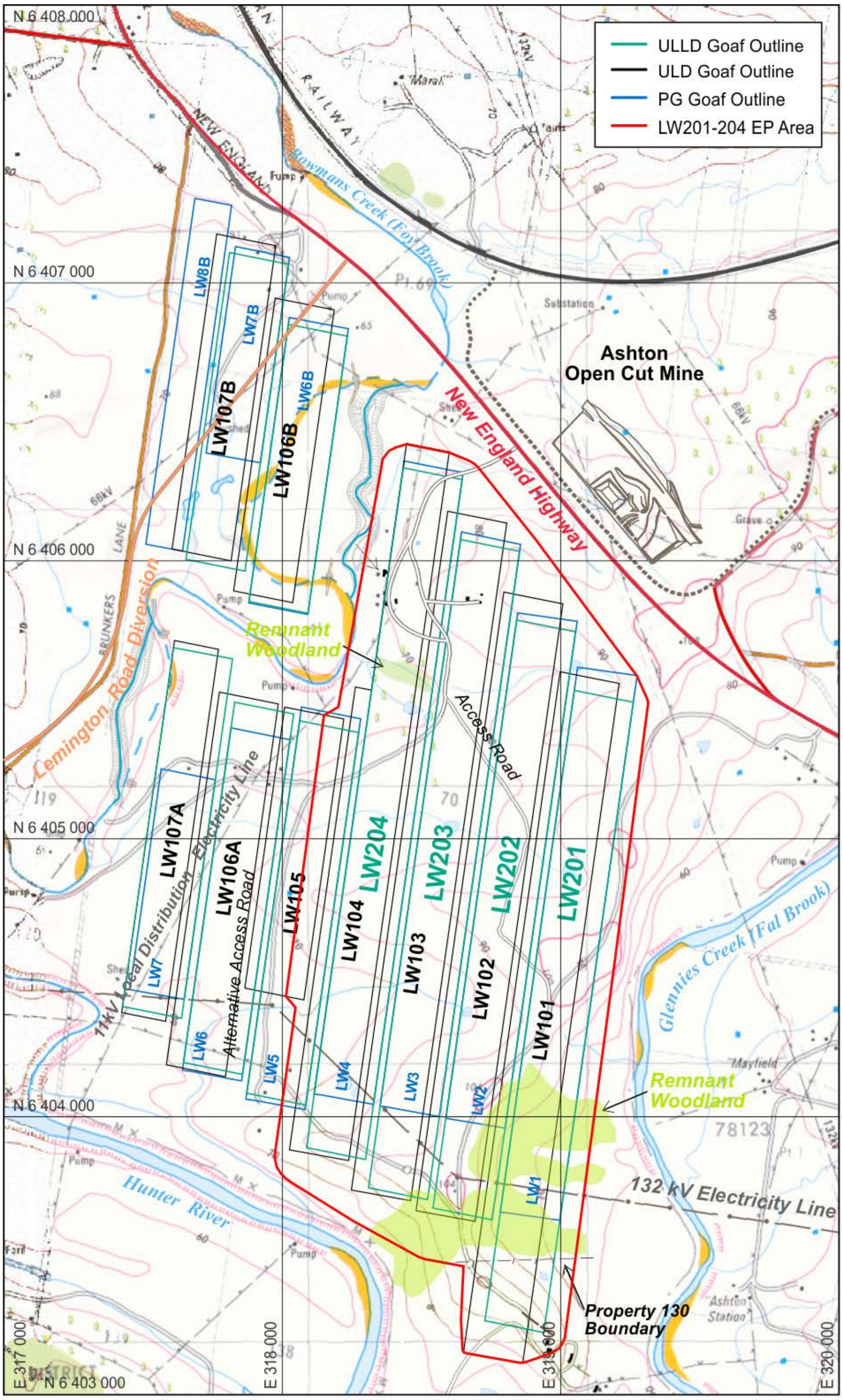

Figure 1: Site Plan showing proposed mining within the EP Area superimposed onto a 1:25,000 topographic series map of the area updated to reflect changes since the map was originally produced in 1982.

Figure 1 shows the EP area. This EP area was determined as encompassing all the areas likely to be impacted by vertical subsidence movements. For the purposes of defining the boundary of the Longwall 201-204 EP area, a distance equal to overburden depth outside the goaf edge was used except at the finishing end of each panel where this distance was reduced to half the overburden depth. These distances are based on previous experience at the site, consideration of the irregular geometries, and expectations of the likely extent of subsidence effects.

The concept of an angle of draw is commonly used to define an EP area. This concept becomes somewhat less meaningful in a multi-seam mining environment because of the influence of previous mining and the interaction of overlying geometries. For instance, following the completion of mining Longwall 102, the incremental vertical subsidence above the solid ULD Seam coal on the western side of the panel reduced to less than 20 mm at a distance of 120 m or approximately equal to the overburden depth. However, previous mining in the PG Seam had caused some 1.5 m of subsidence at this location. Conversely, where there is a solid goaf edge in the outermost seam, subsidence behaviour beyond this goaf edge in a multi-seam environment is similar to subsidence behaviour in a single seam mining environment.

Incremental vertical subsidence is generally expected to be less than 20 mm within the EP area. Horizontal movements of greater than 20 mm and other effects may extend outside the EP area but their impacts are expected to be imperceptible for all practical purposes. Irrespective of the limit of the EP area, sensitive features located outside the area that have potential to be affected by mining subsidence impacts are included in this assessment.

At the Ashton underground mine, Longwalls 1 – 8 were mined in the PG Seam, the uppermost of the four mining horizons proposed to be mined. The ULD Seam is located approximately 35-40 m below the PG Seam. To date Longwalls 101-105 have been mined in the ULD Seam. Longwall 106A is currently in progress. These ULD Seam longwalls are located in substantially the same area as Longwalls 1 – 4 in the PG Seam except that the geometry of the ULD Seam longwalls is offset 60 m to the west and the start and finishing lines for the longwalls are different. Longwalls 201–204 in the ULLD Seam are positioned directly below the PG Seam layout and are therefore offset 60 m to the east of the ULD Seam Longwalls 101-104.

The longwall voids are 216 m wide. The inter-panel chain pillars are 25 m wide. These dimensions are the same as for both the PG and ULD Seams except along a section of the ULD Seam Longwall 104 where the panel width is reduced by 60 m to protect the eastern diversion of Bowmans Creek. In this area the goaf edge in the ULD Seam aligns with the goaf edge of Longwall 4 in the PG Seam.

The starting and finishing points are generally different in each of the three seams. The various combinations complicate estimation of the subsidence behaviour in these areas.

The interburden thickness between the ULD and ULLD Seams ranges from about 15 m to 30 m, but is more generally around 20-25 m within the area of Longwalls 201-204.

Table 1 summarises the proposed ULLD Seam longwall panel dimensions.

Table 1: Proposed Longwall 201 to 204 Panel Dimensions

Panel	Nominal Gateroad Width (m)	Chain Pillar Width Rib to Rib (m)	LW Void Width (m)	LW Void Length (m)
LW201	5.4	24.6	215.8	2290
LW202	5.4	24.6	215.8	2137
LW203	5.4	24.6	215.8	2355
LW204	5.4	24.6	215.8	2470

Figure 2 shows the isopachs of overburden depth to the ULLD Seam. The overburden depth ranges from approximately 105 m in the north eastern corner of Longwall 201 to around 230 m in the south western corner of Longwall 204, mainly as a result of the general dip of the strata to the west-southwest. The range in the depth of cover for individual panels is approximately 105 m to 175 m for Longwall 201, 125 m to 190 m for Longwall 202, 145 m to 210 m for Longwall 203 and 150 m to 230 m over Longwall 204.

The ULLD Seam mining height is planned to be similar to the mining height in the two previous seams. Within the EP area the ULLD Seam thickness varies from a localised low of 1.7 m in the middle of Longwalls 201 and 202 and up to around 2.8 m at the ends of the panels. The extraction height for Longwalls 201-204 is understood to be planned to range between 2.3 m and 2.8 m to accommodate the practical operational requirements of the mining equipment. Within the EP area, the height of previous longwall extraction in both the PG and ULD Seams has generally averaged about 2.5 m with variations of about ±0.3 m.

2.2 Overview of Surface Features and Surface Infrastructure

Figure 3 shows the proposed mining layout superimposed onto a more detailed plan of the natural surface features and surface infrastructure. The EP area is predominantly cattle grazing land owned by ACOL. There is a small area of privately owned land in the south east known as Property 130.

2.2.1 Surface Features

The surface topography in the EP area is dominated by a steeply rising ridge line adjacent to Glennies Creek above Longwall 201 from which the ground slopes west toward Bowmans Creek (Foy Brook) floodplain and the broader Hunter River floodplain to the south. There are a number of ephemeral streams and drainage lines that flow mainly in the direction of Bowmans Creek. A series of farm dams are located on these drainage lines. Most of these dams were constructed prior to mining.

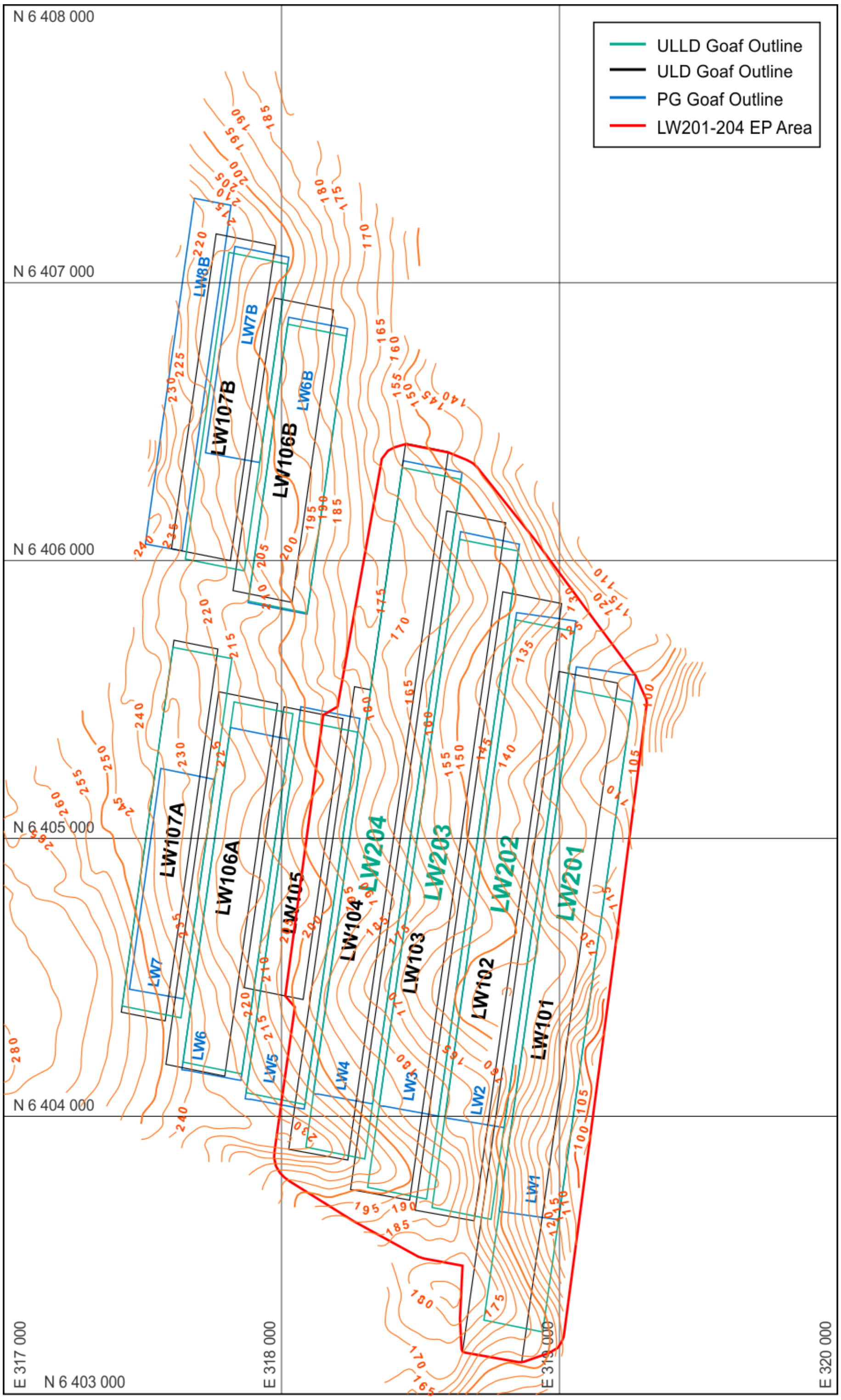

Figure 2: Overburden depth isopachs to the ULLD Seam.

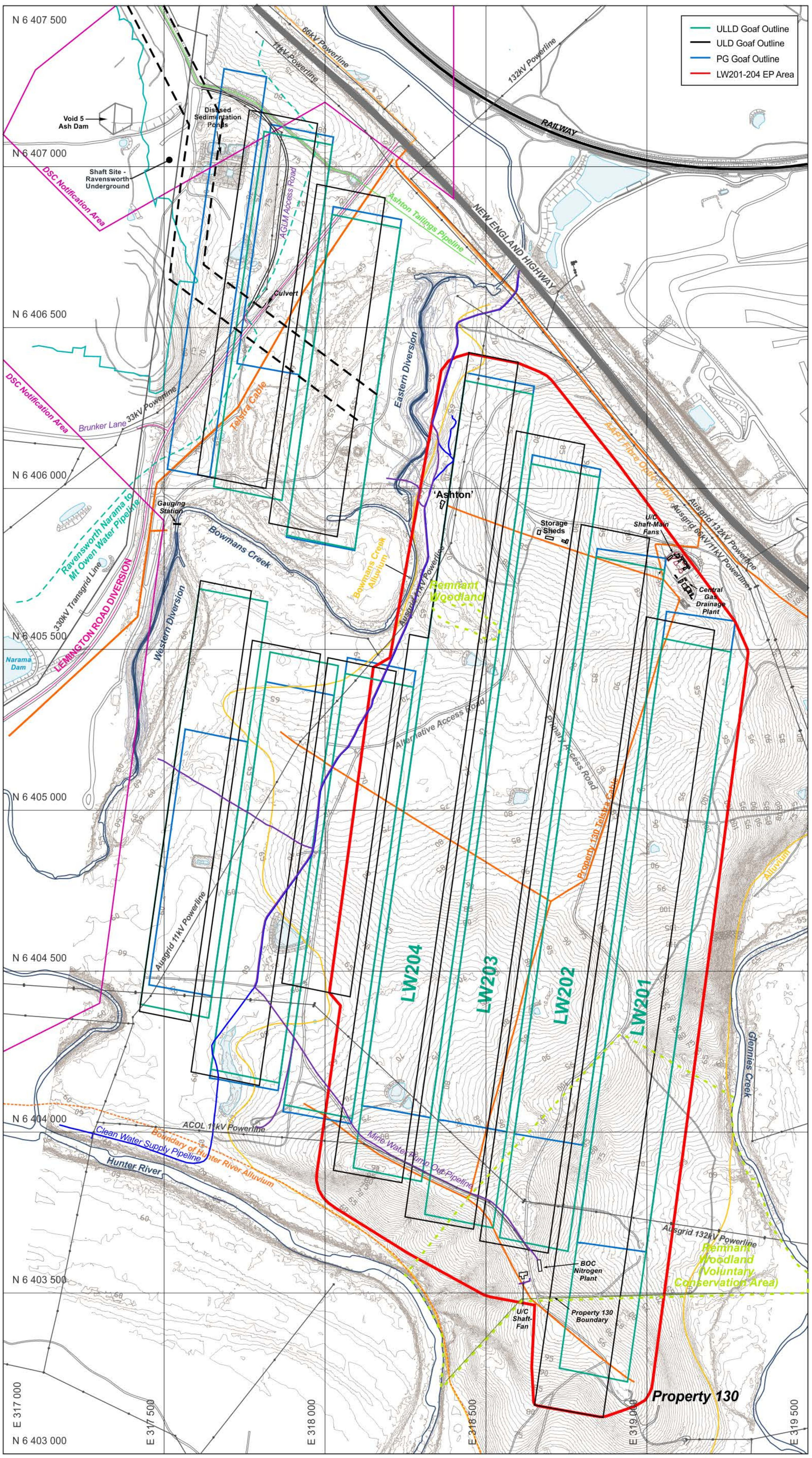

Figure 3: Surface features and surface infrastructure.

On the western edge of the EP area, Bowmans Creek flows down a channel incised into a broad floodplain and the adjacent slopes. This watercourse was previously diverted by ACOL in two locations to allow for more efficient recovery of the coal resource. A portion of both the original creek alignment and the eastern diversion channel are within the EP area adjacent to the northern part of Longwall 204.

The Hunter River, as defined by the edge of the Hunter River Alluvium, is located outside the southern edge of the EP area and comes within approximately 160 m and 150 m respectively of the corners of Longwalls 203 and 204. In both cases, the offset distances are greater than in the corresponding overlying ULD Seam.

Glennies Creek meanders along the eastern side of the proposed mining but is outside the EP area. The boundary of alluvium associated with the Hunter River, Bowmans Creek and Glennies Creek bounds the EP area on three sides however Longwalls 201-204 are not located directly below any alluvium.

The EP area is predominantly cattle grazing land owned by ACOL other than a small part in the far southeast known as Property 130. Property 130 is a privately owned dairy farm. This property is serviced on a daily basis with access across ACOL land located above the underground mine provided via a 'right of way' agreement. The access road is an unsealed road that traverses the EP area from north to south. An alternative access road is available across the central part of the mining area. This alternative access can be used during periods when the primary right of way is being undermined. The access road is not duplicated in the north and south of the EP area.

Other natural features include two remnant woodlands, one of these is a Voluntary Conservation Area located immediately north of the Property 130 boundary, and the other woodland is alongside a tributary of Bowmans Creek near the middle of Longwall 204. Aboriginal artefact sites and nesting sites for native birds, including threatened species, are understood to be present in both woodlands. Potential impacts to these features are addressed in separate specialist reports.

Heritage items in the area comprise mainly archaeological scatter sites. The management of heritage features are outlined in ACOL's Aboriginal Cultural Heritage Management Plan and are not discussed further in this report.

The assessment of subsidence impacts to landform and groundwater are limited in this report to an overview of the landform changes and nature of surface cracking. Impacts on the landform and groundwater systems are assessed in separate specialist reports.

2.2.2 Surface Infrastructure

Table 2 presents a list of surface features and infrastructure located within or adjacent to the EP area.

Table 2: Surface and Sub-surface Infrastructure in the General Vicinity of Longwalls 201–204

Infrastructure	Brief Description	Owner / Authority	Within EP Area
Roads	Lemington Road	Singleton Shire Council	No
	New England Highway including bridge over Bowmans Creek	Roads and Maritime Services	No
	Access roads	AGLM / ACOL	No & Yes
	Primary Right of Way Access Road to Property 130	ACOL / Property 130	Yes & No
	Alternative Access Road to Property 130	ACOL	Yes
Electricity Transmission Lines	132 kV traversing the southern extent of the ACOL Mining Lease	Ausgrid	Yes
	132 kV and 66/11 kV lines parallel to New England Highway	Ausgrid	No
	11 kV line traversing ACP	Ausgrid	Yes
	330 kV line along western lease boundary	Transgrid	No
	33 kV transmission line on western side of Lemington Road	Glencore - Ravensworth Operations	No
Dams	Void 5 Ash Dam DSC Notification Area	AGLM	No
	Surface water dams	AGLM and ACOL	No
	Sedimentation dams	AGLM	No
Buried Pipelines	315 mm PN10 PE100 pipeline from Narama Dam to Mt Owen	Glencore - Ravensworth Operations	No
	Gas Pipeline Easement	AGLM	No
Buried Communication Lines	Telstra cables providing service to subdivided blocks on Ravensworth Operations	Glencore - Ravensworth Operations / Telstra	No
	Telstra cables providing service to NOW Stream Gauging Station on Bowman's Creek	NOW / Telstra	No
	Telstra cables providing service to Property No. 130	Property 130 / Telstra	Yes
	Sydney to Brisbane fibre optic cable	AAPT	No
	Fibre Optic Cable to Ravensworth Operations	Glencore - Ravensworth Operations	No
Underground Mines	Ravensworth Underground Mine and No. 5 Shaft	Glencore – RUM	No
Other (Non ACOL)	Fences, gates, cattle grids	AGLM	No
	Stream Gauging Station 'Foy Brook' Station No. 210130, on Bowmans Creek	NOW	No
Farm buildings	Rural residences / farm sheds)	Property 130	No & Yes
Dams	Farm dam	Property 130 / ACOL	Yes
Roads	Access road and tracks	Property 130	Yes
Fences	Boundary fencing, internal fencing, gates and cattle grids	Property 130	Yes

Non-mining related infrastructure located within the EP area includes a Ausgrid 132 kV electricity line that traverses the southern end of all the ACP longwall panels, an Ausgrid local area 11kV electricity line on the western edge of the EP area, a buried Telstra copper wire telecommunication line servicing Property 130, and various farming related infrastructure such as fences, farm dams, and access roads, most of which are owned by ACOL.

An assessment of the impacts of mining subsidence on these items of infrastructure located within the EP area is presented in Section 5 of this report.

Major infrastructure located in the general vicinity of the EP area but beyond the zone of influence of subsidence impacts includes the recently constructed Lemington Road diversion, a fibre optic cable servicing Ravensworth Operations, the New England Highway to the north of the mining area including a bridge over Bowmans Creek, a buried AAPT fibre optic cable alongside the New England Highway, four high voltage electricity lines, two alongside the New England Highway, one alongside Lemington Road and a newly constructed 330 kV Transgrid transmission line located on the western side of Lemington Road, a river gauging station on Bowmans Creek owned by NSW Office of Water (NOW), and Narama Dam owned by Ravensworth. Other mining related infrastructure associated with Ravensworth Operations is all located west of Lemington Road and well outside of the EP area.

The impacts of mining subsidence on these items of infrastructure outside the EP area are generally not considered further in this report.

Table 3 presents a list of ACOL owned infrastructure.

ACOL owned infrastructure located within the EP area includes several farm buildings and houses (not occupied), farm dams, farm roads, fences, a fresh water polyline from the Hunter River and the mine water pump out polyline from the southern end of the panels with associated pumping equipment, ventilation shafts with fan installations, a methane gas drainage plant and associated infrastructure, BOC nitrogen gas plant and associated boreholes with collar hardware and surface pipeline networks as well as 11kV electricity line to supply this infrastructure.

2.3 Approved Subsidence and Performance Measures

Predictions of subsidence movements for mining in the ULLD Seam were made in SCT Report ASH3584 "Multi-Seam Subsidence Assessment for Ashton Coal Mine Longwalls 5 to 8". These predictions were used in the Bowmans Creek Diversion Environmental Assessment (BCDEA) for MOD 6 to DA 309-11-2001i and represent the subsidence movements approved for the site.

Table 4 presents a summary of the expected subsidence movements as presented in SCT Report ASH3584.

The Extraction Plan process (Condition 32 (e) of Schedule 3 - Environmental Performance Conditions - DA 309-11-2001i) provides a basis to revise previous subsidence predictions as more understanding of subsidence behaviour is developed at each site from the available monitoring data. Item 3.1 of the Statement of Commitments in Schedule C of DA 309-11-2001i also highlights this opportunity.

Table 3: ACOL Owned Surface and Sub-surface Infrastructure

ACOL Owned Infrastructure		Within EP Area
Roads	Access road and tracks	Yes
Farm buildings	Rural residences (incl. various sheds)	Yes
	Farm sheds and equipment storage sheds	Yes
Fences	Boundary fencing, internal fencing, gates and cattle grids	Yes
Pipelines	Hunter River pipeline (200 mm PE80 PN8)	Yes
	Underground borehole pump pipeline (355 mm PE100 PN8)	Yes
	Clean water line (90OD PN12.5 PE100)	No
	Mine water line (250OD PN20 HDPE PE100)	No
	Two tailings lines (280OD PN20 HDPE PE100)	No
	Decant return (250OD PN20 HDPE PE100)	No
11kV Electricity line	Supply for upcast shaft, BOC Plant and mine water pumping	Yes
Mine Water Pumping	Borehole collar pumping equipment	Yes
Surface water storages	Farm dams	Yes
Landform	Bowmans Creek diversion	Yes
Main upcast shaft	Mains Fans installation and equipment	Yes
Gas drainage plant	Gas collection, processing and flaring facilities and equipment	Yes
Upcast shaft	Backroad Fan installation and equipment	Yes
BOC nitrogen plant	Gas storage and distribution equipment including pipelines	Yes
Gas Drainage System	Goaf gas drainage boreholes, collar equipment and collection pipelines (Existing and Additional Proposed)	Yes

Table 4: Summary of Expected Subsidence Movements (from SCT Report ASH3584)

SEAM	MAXIMUM SUBSIDENCE (M)	MAXIMUM TILT (MM/M)	MAXIMUM STRAIN (MM/M)
PIKES GULLY	1.6	70	30
UPPER LIDDELL	3.7	150	70
UPPER LOWER LIDDELL	5.8	240	110
LOWER BARRETT	8.3	350	160

Performance measures for subsidence are included in Table 10 of Condition 29 in Schedule 3 - Environmental Performance Conditions of the modified development consent (DA 309-11-2001i). These performance measures are reproduced here as Table 5.

Table 5: Subsidence Performance Measures

Water	
Bowmans Creek	No greater subsidence impact or environmental consequences than predicted in the EA and the previous EIAs
Bowmans Creek – Eastern and Western Diversions	Hydraulically and geomorphologically stable
Bowmans Creek alluvial aquifer	No greater subsidence impact or environmental consequences than predicted in the EA and the previous EIAs No greater subsidence impact or
Biodiversity	
Threatened species, populations, habitat or ecological communities	Negligible impact
Aboriginal Heritage Features	
Waterhole Site	Negligible impact
Other Aboriginal Heritage sites	No greater subsidence impact or environmental consequences than approved under a permit issued under section 90 of the *National Parks and Wildlife Act 1974*
Built Features	
New England Highway, including the bridge over Bomans Creek	Always safe and serviceable. Damage that does not affect safety or serviceability must be fully repairable, and must be fully repaired
Lemington Road and Bunkers Lane	In accordance with recommendations of the report prepared under condition 36
Other built features, including other public infrastructure	Always safe. Serviceability should be maintained wherever practicable. Loss of serviceability must be fully compensated. Damage must be fully repaired or replaced, or else fully compensated.
Public Safety	
Public safety	No additional risk due to mining

3. REVIEW OF PREVIOUS SUBSIDENCE MONITORING

In this section, previous multi-seam subsidence monitoring results from Longwalls 101-104 in the ULD Seam are presented as a basis to estimate the subsidence behaviour and seam interaction effects that may be expected over Longwalls 201- 204 in the ULLD Seam.

3.1 Subsidence Monitoring

Subsidence monitoring has been undertaken at the ACP since the commencement of longwall operations in early 2007. The subsidence behaviour observed in the PG Seam was consistent with the subsidence behaviour expected in panels of supercritical width. Supercritical width is a term used in subsidence engineering to mean that the panels are wide enough for full subsidence to develop over the panel.

Subsidence monitoring above Longwalls 101-104 provides significant insight into the mechanics of multi-seam subsidence at the ACP site. Remote from the pillar and goaf edges, the subsidence behaviour of the ULD Seam is consistent with that observed for the PG Seam. The cross panel horizontal movements are similar for the first four ULD Seam panels indicating a consistent mechanism. Where there is variation in the long panel horizontal movements between adjacent ULD Seam longwalls similar differences were noted between the corresponding PG Seam longwalls in the overlying seam, indicating a geological influence in both seams.

The results of the ULD Seam monitoring are presented in detail in SCT Report ASH4557 "Longwall 104 End of Panel Subsidence Report". These results show that subsidence behaviour falls into two categories depending on the relative geometries of mining in two seams. In most areas, subsidence behaviour can be categorised as general background subsidence behaviour with tilts and strains of similar magnitude to those observed in the PG Seam. Where the goaf edges in two or more seams are located directly above each other, a different style of behaviour is apparent.

Figure 4 shows the latest subsidence monitoring results from XL5 Line, the main cross-panel subsidence line over all the southern panels.

Figure 5 shows subsidence monitoring results from the northern end of Longwall 102 where this panel mined directly under an existing goaf edge in the PG Seam so that the goaf edges in the PG and ULD Seams were momentarily stacked directly above each other. Although Longwall 103 and 104 were mined in a similar stacked goaf edge configuration at their northern ends, the Longwall 102 data is considered to be the most comprehensive dataset because of the position of the monitoring lines relative to the longwall voids and the frequency of surveys that were conducted during the progress of the goaf edge/solid coal undercutting.

Table 6 presents a summary of the subsidence movements observed over Longwalls 102-104 for general background conditions. Table 7 presents a summary of subsidence movements observed above stacked goaf edges.

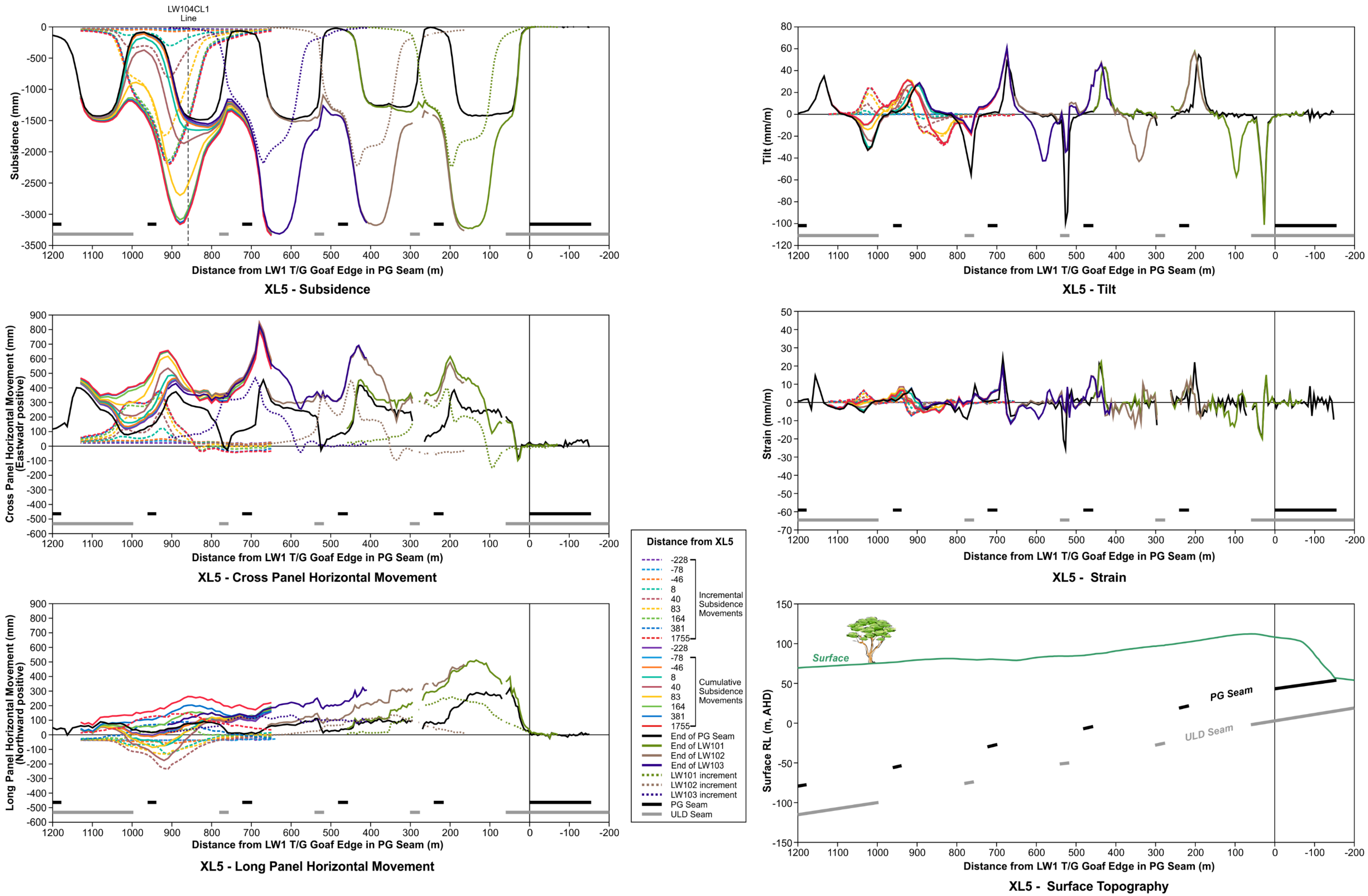

Figure 4: Subsidence movements observed on Line XL5 during mining of Longwall 104 (including Longwalls 101-103).

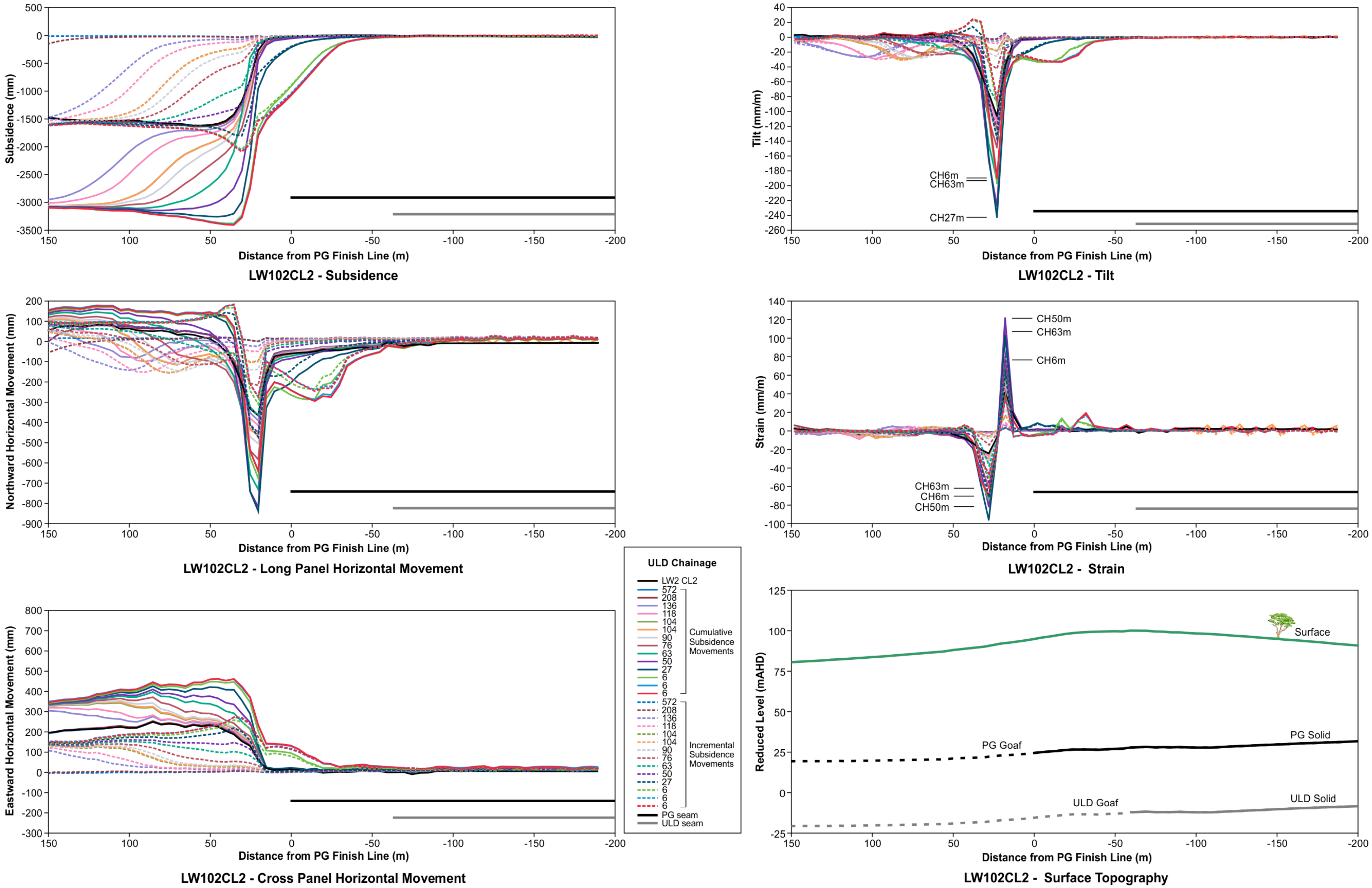

Figure 5: Subsidence monitoring results at the northern end of Longwall 102 where this longwall mined directly below an existing goaf edge in the PG Seam to create a stacked geometry.

Table 6: Background Subsidence Measured for ULD Seam Longwalls (in Offset Geometry)

Longwall	Incremental Subsidence ULD Seam (m)	Max Incremental Tilt (mm/m)	Max Incremental Strain (mm/m)	Max Cumulative Subsidence (m)	Max Cumulative Tilt (mm/m)	Max Cumulative Strain (mm/m)
Measured on LW102CL1 background	2.1	33	14	3.2	38	12
Measured on LW102XL5 background	2.3	66	18	3.2	54	24
Measured on LW102CL2 background	2.1	27	5	3.2	33	4
Measured on LW103CL1 background	2.3	45	12	3.4	41	10
Measured on LW103XL5 background	2.1	43	12	3.4	61	25
Measured on LW103CL2 background	1.7	25	14	3.0	63	40
Measured on LW104CL1 background	2.3	36	27	3.1	34	21
Measured on LW104XL5 background	2.2	28	7	3.3	33	9
Measured on LW104CL2 background	1.7	35	8	3.0	39	29

Table 7: Subsidence Measured at Stacked Goaf Edges for ULD Seam Longwalls

Longwall	Incremental Subsidence ULD Seam (m)	Max Incremental Tilt (mm/m)	Max Incremental Strain (mm/m)	Max Cumulative Subsidence (m)	Max Cumulative Tilt (mm/m)	Max Cumulative Strain (mm/m)
Measured on LW102CL2 stacked	2.1	87	65	3.4	193	107
Measured on LW103CL2 stacked	1.7	106	25	3.2	168	46
Measured on LW104XL10 stacked	1.9	97	19	3.2	126	27
Measured on LW104CL2 stacked	1.8	89	44	2.9	120	59

3.2 General Subsidence Behaviour

The subsidence monitoring above Longwalls 101-105 indicates that for an offset mining geometry, the maximum subsidence can be estimated with reasonable confidence and the subsidence profile is also relatively predictable although the specific mechanics of the interaction of the two seams needs to be recognised.

Where panels in the two seams overlap in an offset geometry, maximum cumulative subsidence from mining both seams is in the order of 62-72% of the combined mining thickness of both seams (compared to 50-60% for the first seam mined) and incremental subsidence is in the order of 72-83% of the height of the second seam mined.

Figure 6 shows a summary of the incremental subsidence movements measured over Longwalls 101-105 in the ULD Seam. The incremental profiles are adjusted so that the subsidence from each panel is overlaid relative to a single panel.

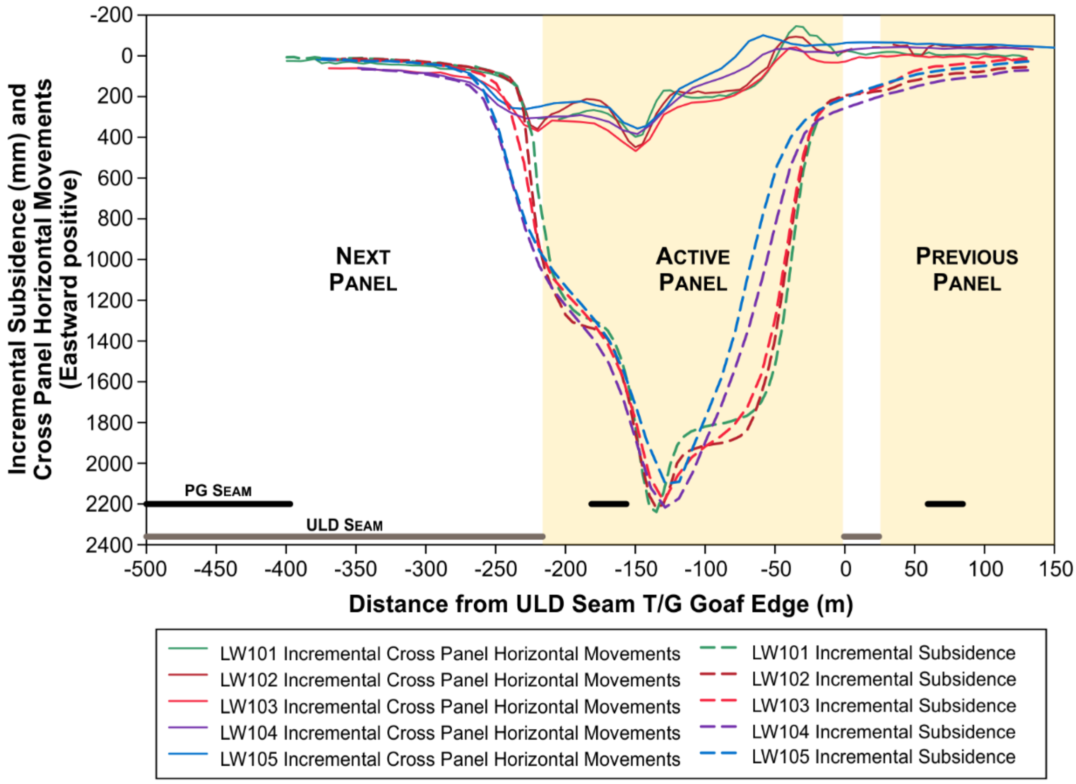

Figure 6: Incremental Vertical Subsidence and Cross Panel Horizontal Movements and for LW101, LW102, LW103, LW104 and LW105.

The subsidence behaviour observed indicates:

- regular, repeatable form of incremental subsidence
- general smoothing and reduction in peak values with increasing overburden depth
- maximum vertical and horizontal movements occur substantially within the footprint of the active panel
- movements over the previous panel are less than 200mm and insignificant for all practical purposes
- the influence of latent subsidence from mining in the PG Seam causes subsidence movements to extend over the next panel because the PG chain pillar is located on this side of the ULD panel.

The maximum values of subsidence parameters such as strain and tilt are typically of a similar or lower magnitude to the subsidence parameters measured in the first seam mined despite the greater subsidence. The maximum values of tilt and strain are typically less than the maximum calculated assuming single seam mining conditions but occasionally increase to the same magnitude as parameters measured during mining in the PG Seam. This behaviour is thought to be due to a general softening effect of the multi-seam mining and the difference in behaviour between strata that is undisturbed by previous mining and strata that has already been subsided.

3.3 Stacked Goaf Edge

A different behaviour is observed in areas where overlying goaf edges interact to form a stacked goaf edge. At these stacked goaf edges and particularly when the deeper seam has undercut the upper seam by a distance about equal to the interburden depth between seams, transient tilts and strains have been recorded as being much higher than elsewhere.

At a stacked goaf edge where the lower seam is mined into solid from below an existing goaf in the upper seam, a double goaf edge is formed. Maximum tilts in these areas are observed to be about double the maximum general background levels. Horizontal strains are observed to peak at about four times background levels observed more generally along the panel.

Where mining in the lower seam has continued beyond the stacked goaf edge and beyond the undercut these high values associated with the stacked goaf edge decrease towards the more general levels measured elsewhere along the panel.

The presence of the transition from goaf to solid at a goaf edge created by mining in the overlying seam appears to focus additional subsidence movements associated with mining the deeper seam into the same location. The strains and tilts reach a maximum when the lower seam has mined past the upper seam goaf edge by a distance of about equal to the separation between the two seams (i.e. about 30 m for the ULD and PG Seams) or where the caving of the goaf at the lower seam longwall face intersects the goaf edge in the upper seam.

Where the lower seam is mined from a single seam situation to under an overlying goaf, a variation of stacked goaf edge is formed, but the subsidence parameters are of similar magnitude to single seam mining. The nature of the subsidence profile in this circumstance is significantly different with a large block above the start of the overlying panel subsiding en masse as the existing goaf edge is mined under in the lower seam.

The direction of mining under an existing goaf is therefore very important in terms of the surface effects that develop. Mining from a goaf under solid leads to a stacked goaf edge that produces very high tilts and strains and much higher than the general background values. Mining from solid to under a goaf produces an en masse subsidence effect with tilts and strains that are comparable to general background levels.

3.4 Other Parameters

Incremental vertical subsidence above the ULD Seam chain pillars between Longwall 101 and Longwall 104 is approximately 200-300 mm. This subsidence is much higher than the elastic strata compression of 20-30 mm observed above the chain pillars formed by mining in the PG Seam.

Horizontal subsidence movements measured above the first four longwalls in the ULD Seam are typically in the range of 20-30% of the vertical subsidence. There is a strong similarity in the characteristics and distribution of horizontal subsidence movements between these longwalls indicating a consistent mechanism driving the horizontal movements and a strong influence of strata dilation in this process.

The maximum total horizontal movement above each of the first four ULD seam longwalls is typically about 0.8 m. This total horizontal movement is dominated by the cumulative cross panel movements which generally reaches a magnitude of about 0.7 m to the east (i.e. uphill) at a location near the western edge of the overlap between each of the ULD Seam longwalls and the corresponding PG Seam longwall above. The magnitude, direction, and form of the total horizontal movement are consistent with the cross-panel horizontal movement observed during mining of the PG Seam.

3.5 Implications for Predictions

It is clear from this data that multi-seam subsidence presents a number of challenges for describing the subsidence behaviour. In a single seam mining environment, the subsidence behaviour is consistent with and largely controlled by the mining geometry in the seam that is mined. In a multi-seam mining environment, the presence of previous mining in an overlying seam means that the starting point for subsidence estimation for the second seam is not necessarily zero subsidence and the subsidence behaviour is no longer simply a geometrical function of the seam being mined, but rather a sometimes complex interaction of the geometries in both seams.

At some locations, the incremental subsidence may be a higher proportion of the seam thickness in the second seam mined when subsidence associated with mining in the first seam is recovered. This phenomenon, known as recovering latent subsidence, is particularly evident around the edges of the first seam panels where the overburden strata was supported on the chain pillars and abutments following mining in the first seam and full subsidence did not occur at that time.

When the second seam mines under the chain pillars and other abutment edges, the strata above the first seam chain pillar and abutment edges is disturbed by mining and the supporting effect around the edges is lost. As a result, the ground above the edge of the first seam chain pillar and other abutments subsides by an increased amount that includes subsidence that did not occur during mining in the first seam. An understanding of both the magnitude and distribution of this latent incremental subsidence is useful for estimating the likely cumulative subsidence profile for any future mining because the maximum subsidence is not simply the addition of all the maximum increments.

The concept of an angle of draw determined purely as a function of overburden depth becomes somewhat less meaningful in a multi-seam mining environment because of the influence of previous mining and the interaction of overlying geometries. Beyond the solid goaf edge in the outermost seam, angles of draw appear to have a similar magnitude in a multi-seam environment as they do in a single seam mining environment, but where there is an existing goaf, the concept of an angle of draw becomes less meaningful because of the previous subsidence that has occurred.

3.6 Improved Prediction Methodology

The method used to predict subsidence for the ULD Seam longwalls was originally based on 80-85% of the combined seam mining thickness (after Li et al 2010). The guidelines presented by Holla (1991) for the Western Coalfields were used to estimate tilts and strains. These approaches appear to still be valid based on the comparison of past predictions with subsequent measurements, but there is clearly room for refinement now that multi-seam subsidence monitoring data is available.

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 mining thickness a more conservative approach has been adopted at ACP to date by using a maximum subsidence of 85% of combined mining thickness for the previous ULD Seam predictions.

The measurements from Longwalls 101-104 indicate that the maximum cumulative vertical subsidence was less than 75% of the combined seams extraction heights. The maximum incremental vertical displacement due to the recovery of latent subsidence adjacent to abutment or pillar edges was higher than 85% of the ULD Seam mining thickness but this latent subsidence is subsidence that did not occur during mining in the first seam. Latent subsidence effects need to be determined separately from the general body subsidence.

The monitoring data from Longwalls 101-104 indicates that the use of 85% of the combined seam mining heights is a reasonably conservative approach to estimating maximum cumulative subsidence. A refinement to this estimating method is used to predict the total subsidence profile for the proposed ULLD Seam mining. This method estimates the incremental subsidence i.e. the subsidence associated with mining in the ULLD Seam, additional to subsidence that previously occurred due to mining in the PG and ULD Seams.

Maximum strains and tilts are sometimes of interest on an incremental basis, i.e. the influence of each seam separately, and sometimes on a cumulative basis, i.e. as the total of all seams. The monitoring data from Longwalls 101 to 104 indicates that strains and tilts for general background conditions in an offset geometry are quite different to, and much less than, the strains and tilts observed at stacked goaf edges. Maximum strains and tilts may therefore need to be estimated for four different conditions, incremental and cumulative and general background and stacked goaf edges.

To estimate maximum strains and tilts, the Holla approach captures the key drivers and allows the differences between background offset geometries and stacked geometries to be accommodated by varying the K value (K = a constant of proportionality).

Table 8 presents a summary of the K values indicated from analysis of the subsidence database from Longwalls 101-104 that appear suitable to use with the Holla approach to provide a reasonable and conservative estimate of the measured strains and tilts for the four combinations of incremental and cumulative subsidence and general background and stacked goaf edges. The strain values are maximum values and do not distinguish between tension and compression.

Table 8: K values suitable to use with the Holla approach for estimating maximum tilts and strains in multi-seam conditions

K values	Tilt		Strain	
	General	Stacked edges	General	Stacked edges
Incremental	3500	7000	2000	3500
Cumulative	2500	7000	1500	3500

Using these K values, estimates for the maximum values for tilts and strains expected for the proposed ULLD Seam mining at the stacked goaf edge locations can be calculated. The appropriate K values to use at any given location depend on consideration of the direction of mining and how closely the geometry represents a stacked goaf edge.

3.7 Unconventional Subsidence Movements

Unconventional subsidence movements considered in this section include far-field horizontal movements outside the mining area, horizontal movements associated with strata dilation in uneven topography, shear movements on low strength bedding planes leading to the formation of ripples on the surface, and stepping in the ground surface associated with geological structure.

At the ACP, all four of these mechanisms were observed to occur during mining in the PG and ULD Seams. However, none of the occurrences of these unconventional movements caused significant impacts to surface infrastructure, particularly by comparison with the subsidence movements associated with stacked goaf edges in multiple seams.

Far field horizontal subsidence movements observed outside the mining area during mining in the PG Seam and ULD Seams were so small (less than 100 mm at 50 m) and changed so gradually as to be imperceptible for all practical purposes. The same low magnitudes of horizontal movement outside the mining area are expected during mining in the ULLD Seam. The mechanism that is recognised to cause far-field horizontal movements is associated with horizontal stress relief. Mining in the PG Seam is likely to have relieved most of the horizontal stress directly over the mining area so that any changes to horizontal stress associated with mining subsequent seams are likely to be small.

Strata dilation effects are generally observed as valley closure. At the ACP there has been no direct evidence of valley closure, but there has been a consistent pattern of horizontal movement in an upslope direction over each of the mined panels. This pattern is considered to be associated with the same mechanism that causes valley closure. However at the ACP, the general dip of the strata is to the west at a rate greater than the topography. This general dip has the effect of causing the dilating strata to move upslope toward the free surface in a similar way that dilating strata moves toward the free surface of a valley in horizontally bedded strata. The magnitude of this upslope horizontal movement has been about 200 mm over each panel and similar movement is expected above proposed panels mined in the ULLD Seam.

There is evidence of low strength bedding plane shear movements causing a surface ripple near the northern end of Longwalls 4 and 104. Differential horizontal movements of about 500 mm were measured across this ripple on the longitudinal line at the end of Longwall 4 at the completion of mining in the PG Seam. A further 300 mm were measured during mining of the ULD Seam. In both cases some regrading of the access road was undertaken to smooth the effects of the ripple. Some further differential movement is expected during mining in the ULLD Seam, but the incremental magnitude is expected to continue to decrease with each additional seam mined.

A step change was observed at the location of a geological dyke structure above Longwalls 2 and 102. This step change occurred in an area of bushland remote from any surface infrastructure. It is possible that similar behaviour may occur again during mining of Longwall 202, but the surface impacts are not considered likely to be significant. A remediation strategy involving ripping the surface is expected to be effective.

4. ESTIMATES OF SUBSIDENCE BEHAVIOUR FOR ULLD SEAM MINING

In this section, subsidence and subsidence parameters expected over the proposed longwall panels are estimated based on a review of the subsidence data and prediction methodologies presented in Section 3.

4.1 Subsidence

Subsidence from mining Longwalls 201-204 in the ULLD Seam is expected to cause additional incremental subsidence of up to 2.7 m. The total cumulative subsidence is expected to be up to 5.8 m in the central part of areas where there is overlap between longwall panels in three seams.

A conservative approach is adopted for estimating the total subsidence. The estimated incremental subsidence profile for the ULLD Seam is based on 85% of the planned mining height of this seam plus an allowance for the amount of latent subsidence to be recovered from around pillar and abutment edges in the overlying seam (or seams). The allowance for latent subsidence is somewhat interpretative but is consistent with improved understandings of multi-seam subsidence gained from the monitoring conducted to date.

Figure 7 shows the estimated incremental subsidence profile and cross-section for the Longwalls 201-204. The predicted cumulative subsidence profile estimated for the ULLD Seam is then derived by adding the incremental profile to the existing cumulative profile for the previous PG and ULD Seam mining. An additional factor is applied to allow for any remaining uncertainties around the extent of multi-seam interactions and any other variations in mining heights and overburden depths along the panels.

The total subsidence is generally slightly less than, but nevertheless comparable with, previous estimates for vertical subsidence from the mining of the first three seams at the ACP. However, as the actual measurements for the PG and ULD Seam mining to date have totalled less than 75% of the thickness of the combined seams extracted, this total cumulative estimate for the PG, ULD and ULLD Seams is at the low end of the 80-95% range of total extraction thickness suggested by Li et al. (2010) for longwall mining in more than two seams.

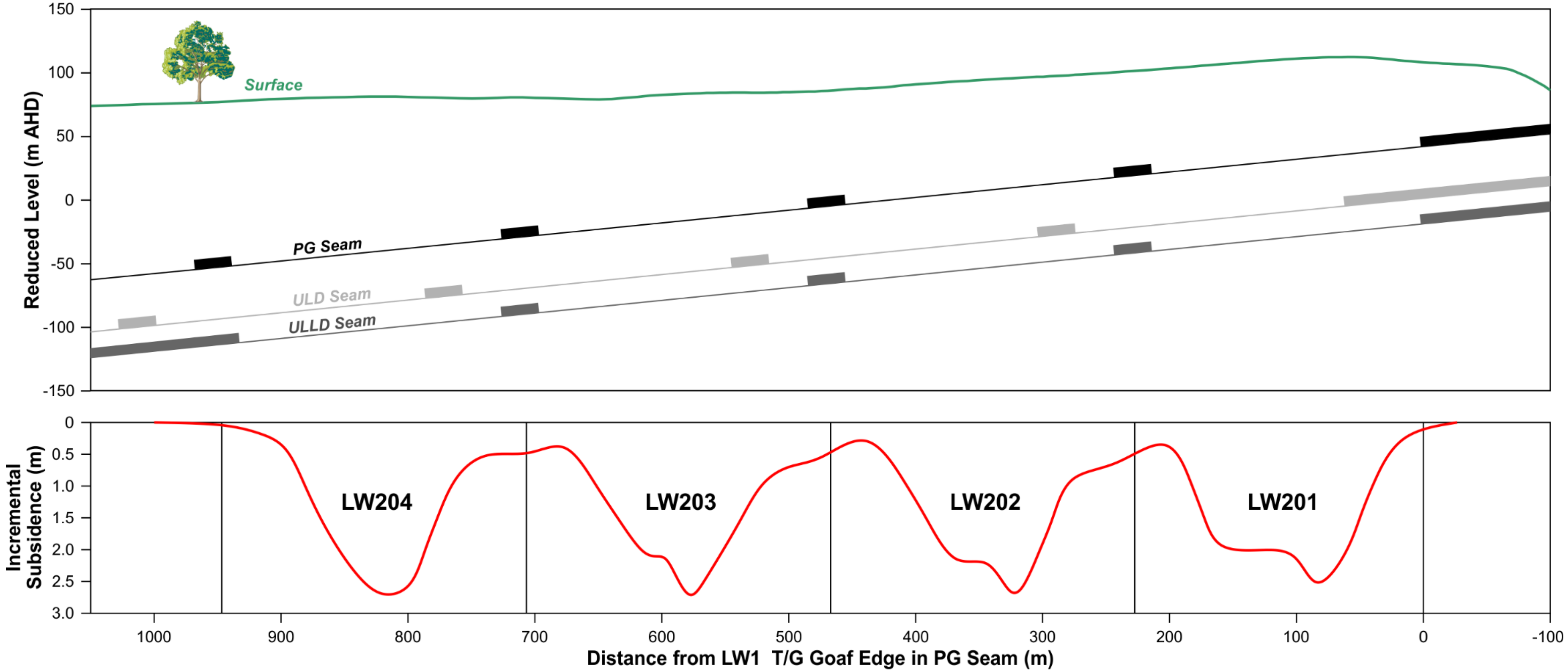

Figure 7: Incremental subsidence profile prediction for Longwalls 201 to 204 in the ULLD Seam (profile at XL5).

Figure 8 shows the predicted incremental subsidence contours for Longwalls 201-204. 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 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. Any variations in cutting heights that may occur for a range of reasons are then expected to proportionally influence the maximum subsidence and other subsidence parameters. However, given the existence of previous subsidence, the consequences of any variations from predictions are considered to be less for multi-seam mining at the ACP site than they would be for single seam mining where no previous subsidence has occurred.

At the completion of mining Longwalls 201-204, almost all the footprint of the ULLD Seam mining area is expected to have been subsided by more than 1 m and greater than 90% by more than 2 m. The proportion of the total area subsided by more than 3 m, 4 m, and 5 m is estimated to be 57%, 38%, and 26% respectively.

4.2 Tilts and Strains

Table 9 presents a summary of the subsidence parameters expected from mining Longwalls 201-204. The estimates are divided into two categories: general background and stacked goaf edges. The general background levels are expected across most of the mining area. The higher values of tilts and strains indicated for stacked goaf edges are expected to occur locally at specific, predictable locations.

Table 9: Incremental and Cumulative Subsidence Parameters Predicted for ULLD Seam Longwall Panels

ULLD Seam Longwall Panels And Depth (m) and Depth Range (in brackets)	Longwall 201-204 ULLD Seam Predictions				
	ULLD Subs (m)	ULLD Tilt (mm/m)		ULLD Strain (mm/m)	
	Background and Stacked Edges	General Background	Stacked Edges	General Background	Stacked Edges
Incremental Subsidence Parameters					
LW201 115 (105-175)	2.5	76	150	43	76
LW202 135 (125-190)	2.7	70	140	40	70
LW203 155 (145-210)	2.7	61	120	35	61
LW204 165 (150-230)	2.7	57	120	33	57
Cumulative Subsidence Parameters					
LW201 115 (105-175)	5.7	120	350	74	170
LW202 135 (125-190)	5.7	110	300	63	150
LW203 155 (145-210)	5.8	94	260	56	130
LW204 165 (150-230)	5.7	86	240	52	120

Figure 9 shows a summary of the areas where stacked geometries are likely to occur. Very high tilts and strains are expected in these areas leading to perceptible changes in elevation, large cracks, and local steep grades.

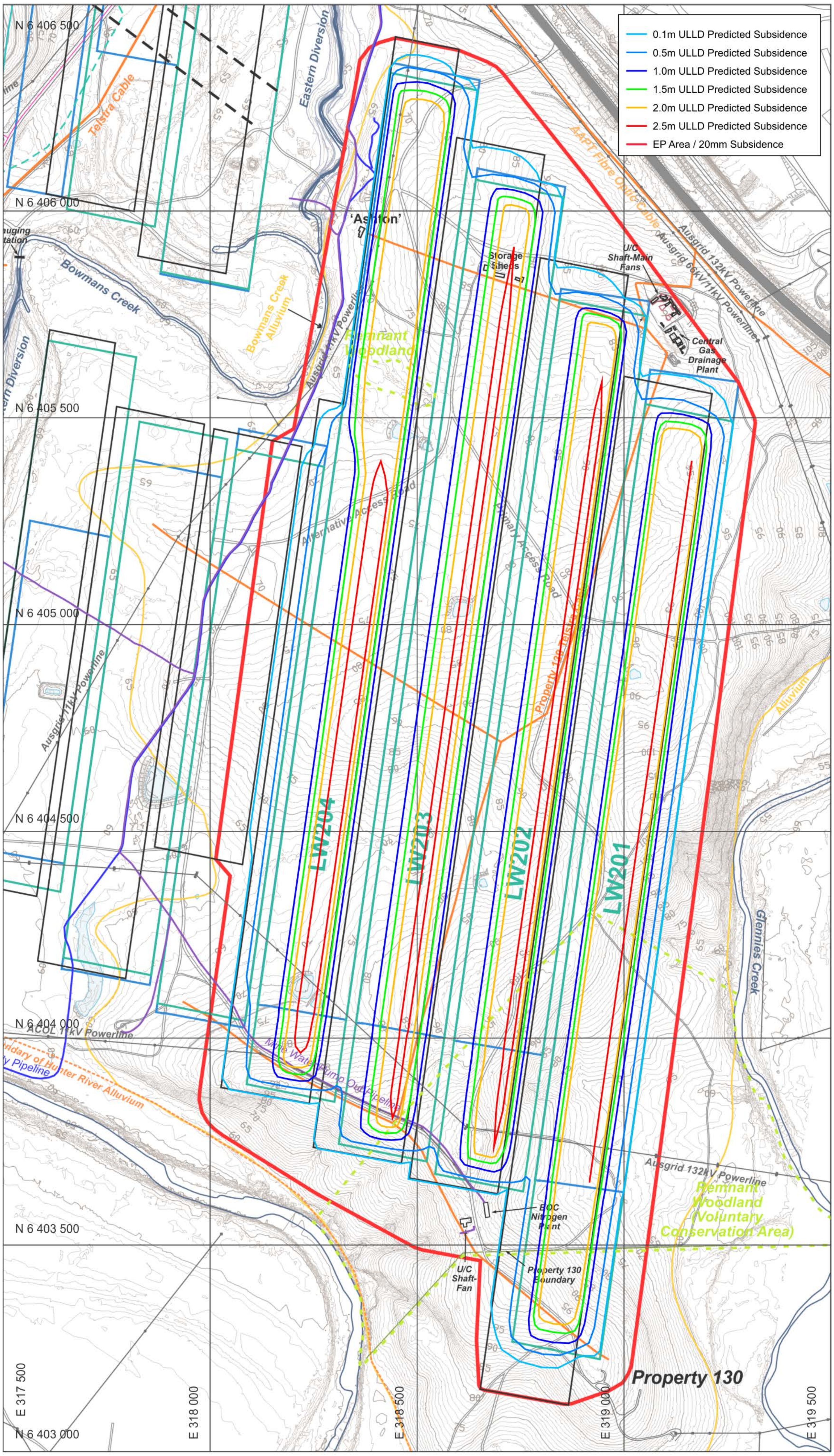

Figure 8: Incremental subsidence contours for Longwalls 201-204 in the ULLD Seam superimposed onto the surface feature and surface infrastructure plan.

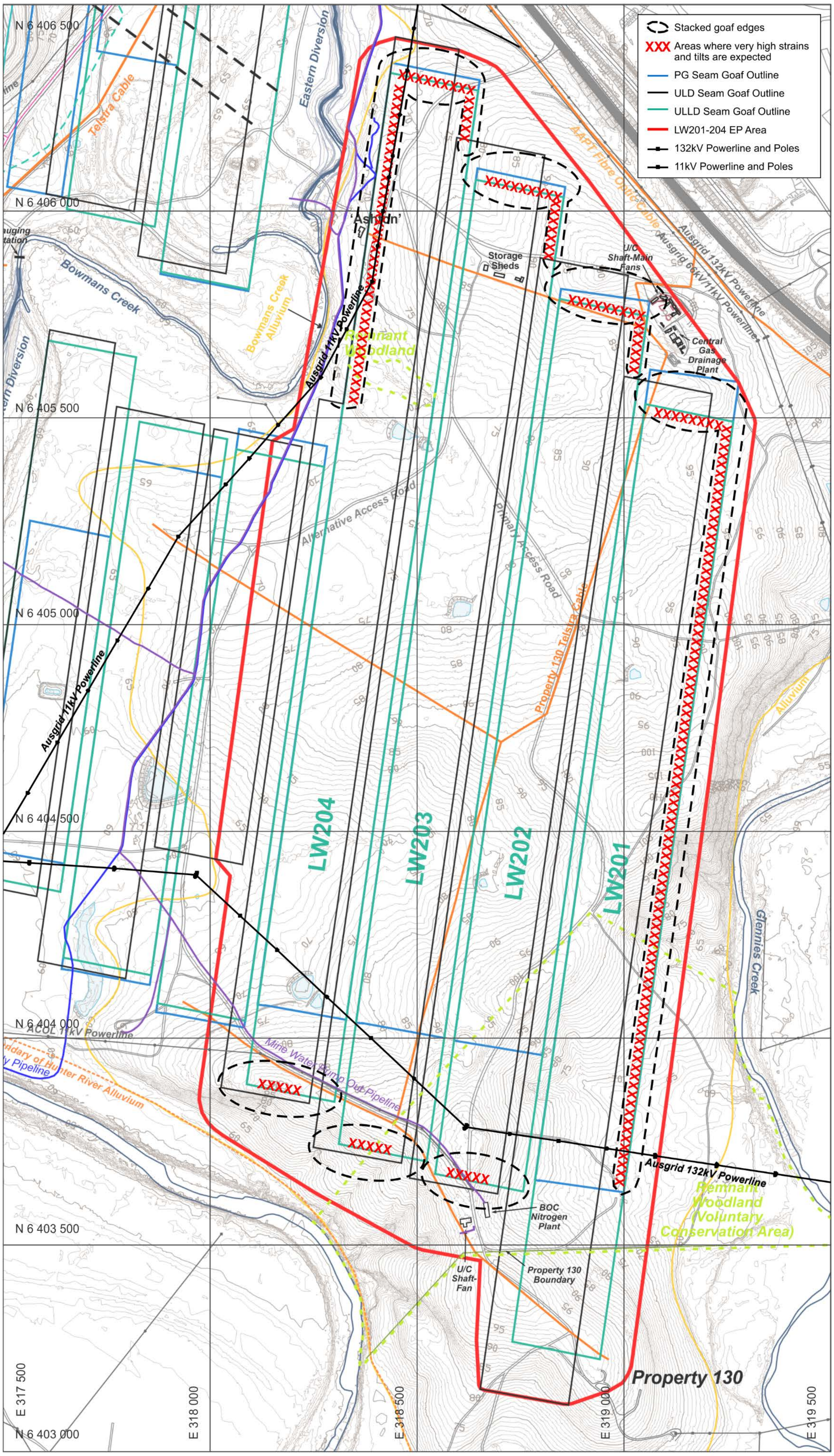

Figure 9: Location of stacked goaf edges for Longwalls 201-204 in the ULLD Seam superimposed onto the surface feature and surface infrastructure plan.

Areas where very high tilts and strains are expected above stacked goaf edges include the start of Longwalls 202, 203 and 204 and to a lesser extent, due to the ULD Seam mining, the finish lines of Longwalls 201-204. There are no areas in the proposed mine plan where an existing goaf edge is planned to be undercut.

The start lines of Longwalls 202, 203 and 204 are close to a double stacked goaf edge configuration because of the start positions of the PG Seam longwalls is further north.

At the finish lines of Longwalls 201-204 the extraction limit for each of the three seams is planned to terminate in close proximity to each other, but due to the offsets distances between these finish lines the subsidence profile for the triple goaf edges is more likely to represent a series of steps rather than a single sheer step that would occur at a truly stacked goaf edge.

A double stacked goaf edge is formed along the eastern side of Longwall 201 where the ULLD Seam layout is directly below the PG Seam layout. Solid ULD Seam coal remains, but the goaf edge is still a double stacked goaf edge similar to the goaf edge that has recently been formed in the ULD Seam along the northern end of Longwall 104.

A triple stacked permanent goaf edge is formed along the northern section of Longwall 204. Very high tilts and strains are expected in this area.

The triple stacked goaf edge is designed to protect Bowmans Creek. Subsidence monitoring to date confirms that the solid coal barrier pillars left in each seam is controlling subsidence over the coal barrier to less than 120 mm at the goaf edge and less than 20 mm at half depth. Horizontal movements are also limited and only extending about 40 m over the solid coal to the west of the goaf edge.

4.3 Compliance with Performance Measures and Comparison with Bowmans Creek Diversion Environmental Assessment

The estimate of total cumulative subsidence at the completion of mining in in the ULLD Seam predicted for the current EP is consistent with the maximum subsidence predicted in the BCDEA for the mining of the first three seams at the ACP.

The general background levels of tilts and strains predicted for Longwalls 201-204 in the ULLD Seam are also consistent with and less than the maxima predicted in the BCDEA.

Tilts and strains significantly higher than general background have been observed at stacked and undercut goaf edges during mining in the ULD Seam. While the vertical subsidence has been less than predicted, the tilt and strain levels at isolated stacked goaf edge locations have on occasion been greater than predictions. To date the impacts and consequences of these higher tilts and strains are negligible with any additional surface cracking effectively remediated using the existing subsidence management systems.

The mechanics that generate higher tilts and strains in multi-seam mining are now recognised. Higher levels of tilts and strains are now predicted for stacked geometries in the EP for the ULLD Seam based on the monitoring experience from the ULD Seam. These changes are consistent with Condition 32 (e) of Schedule 3 - Environmental Performance Conditions of the modified development consent (DA 309-11-2001i).

As demonstrated previously, compliance with the subsidence performance measures, detailed in Table 5, is expected to continue during the proposed mining of Longwalls 201-204 via the effective processes within existing Built Features, Public Safety, Rehabilitation, Water, Biodiversity, Land and Heritage management plans for the ACP site.

4.4 Reliability of Subsidence Estimates

Monitoring data from the mining of Longwalls 1-8 in the PG Seam and Longwalls 101-104 in the ULD Seam provides the opportunity to better understand the ground behaviour in response to multi-seam mining in a regular geometry. The mechanics involved and relationships between the various subsidence parameters have been inferred and quantified to give a higher level of confidence in the subsidence estimates for the ULLD Seam than was previously possible for the ULD Seam.

The subsidence estimates for proposed mining in the ULLD are considered to be somewhat less reliable than the predictions for mining in the PG Seam but the consequences of any variations from predictions are considered to be less because of the relatively high levels of previous subsidence.

Observations from around the temporary stacked goaf edges as they are undercut (and the recent permanent stacked goaf edge) as well as from the undermining of load bearing chain pillars and abutment edges for different mining directions have allowed quantification of both magnitude and the location of the recovered latent subsidence from around these edges.

The quantification of this latent subsidence and the corresponding horizontal movements as well as the ground behaviour at either end of the longwall panels has increased confidence in the subsidence predictions for the proposed ULLD Seam mining.

The challenge for the proposed ULLD Seam mining subsidence predictions remains in accurately estimating the profile of incremental subsidence and tilts and strains from the various components that are now recognised to contribute to this subsidence. Additional factors not significant in single seam mining such as direction of mining relative to existing goafs, separation between existing goafs, and latent subsidence effects have a significant influence on estimation of the subsidence profile and maximum tilt and strain.

With no available data from mining in the ULLD Seam, there is an element of uncertainty about the predictions, so some greater allowance for variation from predicted is appropriate and is included in the subsidence predictions provided.

5. ASSESSMENT OF SUBSIDENCE IMPACTS

In this section, the impacts of the expected subsidence movements on the natural features and surface improvements are described and assessed.

Table 10 presents a summary of the expected subsidence impacts to the significant features within or immediately adjacent to the EP area. Individual assessments for natural features and surface infrastructure are presented in more detail in the sections that follow.

The natural features and surface improvements in the proposed mining area have been identified on the basis of multiple site visits, information provided by ACOL, and the work of other specialists.

5.1 Natural Features

Natural features in or immediately adjacent to the EP area include:

- A section of the main channel of Bowmans Creek and a small part of the eastern diversion channel with associated alluvium.
- The Hunter River and associated alluvium.
- Two sections of remnant woodlands (one a Voluntary Conservation Area).
- A number of minor drainage lines and ephemeral streams.

Glennies Creek, the other major watercourse in the general area, is located to the east but well outside of the EP area.

5.1.1 Bowmans Creek

The main channel of Bowmans Creek, including the two diversions is fully protected from subsidence effects by solid coal barriers in the PG, ULD, and ULLD Seams.

The proposed layout in Longwalls 201-204 in the ULLD Seam is consistent with keeping all secondary extraction at least 40 m (in a horizontal direction) from the high bank of Bowmans Creek in its diverted function form as per the Statement of Commitments made for Longwalls 5 to 7 in the PG Seam in Schedule C of DA 309-11-2001i Mod-6 Item 5.3.

The recent monitoring conducted on XL10 subsidence line over Longwall 104 panel across to the oxbow section of Bowmans Creek indicates low levels of vertical displacement, horizontal movements, tilts and strains in the area above the solid coal barrier between the stacked goaf edge and the main channel of Bowmans Creek. Mining of Longwall 204 is not expected to change the high level of protection provided to Bowmans Creek by the existing barrier.

Table 10: Summary of Impacts to Surface Features

Feature	Section	Impact
Natural Features		
Bowmans Creek	5.1.1	No perceptible impacts.
Bowmans Creek Alluvium	5.1.2	No perceptible impacts.
Hunter River Alluvium	5.1.3	No additional impacts expected. Assessed in specialist report.
Remnant Woodlands	5.1.4	Assessed in specialist report.
Landform Drainage	5.1.5	General lowering of the landform by up to an additional 2.7 m (5.8 m in total) in some areas expected to cause ponding on drainage lines within the EP area. Steep grades and tensile cracking are expected at stacked goaf edges.
Infrastructure		
Property 130	5.2	Slightly greater but similar in nature to previous impacts requiring remediation measures.
Access Roads including right of way (ACOL and Property 130)	5.3.1	Additional incremental subsidence of up to 2.7m with high strains and tilts expected at the stacked goaf edges with ponding likely to occur at several places requiring mitigation and remediation measures to maintain accesses.
New England Highway	5.3.2	No perceptible subsidence impacts.
Ausgrid 132 kV Line traversing east-west in the southern part of the EP area	5.4.1	Minor impacts expected. Subsidence greater than that for the PG and ULD Seams expected, however specific assessment and monitoring of upgraded structures expected to be successful in managing any impacts. Minor ponding expected.
Ausgrid 11 kV line traversing north-south in the EP area	5.4.2	Impacts greater but similar to those previously experienced for the PG and ULD Seams. Some additional works such as sheaving conductors recommended at stack goaf edges and changes of direction. Minor ponding expected.
Ausgrid 132 kV and Combined 66/11 kV lines parallel to New England Highway	5.4.3	No perceptible subsidence impacts.
Farm dams (ACOL and Property 130)	5.1.5 5.5	Minor impacts expected requiring remediation.
Telstra Cables (including Property 130)	5.6	Any impacts expected to be manageable.
AAPT Sydney to Brisbane fibre optic cable	5.6	No perceptible subsidence impacts.
Ravensworth Fibre Optic	5.6	No perceptible subsidence impacts.
Buried Pipelines (owned by ACOL)	5.7	Potential impact in stacked goaf edge areas of high strain.
Fences and Farm Infrastructure (ACOL and Property 130)	5.8	Minor impacts requiring visual inspection and regular maintenance.
Major infrastructure - owned by ACOL		
Structures	5.9.1	Impacts expected but structures are not occupied.
Main Upcast Shaft, Main Fans and Gas drainage Plant	5.9.2	Impacts expected to be imperceptible for all practical purposes.
Gas drainage pipelines	5.9.3	Any impacts expected to be manageable.
11 kV electricity line	5.9.4	Impacts greater but similar to those previously experienced for the ULD Seam. Some additional works such as sheaving conductors recommended at stack goaf edges and changes of direction.
Upcast shaft and backroad fan	5.9.5	Any impacts expected to be manageable.
BOC nitrogen plant	5.9.6	Any impacts expected to be manageable.

5.1.2 Bowmans Creek Alluvium

The proposed Longwalls 201-204 do not extend directly below the Bowmans Creek Alluvium. This alluvium does extend into the EP area at the northern end of Longwall 204, but is not expected to be impacted by the proposed mining because it is located on solid coal beyond the edge of the panels.

The surface cracking observed during the site inspection at the completion of mining Longwall 104 in the ULD Seam was within the panel boundary formed by the mining of Longwall 4 in the PG Seam and Longwall 104 in the ULD Seam. Although further cracking is expected after mining of Longwall 204 in the ULLD Seam, this cracking is expected at the same location as before and so cracking will continue to be beyond the edge of the alluvium.

5.1.3 Hunter River Alluvium

The alluvium associated with the Hunter River is continuous with the Bowmans Creek Alluvium, but for a range of administrative purposes, the boundary of the Hunter River Alluvium is defined as shown in Figure 3.

The Hunter River, as defined by the edge of the Hunter River Alluvium, is located along the southern edge of the EP area and comes within approximately 160 m and 150 m respectively of the corners of Longwalls 203 and 204. In both cases, the offset distances are greater than in the corresponding overlying ULD Seam.

The proposed layout in Longwalls 201-204 in the ULLD Seam is less than 200 m from the Hunter River Alluvium, the distance defined for the Statement of Commitments made for Longwalls 5 to 7 in the PG Seam in Schedule C of DA 309-11-2001i Mod-6 Items 3.2. However, the proposed layout is within the boundary of previous longwall panels in the ULD Seam and there are not expected to be any additional impacts to the Hunter River Alluvium from the proposed mining.

The Hunter River Alluvium is remote from the longwall panels and any changes to the hydraulic conductivity of the strata between the Hunter River Alluvium and the mining horizon from the proposed mining in the ULLD Seam are expected to be small. The impacts of mining subsidence on the Hunter River Alluvium are addressed in other specialist reports.

5.1.4 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 the branches of a tributary to Bowmans Creek near the middle of Longwall 204 include Aboriginal artefact sites and nesting sites for native birds including some threatened species.

Surface cracking is expected in both areas, typically at the location of previous cracks. The subsidence bowls formed by mining in the ULD Seam are expected to increase in depth in the woodland area above Longwall 204 and may extend the period and extent of inundation following heavy rainfall.

SCT understands that subsidence impacts on Aboriginal heritage sites and flora and fauna in the woodland areas are addressed in other specialist reports.

5.1.5 Landform Drainage

The surface area above Longwalls 201-204 is expected to be further subsided by up to 2.7 m to give total cumulative subsidence of up to 5.8 m. At the end of mining the four longwall panels in the ULLD Seam, subsidence is expected to be greater than 3 m, 4 m, and 5 m over approximately 57%, 38%, and 26% respectively of the footprint of the ULLD Seam panels. Subsidence is not expected to exceed 5.8 m.

The resulting changes in the landform are expected to restrict natural drainage in some areas and some ponding is expected to develop as a consequence. The duration of ponding is expected to depend on a range of factors mainly associated with the hydraulic conductivity of the immediate overburden strata. The changes in elevation may lead to ponding that is up to about 3.5 m deep depending on the gradients in the original landform and any landform drainage works that may have been undertaken since the completion of mining in the PG Seam and Longwalls 101-104 in the ULD Seam.

Figure 10 shows the outline of all areas where ponding is considered possible after the completion of mining Longwalls 201-204 in the ULLD Seam.

Potential areas of ponding have been determined based on consideration of the subsided surface developed by subtracting the actual measured and predicted subsidence due to mining in the ULD Seam from the surface topography measured by LiDAR at the completion of mining Longwall 8 in the PG Seam. Subsidence associated with mining Longwall 6B in the PG Seam occurred after the LiDAR survey was undertaken. The estimated subsidence associated with mining Longwall 6B was also subtracted from the LiDAR surface to give a final landform over the area at the completion of mining in both the PG and ULD Seams. This theoretical landform was then further modified by subtracting the incremental subsidence expected from mining Longwalls 201-204 in the ULLD Seam.

All the areas of potential ponding are numbered in Figure 10 for ease of reference. The ponding areas listed represent all places where ponding potential has been identified at the resolution of the technique used to determine the final landform.

Table 11 summarises the estimated area, depth, and approximate volumes of each of the ponding areas identified in Figure 10.

All of the potential ponding areas identified as a result of the planned ULLD mining are located on natural drainage lines that flow to Glennies Creek, Bowmans Creek, or the Hunter River.

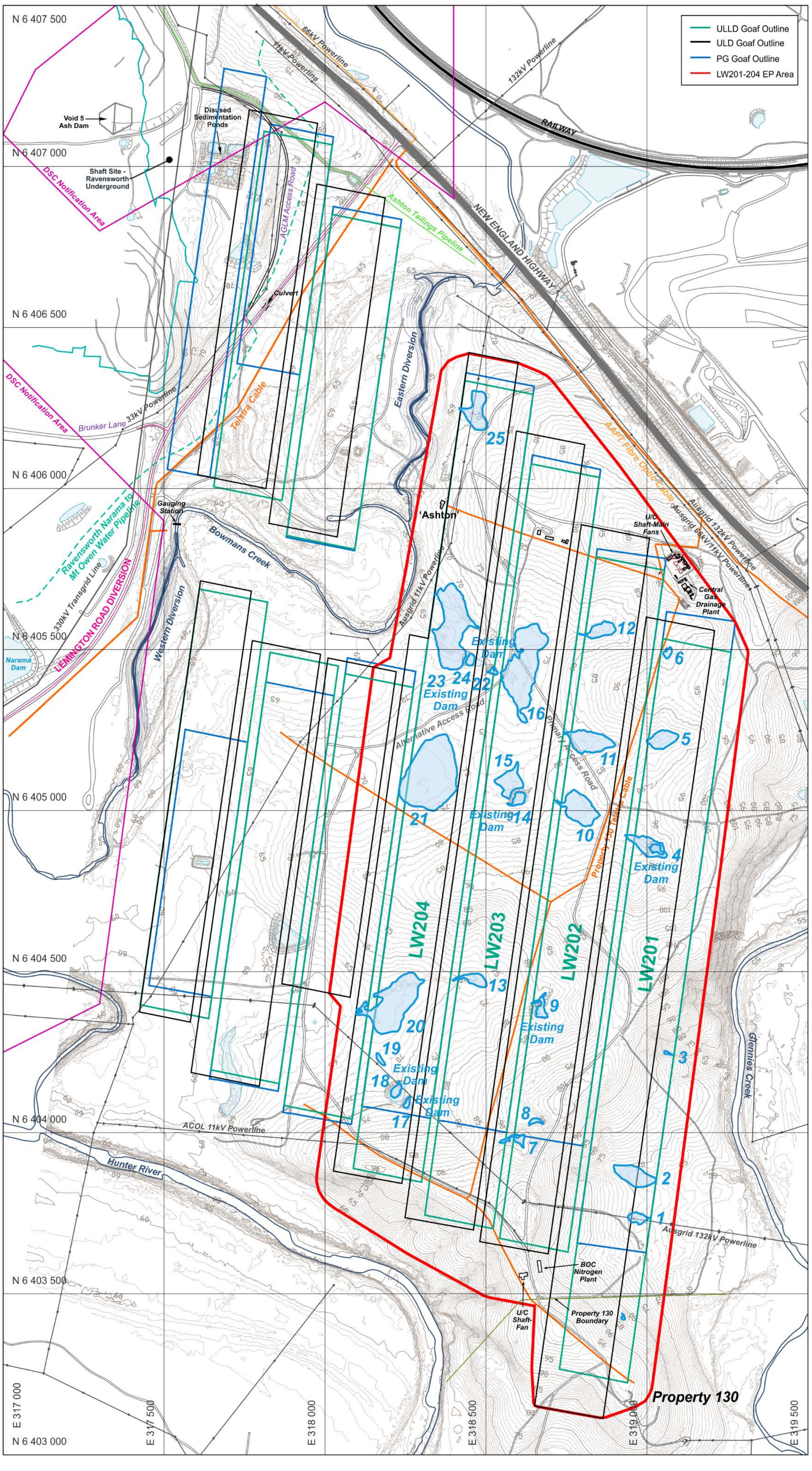

Figure 10: Areas where ponding is expected to develop in the landform above Longwalls 201-204 at the completion of mining in the ULLD Seam.

Table 11: Summary of Potential Ponding Areas and Volumes (Including Existing Storages)

Pond	Longwall	Comments	Area (m^2)	Maximum Estimated Depth (m)	Approx. Volume (m^3)
1	LW201	New - from ULLD	1,497	0.75	374
2	LW201	New - from ULLD	5,507	1.75	3,212
3	LW201	New - from ULLD - Marginal	139	0.50	23
4	LW201	Includes Existing Farm Dam	4,782	2.00	3,188
5	LW201	Enlargement of PG & ULD depression	3,686	1.50	1,843
6	LW201	New - from ULLD - Marginal	579	0.50	97
7	LW202	Enlargement of depression at old Quarry	1,041	0.50	174
8	LW202	New - from ULLD - Marginal	477	0.50	80
9	LW202	Existing Farm Dam	1,453	1.5	727
10	LW202	Enlargement of ULD depression	7,782	1.25	3,243
11	LW202	Enlargement of PG & ULD depression	7,161	1.50	3,581
12	LW203	Enlargement of ULD depression	3,005	0.75	751
13	LW203	Enlargement of PG & ULD depression	2,177	1.00	726
14	LW203	Existing Farm Dam	1,311	1.5	656
15	LW203	Moving of ULD depression	4,567	1.25	1,903
16	LW203	Enlargement/joining of PG & ULD depression	21,174	Up to 1.50	8,198
17	LW204	Existing Farm Dam	397	1.5	199
18	LW204	Existing Farm Dam	975	1.5	488
19	LW204	New - from ULLD - Marginal	444	0.50	74
20	LW204	Enlargement/joining of ULD depression	18,199	1.00	6,066
21	LW204	Enlargement of PG & ULD depression	29,698	2.25	22,274
22	LW204	Existing Farm Dam	355	1.5	178
23	LW204	Enlargement/joining of PG & ULD depression	19,939	Up to 3.25	19,217
24	LW204	Existing Farm Dam	731	1.5	366
25	LW204	Enlargement of PG & ULD depression	5,659	1.75	3,301
		Total	**142,735**		**80,933**

With the exception of an existing small farm dam on Property 130, all ponding thought likely to be created or modified due to the estimated subsidence from the proposed ULLD Seam Longwalls 201-204 is located on grazing land owned by ACOL.

Some 7% of the total ponding areas (Ponds 4, 9, 14, 17, 18, 22, and 24) estimated as likely to be caused by mining Longwalls 201 to 204 in the ULLD Seam are associated with existing farm dams constructed before underground mining started on site.

There are several other small marginal ponds (3, 6, 8, and 19) representing about 1% of the total ponding area that may or may not form depending on the interaction of actual subsidence and the local landform. The depth of these ponds is close to the resolution and effective accuracy of the landform generated from the LiDAR data and superposition of estimated subsidence. These ponds are of small volume, are relatively insignificant, and have only been included for completeness.

From the analysis methodology outlined, a number of new ponds have been attributed solely to the mining of the ULLD Seam. Apart from the four small marginal ponds referred to above, two other ponds are likely to be created as a result of the predicted subsidence above Longwalls 201-204. These are Ponds 1 and 2 located over Longwall 201 on tributaries of Glennies Creek. These ponds represent about 5% of the total ponding area expected.

The remaining 12 ponds (5, 7, 10, 11, 12, 13, 15, 16, 20, 21, 23 and 25) make up the majority (87%) of the areas identified as having the potential for ponding. These ponds are formed through the enlargement, moving, or, in some cases, the joining of basins that have previously formed as a result of the mining in the PG and ULD Seams.

The overflow points and drainage directions to and from currently existing individual depressions may be altered by the estimated subsidence from the planned ULLD Seam mining. Some of the larger ponds are likely to be up to 2.0 m deep and may be up to 200 m long if no remediation works are undertaken. However, most of the ponds are much smaller in surface area with depths of around 1.0-1.5 m.

Pond 23 is located in the natural drainage lines of the remnant woodland/aboriginal archaeological area adjacent to Bowmans Creek over Longwall 4 in the PG Seam. Pond 23 is expected to develop in the two parallel drainage lines and link into a single pond with depths of 2.5-3.5 m in places. This area has already been mined under in both the PG and ULD Seams in a permanent stacked goaf edge geometry resulting in the relatively steep surface gradients that control the surface water flows.

The planned ULLD Seam Longwall 204 is configured so as to create a third stacked goaf edge at this location. Any remediation works involving construction of drainage channels would be extensive because two channels are likely to be required.

Pond 25 is another existing depression likely to be increased by the influence of the triple stacked goaf edge at the northern end of Longwall 204. Surface works at the completion of mining Longwall 104 in the ULD Seam has recently returned this area to a free draining state.

Stacked goaf edges also represent areas of high strain (120-170 mm/m cumulative strain) with cracks of up to about 200-300 mm wide similar to those already observed during the mining of Longwalls 101-104 in the ULD Seam. These high strain areas have the potential to provide an enhanced pathway for ingress of ponded water into the overburden strata if ponding occurs and cracks are not remediated.

A program of reshaping the surface landform is expected to be necessary to reduce the potential for ingress of water into the overburden strata through mining induced tension cracks, particularly along stacked goaf edges, and above subsided panels. ACOL routinely undertakes remediation of subsidence cracks. Previous remediation of surface cracking at goaf edges from the PG and ULD Seam mining was successful at restricting the ingress of water into the overburden strata. Continuation of this work is anticipated along goaf edges in the EP area for Longwalls 201-204.

It is understood that ACOL are planning to manage the impacts of ponding to those sections of the landform that may be required to be free draining using a combination of approaches via an adaptive management strategy that includes:

- Forming channels that allow ponded areas to overflow into existing drainage lines that feed into the adjacent Bowmans or Glennies Creek or the Hunter River.

- Regular landform reshaping to improve visual and general safety aspects.

These measures are expected to minimise the volumetric holding capacity of the subsidence bowls and reduce the potential for increased inflows into the overburden strata.

A recent surface inspection indicated that some of the areas where ponding has been created by the subsidence bowls from the PG and ULD Seam mining are modifying the habitat and land use to create wetland habitat. Areas where ponding may impact on surface infrastructure include:

- Pond 1 causing local flooding around power poles on the southern 132 kV electricity line (specifically Set 21 - CN90079) during the mining of Longwall 201.

- Pond 11 causing minor flooding of the primary right of way access road to Property 130 during the mining of Longwall 202.

- Pond 16 causing local flooding at the junction of both the primary right of way and alternative access roads to Property 130 during the mining of Longwall 203.

- Pond 25 causing flooding of a timber power pole on the local distribution 11kV electricity line towards the end of mining in Longwall 204 panel.

Potential options to improve the draining characteristics of those sections of the landform to reduce the impact on serviceability of the infrastructure include:

- Forming a channel from Pond 1 that would allow flow into the existing drainage line that feeds into Glennies Creek to avoid ponding at power pole Set 21 - CN90079. A suitable channel is estimated to be about 70 m long and up to about 1 m deep.

- For both access roads into Property 130, a combination of raising the level of the road surface and installing a small drainage culvert in conjunction with any drainage channels required to keep the area free draining.

- Additional channels to allow flow from Pond 25 into the existing drainage line feeding Bowmans Creek to completely drain the depression that is expected to form at the timber power pole positioned close to the lowest point of this pond after the mining of Longwall 204. Alternatively, the pole and a section of the electricity line could be relocated to higher ground unaffected by subsidence.

- Diversion of overland flows so that rainfall runoff is not directed to areas of potential ponding.

Ponding around power poles and other infrastructure such as buried cables, and buried pipes does not necessarily directly affect their operation, but it may potentially reduce access for maintenance work and increase the rate of deterioration of wooden poles. Foundation strength may also be affected. A program of drainage channels would be expected to be effective to manage the potential for long term impacts to surface infrastructure.

5.1.6 Surface Topography

The steepest slope within the vicinity of Longwalls 201-204 is located between Longwall 201 and Glennies Creek outside of the EP area. The vertical and horizontal movements expected from the mining of Longwalls 201-204 are not expected to impact on the grade or the stability of this slope.

The maximum gradient of this slope is less than 30° from horizontal. The location of this maximum gradient coincides with the location of XL5 subsidence monitoring line.

Figure 11 shows the original pre-mining surface profile at natural scale with the surface profiles after the mining of the PG and ULD Seams. The predicted surface profile after the proposed mining of Longwall 201 is also shown.

Other slopes with lesser grade located adjacent to the Hunter River near the southern ends of Longwalls 202-204 are not expected to be impacted by the planned mining in the ULLD Seam due to their remoteness from the start position of these longwalls and the direction of mining.

5.2 Property 130

Property 130 is located in the south eastern corner of the EP area. Infrastructure present on the property includes fences, roads, a farm dam, tracks, water troughs, buried water pipes, sheds and a rain water tank. Other buildings associated with the residence and milking shed are outside the EP area and beyond the area where perceptible impacts are expected. These structures are therefore not assessed. Infrastructure that services Property 130 (the unsealed access roads and Telstra communication line) are discussed in other sections.

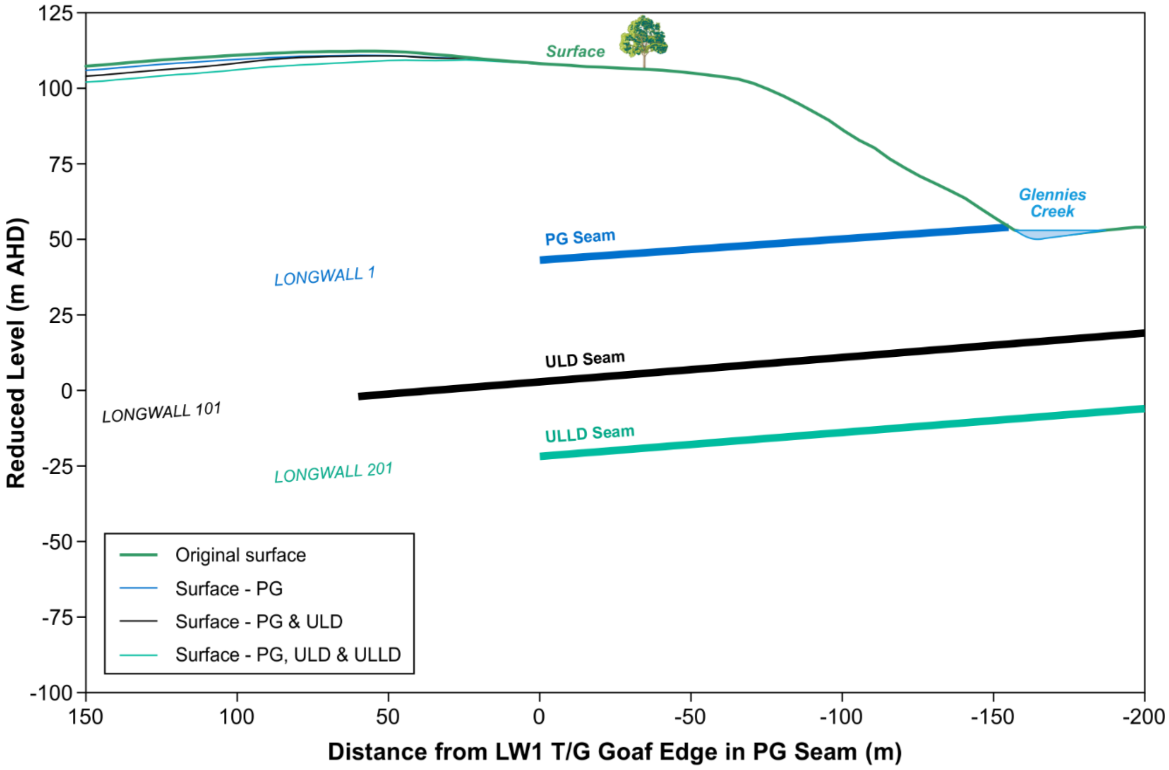

Figure 11: Surface profiles (at natural scale) after subsidence along XL5 subsidence monitoring line from Glennies Creek.

Previous mining in the PG Seam did not occur below Property 130. A small area was mined under by Longwall 101 in the ULD Seam. At an overburden depth of about 140 m, maximum subsidence is estimated to have been about 1.2 m with tilts of around 20 mm/m and strains of less than 10 mm/m.

A somewhat smaller area is planned to be mined under by Longwall 201 in the ULLD Seam. Due to the offset geometry and a shortened start position, the farm infrastructure affected by the proposed mining will be substantially the same infrastructure that was affected by the ULD Seam subsidence. A small farm dam located on the eastern side of the panel is the only additional infrastructure likely to be affected and the landform drainage analysis indicates no significant changes are expected at this dam.

Proposed ULLD Seam mining is not expected to create a stacked goaf edge below Property 130 so the nature of subsidence impacts is likely to be substantially similar to the impacts observed in the same area during mining of Longwall 101. Surface cracking and changes in surface grade are expected to be perceptible.

An increased gradient is likely to develop on the main access road near the western edge of the Longwall 201 block due to the local topography but this gradient is expected to be no greater than that currently existing elsewhere on the access road to the milking shed further to the south east.

After mining of Longwall 201, maximum cumulative subsidence of about 3.0 m is expected along the northern section of the main access road within Property 130. Increases in tilts to around 30 mm/m and strains to 25 mm/m are also expected. In general, any impacts should be able to be managed without undue difficulty with only relative minor works such as regrading of the roads and tracks, re-tensioning fences, and closing any open cracks that may develop. Permanent surface cracks may need to be filled by ripping or importing material and re-compaction.

5.3 Road Infrastructure

The access roads to Property 130 and internal access roads on ACOL owned land are the only roads within the EP area that are expected to be affected by subsidence.

5.3.1 Access Roads (Property 130 and ACOL)

There are several unsealed access roads that cross the EP area. The main access road is the primary right of way to Property 130. This road is used on a daily basis. An alternative access road (alternative right of way) is available across the central part of the EP mining area. These roads and several others also provide access to ACOL infrastructure for daily operational and maintenance requirements.

The access route to Property 130 is duplicated in the central part of the EP area. However, there is only one access road in the northern and southern parts of the EP area.

Given this access road is the most practical access for the residents and daily milk tanker run to the dairy farm on Property 130, remediation works are likely to be required on a daily basis during the period of active mining, particularly in areas at either end where the road passes over stacked goaf edges.

An additional maximum incremental subsidence of 2.7 m is expected during mining of Longwalls 201-204 giving cumulative subsidence of up to about 5.8 m from the combined effects of mining in the all three PG, ULD and ULLD Seams. Maximum tilts and strains are expected at locations where these access roads cross stacked goaf edges and a dyke located below the eastern access road above Longwall 202.

The magnitudes of tilts and strains expected are likely to result in localised steep gradients, surface cracking of up to about 300 mm wide, compression humps greater than 100 mm high, and a possible step at the location of geological dyke structures. Most of these high strain areas are likely to occur at the same locations that were impacted by previous mining.

Some areas of the access road are also expected to be impacted by flooding as a result of changes to the landform. These areas have been identified and are likely to affect both the primary and alternative access roads at their northern junction effectively removing the option of the alternative right of way pathway. Details of this expected ponding and suggested mitigation and remediation works are included in Section 5.1.5.

It is anticipated that uninterrupted access to Property 130 could be maintained with frequent treatment of subsidence impacts as they develop.

5.3.2 New England Highway

No perceptible impacts are expected at the New England Highway and bridge over Bowmans Creek as a result of mining Longwalls 201-204.

The New England Highway is located approximately 140 m north of the nearest corner of the EP area. Subsidence monitoring experience above previous longwall panels in the PG Seam and ULD Seam indicates that subsidence movements above the finishing end of the panels are largely restricted to within the footprint of the longwall panels and do not extend across the very large barrier to the highway.

5.4 Electricity Transmission Lines

There are several electricity transmission lines located in the vicinity of the EP area, however only the 132kV line traversing the southern longwall blocks and sections of 11kV local distribution lines, both owned by Ausgrid, are within the EP area. The impacts of mining subsidence on each of these lines are discussed in this section.

The impacts of mining subsidence are not expected to cause electricity interruptions but some mitigatory work is likely to be required on the lines and drainage works may be required to prevent periodic flooding around poles located in areas where ponding is expected.

5.4.1 132kV Line Traversing Southern Longwall Blocks

Figure 12 shows a photograph of the Ausgrid owned 132 kV electricity transmission line that crosses the southern ends of all the proposed panels. The line was originally supported on two pole structures along straight sections and three pole structures at changes of direction. Over the EP area, all but one of the two pole structures were upgraded and replaced with single poles. The only two pole structure remaining is located on the eastern fringe of the EP area where no subsidence movements are expected.

An assessment of subsidence levels expected along this infrastructure for future mining was recently updated in September 2016 and is presented in SCT Report ASH4586 "Southern 132kV Power Line at Ashton Coal Mine: Update of Subsidence Assessment for Longwalls 201-204 in the Upper Lower Liddell Seam".

None of the poles are located above stacked goaf edges. Maximum tilts and strains are expected to be generally similar to tilts and strains experienced previously during mining in the Pikes Gully (PG) Seam and then again in the Upper Liddell (ULD) Seam.

The three pole set at the change of direction (Set 24 -CN90469, CN90470 and CN90471) have previously been had mitigation measures including conductor sheaves and concrete pad bases installed. These poles are located away from the where the maximum vertical subsidence from Longwall 202 is expected.

Figure 12: 132 kV powerline that traverses the southern end of Longwalls 201-204.

The program of upgrading and structural assessment has allowed the subsidence movements to be successfully managed in the past and it is anticipated that this previous work and continuing review, with appropriate mitigation measures where required, will allow successful management of the subsidence movements expected within the EP area from the mining of Longwalls 201-204 in the ULLD Seam.

There is potential for the Set 21 (CN90079) to be become periodically submerged as surface ponding is expected to be created in this location by the mining of Longwall 201. As discussed in Section 5.1.5, surface drainage works are expected to be effective in managing any impacts from ponding.

5.4.2 11kV Local Area Electricity Transmission Lines

There are two areas where 11 kV electricity transmission lines the EP area. One in the north of Longwall 204 owned by Ausgrid discussed in this section and the other one crossing the southern part of Longwalls 202-204 owned by ACOL discussed in Section 5.9.4.

Figure 13 shows a photograph of the section of local area 11 kV line owned by Ausgrid that crosses the stacked goaf edges in the northern part of Longwall 204.

Figure 13: 11 kV powerline over the northern section of Longwall 204.

Longwall 204 is planned to mine directly under six single pole structures on this line with a seventh pole in close proximity. The six poles are located

adjacent to existing surface cracking from the double stacked goaf edge on the side of Longwall 4 and Longwall 104 in the PG and ULD Seams respectively. The mining of Longwall 204 in the ULLD Seam creates a triple stacked goaf edge with very high tilts and strains expected. The magnitudes of these movements are expected to approach twice the values observed to date.

The single pole structures on these lines are generally tolerant of subsidence movements and the poles are closely enough spaced that ground clearances are not likely to be compromised. However, the very high tilts and strains expected may require the line to be temporarily supported during the period of active mining and some poles to be replaced at the completion of mining.

Sheaving of the conductors on poles located in areas of high tilt particularly close to the stacked goaf edges is recommended to ensure that insulators and supporting cross re-routing members do not become overloaded by changes in conductor tension. A program of monitoring, regular visual inspection and appropriate remediation as required is considered a satisfactory way to manage most of the expected impacts but relocation may also be required.

There is potential for the most northerly pole to be become periodically submerged as surface ponding is expected to be created in this location by the mining of Longwall 204. Surface drainage works are expected to be effective in managing the impacts of ponding.

Given the small number of poles involved and the significant magnitude of the tilts and surface cracking expected, a strategy of re-routing a 650 m section of the line some 50-100 m to the west may be worthy of consideration. By moving the line, the subsidence impacts from mining in the ULLD Seam and any future mining in deeper seams including inundation of one of the poles are eliminated.

5.4.3 132kV and Combined 66/11kV Lines along New England Highway

The electricity transmission lines located alongside the New England Highway are owned by Ausgrid. These lines are more than 70 m outside of the EP area. No subsidence movements are expected at the location of these structures as a result of mining Longwalls 201-204. The single pole structures supporting these lines are tolerant of any minor subsidence movements. No monitoring of subsidence movements on these lines is considered necessary.

5.5 Farm Dams

There are eight farm dams within the EP area. These dams are mostly located on ACOL owned land. One dam is located on Property 130. Experience of mining below these dams indicates that some cracking may cause minor water loss in a small proportion of dams that are mined under.

These losses have not posed an operational risk to mining underground in the past as there is no experience of inflows during previous mining. With a small amount of crack filling remediation work, the dams are typically restored to their original condition. Increased subsidence and ground disturbance expected during mining in the ULLD seam may lead to an increased risk of water loss from farm dams but there is not expected to be a significant operational risk to mining underground.

If undermining occurs when the dams are full, reducing the level may reduce the potential for scour of the dam wall and more substantial rectification required in the event of overtopping or significant cracking.

The seven ACOL owned farms dams are identified in Section 5.1.5 and details of the farm dam on Property 130 are discussed in Section 5.2.

5.6 Fences and Other Farm Infrastructure

Most of the fences in the EP area are on ACOL owned land with the balance on Property 130. Across most of the EP area, the horizontal strains and tilts expected from proposed mining in the ULLD Seam are not expected to cause significantly more impact to fences and other farm infrastructure than occurred during mining in the PG and ULD Seams. The areas where greater impacts are expected are likely to be at stacked goaf edges at the start of Longwalls 202-204, the finish of all the panels, along the majority of the eastern edge of Longwall 201 and alongside the western edge of the northern section of Longwall 204.

In areas of high strain, fences are likely to become tight so that wires snap or loosen to the extent that they become ineffective for stock control.

Farm buildings constructed with brick and masonry walls or large floor slabs are likely to be perceptibly impacted in areas where horizontal strains are greater than about 7-10 mm/m. Other infrastructure such as water reticulation systems, gates, cattle grids, and stockyards may also be affected depending on their specific location. In general, these impacts can most easily be managed as and when they occur.

A program of regular visual inspection and appropriate remediation as required is considered a satisfactory way to manage most of the impacts.

5.7 Buried Communications Cables

There are two buried fibre optic cables located outside the EP area and one buried copper line located within the EP area. The AAPT fibre optic cable parallel to the New England highway and the Ravensworth fibre optic cable alongside Lemington Road are remote from mining and no impacts are expected. The buried copper line is a Telstra telecommunication cable servicing Property 130 and other ACOL owned properties.

The Telstra cable that services Property 130 and other ACOL owned properties runs north-south across the EP area mainly over Longwall 202. The cable has been previously undermined by Longwalls 1-3 in the PG Seam and Longwalls 101-103 in the ULD Seam. No damage or adverse impacts have been observed and to date the cable has remained serviceable throughout the periods of active mining.

The maximum strains along this line are estimated as likely to reach 170 mm/m at stacked goaf edges near the finish of Longwall 201. The maximum strains to date are estimated to have been about 40 mm/m. Buried cables are considered to be susceptible to damage at strains above about 20 mm/m but the severity of any damage is strongly dependent on the burial details of the line.

The option of leaving the line in place, repairing it if necessary, and providing a mobile service to potentially affected Telstra customers in the event there is some loss of service is considered to be a practical approach to managing potential subsidence impacts. Alternatively, the line could be uncovered in the vicinity of the stacked goaf edge or this area could be bypassed with a second line.

5.8 Buried Pipelines

There are two pipelines associated with ACOL operations located in the vicinity of EP area. In general, mine owned infrastructure does not require to be assessed for an EP, but these lines are assessed in this section because of the potential for consequential environmental impacts should the pipelines be ruptured. ACOL's Hunter River clean water supply pipeline and mine water pump-out pipeline traverse the EP area.

The Hunter River pipeline is a 200 mm diameter PE80 PN8 polyline that provides clean water from an intake near the river to the ACP Coal Preparation Plant. The pipeline route extends from the inlet to the south west of the EP area and then runs south–north almost parallel to the western limit of the EP area. The line enters the EP area in the northern half of Longwall 204 but remains outside of the estimated 100 mm subsidence contour. There is considered to be no potential for subsidence impacts to this line from the mining of longwalls 201-204.

A 355 mm diameter PE100 PN8 pipeline delivering mine water, pumped to the surface from underground, back to the ACP Coal Preparation Plant traverses the southern ends of Longwalls 202-204 and then follows a similar route to the Hunter River water pipeline to the north.

A rupture of this mine water pump-out pipeline has potential to present an environmental issue, especially over the start of Longwall 202 where the surface gradients allow flow towards the Hunter River. Elsewhere outflows are likely to be substantially contained within the subsidence bowls created by mining.

For the proposed layout, the mine dewatering line crosses in close proximity to the stacked goaf edge at the start of Longwall 204 and directly over the stacked goaf edge at the start of Longwall 202.

The area at the start of Longwall 202 where the pipeline crosses the start of Longwall 102 has already experienced horizontal strains of up to about 15 mm/m from mining in the ULD Seam. The incremental horizontal strains in this area due to mining Longwall 202 are estimated to reach up to about 45 mm/m at the stacked goaf edge giving a total horizontal strain of approximately 60 mm/m.

This level of horizontal strain is expected to cause high loads on the polyline and depending on the burial detail may be sufficient to cause it to rupture.

Uncovering the pipe over the start of Longwall 202 in the vicinity of cracks associated with Longwall 102 is expected to significantly reduce the potential for mining induced subsidence impacts because the strains developed in the ground are then not able to be transmitted to the pipeline. Where buried pipelines are uncovered as a preventive measure some regular inspection and visual monitoring during the period of active subsidence is recommended to confirm that there is sufficient slack in the lines to accommodate the ground movements occurring. The period of monitoring should continue for the first 200 m of retreat of Longwall 202.

Other strategies that may be considered include a system for monitoring pressure or flow that can detect a leak and shut down the pump may be useful to provide a backup system, particularly if the pipe is not uncovered. Isolating the line during the period of active mining and pressure testing it prior to returning it to service may also be a satisfactory option.

In the northern half of Longwall 204 where the mine water line and clean water pipeline run close together, there is considered to be no potential for subsidence impacts.

Minor pipelines and water delivery networks may be affected by mining subsidence movements particularly where they cross stacked goaf edges or compression overrides but in general it is expected these would be repaired on an as required basis without the need for any mitigatory work.

5.9 ACOL Owned Infrastructure

The major infrastructure within the EP area owned by ACOL includes one residential structure, mining equipment storage sheds and yards, the main ventilation and gas management infrastructure, a second shaft and fan, mine dewatering equipment and electricity supply. Although these items of infrastructure are not required to be assessed in detail for an EP assessment because they are owned by ACOL, a general assessment is included for completeness.

5.9.1 Structures (including Residential)

Figure 14 shows a photograph of the unoccupied residential structure known as “Ashton”. This structure is located inside the EP area at the northern end of Longwall 204 but outside the area significantly affected by subsidence. No perceptible impacts are expected to the structure itself or surrounding facilities west of the surface cracks in the parking area created by mining Longwall 104 in the ULD Seam.

Other structures such as mining equipment storage sheds and pre-existing farm buildings are expected to experience a full range of subsidence movements. None of these structures are located on stacked goaf edges so maximum tilts and strains of 120 mm/m and 74 mm/m representing the maximum background levels are considered possible at these locations. Significant tilting and damage to panels on the sides of buildings is considered possible on those structures located directly over goaf edges.

Figure 14: Residential structure 'Ashton' located to west of Longwall 204.

5.9.2 Main Upcast Shaft, Main Fan Installations, and Gas Drainage Plant

The main upcast shaft for the underground ventilation system of the mine, ventilation fan, and gas drainage plant are located within the EP area near the northern end of Longwall 202. There are also a number of associated buildings located in this area. Monitoring from the finish of Longwall 102 in the ULD Seam indicates that no impacts from subsidence are expected in the area of this infrastructure.

Figure 15 shows a plan of the structures and their position relative to the northern end of Longwall 202 in the ULLD Seam. Maximum subsidence is expected to be less than 50 mm at the corner of the nearest structure and strains and tilts less than 1 mm/m are expected. Ground movements at the location of this infrastructure are expected to be imperceptible for all practical purposes.

5.9.3 Gas Drainage Pipelines

ACOL maintain a network of gas drainage collection pipelines across the EP area. These pipelines have been designed to accommodate subsidence movements. Surface to seam boreholes are part of this network. Horizontal movements of up to 800 mm have been observed at the completion of mining in the ULD Seam.

Additional horizontal movements of up to about 400 mm are expected as a result of mining in the ULLD Seam. These horizontal movements have potential to be accommodated within the overburden strata at a number of discrete horizons where they may affect the efficiency of gas drainage boreholes.

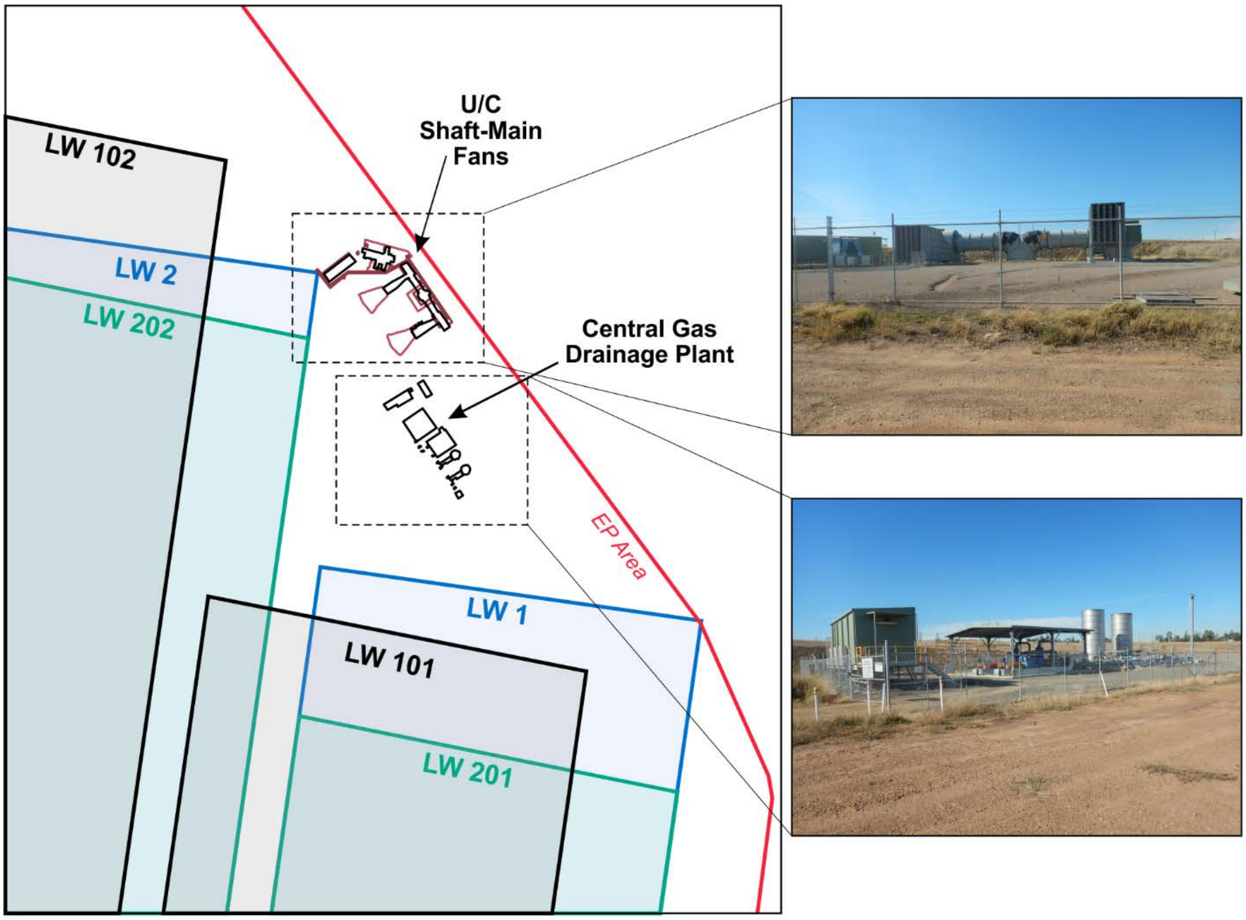

Figure 15: Location of upcast shaft - main fans installation and gas drainage plant relative to Longwalls 201 & 202 in the ULLD Seam.

5.9.4 11 kV Electricity Transmission Line

An 11kV electricity line owned by ACOL traverses the southern ends of Longwalls 202-204. This line supplies the upcast shaft, back road fan, BOC Plant, and a number of mine water pumping installations. A section of this electricity line has previously been mined directly under by Longwalls 102-104 in the ULD Seam and in its current configuration would be mined under again by Longwalls 202-204 in the ULLD Seam.

For the proposed layout, a seven pole section of this line crosses in close proximity to the stacked goaf edge at the start of Longwall 204 and directly over the stacked goaf edge to be formed at the start of Longwall 202.

The area at the start of Longwall 202 where the line crosses the start of Longwall 102 has already experienced maximum permanent tilts of up to about 25 mm/m. Tilts are expected to increase up to about 120 mm/m at the stacked goaf edge area potentially affecting two poles at the start of Longwall 202 and two poles over Longwall 204.

Strains of up to about 15 mm/m are estimated to have occurred as a result of mining in the ULD Seam. The incremental horizontal strains in this area due to mining Longwall 202 are estimated to reach up to about 45 mm/m for a stacked goaf edge giving a total horizontal strain of approximately 60 mm/m.

Sheaving of the conductors on poles located in areas of high tilt particularly at the stacked goaf edge is recommended to ensure that insulators and supporting cross re-routing members do not become overloaded by changes in conductor tension. Some ground clearance issues may eventuate at the stacked goaf edge. A program of regular inspection during the period of active mining is recommended.

5.9.5 Upcast Shaft with Back Road Fan Installation

A small bore surface to seam upcast shaft with fan installed that provides ventilation to the ULD Seam is located approximately 70 m to the south of the start line of Longwall 102 in the ULD Seam and 90 m to the south of the Longwall 202 installation roadway. In this position any shear movements from the ULLD Seam mining are likely to be less than 50 mm and are not expected to impact on the integrity or serviceability of this shaft and surface facilities.

5.9.6 BOC Nitrogen Plant

A surface nitrogen storage plant and delivery equipment used for inertisation of underground goaf voids is located about 40 m to the south of the Longwall 202 start line. In this position the plant is more than 20 m from the ULD Seam goaf edge. This plant was constructed after the mining of Longwall 1 in the PG Seam but before the neighbouring Longwalls 101 and 102 in the ULD Seam were mined.

The mining of the ULLD Seam is expected to result in additional vertical subsidence of less than 50 mm of vertical displacement with corresponding low levels of tilts and strains. Impacts to the BOC nitrogen plant are expected to be similar to those experienced previously from the mining of Longwalls 101 and 102 in the ULD Seam and are considered to be manageable based on previous experience.

6. RECOMMENDATIONS FOR SUBSIDENCE MONITORING AND MANAGEMENT

The program of subsidence monitoring used at ACP to date was suitable to assess the nature of subsidence related ground movements in a multi-seam environment and to manage the associated impacts. It is recommended this program continues for the proposed ULLD Seam mining area to enhance the existing double seam database and take advantage of the unique opportunity to capture triple seam observations for the first time.

The program includes:

- Three dimensional monitoring of longitudinal lines located on the ULLD panel centreline at the start and end of each panel.

- Three dimensional monitoring of a cross line, XL5, that crosses all the southern panels at the mine.
- Three dimensional monitoring of a cross line, XL10, that crosses the northern section of Longwall 204.
- Monitoring of the three dimensional movement of power poles on the southern 132 kV electricity line.
- Three dimensional resurvey of the existing monitoring cross lines XL1 and XL4 or XL7 over Longwall 1 and Longwall 101 during the mining of Longwall 201.

Additional monitoring recommended for the EP area includes:

- Regular visual inspections of the Property 130 access road.
- Monitoring of the three dimensional movement of power poles on the north–south 11 kV electricity line above Longwall 204 during the period of active mining.
- Regular visual inspection of power poles on the southern 11 kV, and 132 kV electricity lines, the surface above buried pipelines, and fences during the periods of active mining in each area.

7. CONCLUSIONS

The surface impacts from mining the ULLD seam are not expected to be significantly different compared to the impacts that were successfully managed during mining in the previous two seams. The subsidence impacts are expected to remain within the Subsidence Performance Measures of development consent DA 309-11-2001i.

Longwalls 201-204 are located substantially on ACOL owned land and substantially within the existing footprint of previous mining in the Pikes Gully (PG) and Upper Liddell (ULD) Seams. The start of Longwall 201 in the far southeast of the EP Application Area (EP area) is located on privately owned land known as Property 130. Longwall mining in the overlying PG and ULD Seams has already been completed over much of the EP area. Although mining in the PG and ULD Seams is not the focus of this assessment, the cumulative effects of mining all three seams is nevertheless taken into account where relevant.

Previous subsidence monitoring at ACP indicates two distinct types of behaviour, the behaviour that occurs generally over the offset panels and the behaviour that occurs over stacked goaf edges where the goaf edges in two seams are located directly above each other. Subsidence movements observed generally over the offset geometries show incremental increases in maximum subsidence but the strains and tilts are of a similar magnitude to single seam mining. By contrast, tilts and strains observed over stacked goaf edges are significantly higher than the general background levels of tilt and strain. The assessments of surface features and infrastructure affected by stacked goaf edges are relatively limited in extent and are considered separately as special cases.

Unconventional subsidence movements associated with ripples, steps, and far field horizontal movements are expected to be similar or less than they were during previous mining in the PG and ULD Seams. Any such movements are expected to be generally insignificant by comparison with the general ground movements associated with mining three seams, particularly ground movements above stacked goaf edges.

Bowmans Creek, the Hunter River and Glennies Creek and associated alluvium are sufficiently remote from Longwalls 201-204 in the ULLD Seam for there to be no significant additional subsidence impacts.

Changes to the natural landform over Longwalls 201-204, are expected to cause some ponding in the natural drainage lines that generally flow down to the Bowmans Creek floodplain including increased ponding within a series of farm dams.

A small portion of Property 130 that was previously mined under in the ULD Seam is proposed to be mined under at the start of Longwall 201. A small farm dam is the only additional farm infrastructure not previously mined under. Mining in the ULLD Seam is estimated to cause incremental subsidence to give a maximum cumulative subsidence below Property 130 of about 3.0 m. No stacked goaf edges are created in this area so tilts and strains are expected to be similar to the general background levels which were experienced previously during mining in the ULD Seam. Re-grading of the access road, re-tensioning of fences, and back filling any open surface cracks that may develop is expected to be required to manage the surface impacts.

The access road to Property 130 crosses stacked goaf edges at the northern end of Longwall 204 and the southern end of Longwall 202. Both of these crossings are in areas where there is no practical alternative route available to be used for daily access to Property 130. Incremental subsidence of 2.7 m is expected during the mining of Longwalls 201-204 with maximum tilts and strains expected at locations of the stacked goaf edges, most likely in areas that were remediated previously during mining in the PG and ULD Seams. The access roads are expected to require mitigation and remediation works on an ongoing basis during the period of active mining in order for daily access to be maintained. The access road is expected to be impacted by inundation as a result of changes to the landform. This ponding is likely to affect both the primary and alternative access roads at their northern junction.

The buried telecommunications line (Telstra cable) to Property 130 is considered to be susceptible to damage from the proposed mining of Longwalls 201-203. Although this cable has been undermined by both the PG and ULD Seam longwalls with no damage or impacts to serviceability reported, the mining of the ULLD seam is expected to increase the ground strain levels, especially at the stacked goaf edges, to levels that may cause an interruption to service. Options to avoid loss of service include relocating the cable sections likely to be impacted away from stacked goaf edges, uncovering these sections of the cable, repairing as necessary, or replacing the fixed land line with a mobile service.

The only significant major infrastructure in the area of the EP area likely to be impacted by mining subsidence is the 132 kV electricity transmission line owned by Ausgrid that crosses the southern ends of all the panels. A specific assessment for these poles has been carried out separately and the poles on the line have been upgraded to better accommodate subsidence movements. The program of upgrading and structural assessment allowed the subsidence movements from the PG and ULD Seam mining to be successfully managed in the past. This previous work and continuing assessment is expected to allow successful management of the subsidence movements expected from the mining of Longwalls 201-204 in the ULLD Seam. Ponding has potential to cause inundation at one pole. Filling or local regrading of the landform is likely to be effective for managing this ponding.

A local area 11 kV electricity line owned by Ausgrid crosses the north-west section of the EP area above Longwall 204. The single pole structures on this line have tolerated the subsidence movements experienced from mining in the PG and ULD Seams. Subsidence effects on this line are expected to be nearly double at two stacked goaf edges. Sheaving of the conductors on poles located in areas of high tilt particularly at the stacked goaf edges is recommended to ensure that insulators and supporting cross members do not become overloaded by changes in conductor tension. In areas of high tilt, some sections of the line may need to be temporarily supported during the period of active mining and the poles may need to be replaced once mining is complete. An option to re-route approximately 650 m of the line onto the solid coal barrier to the west of Longwall 204 may also be cost effective.

Other major infrastructure in the general vicinity but outside the EP area includes the New England Highway, Lemington Road, Ausgrid electricity lines (132 kV electricity line and a combined 66 kV/11kV electricity line), a Ravensworth Operations 33 kV electricity line and a Transgrid 330 kV electricity line alongside Lemington Road, an AAPT fibre optic cable, a Ravensworth Operations fibre optic cable, and a Telstra cable corridor. These infrastructure are all well outside the EP area in locations where no subsidence movements are expected from the mining of Longwalls 201-204.

Impacts to farm infrastructure by proposed mining in the ULLD Seam are expected to be similar to the types of impacts that occurred during mining in the PG and ULD Seams. Farm buildings constructed with brick and masonry walls or large floor slabs may be perceptibly impacted during the period of active mining depending on their location relative to the panel. Other infrastructure such as farm dams, water reticulation systems, fences, gates, cattle grids, and stockyards may also be impacted depending on their specific location. In general, these impacts can most easily be managed as and when they occur. A program of regular visual inspection and appropriate remediation if required is considered suitable to manage these impacts.

Most of the surface infrastructure located within the EP area is owned by ACOL. Buried water pipelines are the only infrastructure that has potential to have impact beyond operational issues. These pipelines could pose an environmental risk if they were to rupture. Strategies to manage this potential include, uncovering the monitor performance with emergency shutdown provisions or isolating the line during the period of active mining and testing prior to returning to service may also provide a satisfactory management option.

Other ACOL owned operational infrastructure includes ventilation shafts, fan installations, a central methane gas drainage plant and associated infrastructure, BOC nitrogen gas plant, associated boreholes with collar hardware and surface pipeline networks, and mine dewatering system equipment as well as 11kV electricity line to supply this infrastructure. Some minor impacts are expected however these are expected to be able to be effectively managed by existing ACOL subsidence management systems.

The existing program of subsidence monitoring has proven to be suitable to assess the nature of subsidence related ground movements in a multi-seam environment and to manage the associated impacts. It is recommended that this program continues for the proposed ULLD Seam mining area to enhance the existing double seam database and take advantage of the unique opportunity to capture high confidence subsidence measurements over regular triple seam longwall panels for the first time.

8. REFERENCES

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