APPENDIX 2

Subsidence Assessment

REPORT TO:

ULAN COAL MINES LIMITED

Subsidence Assessment for
Proposed Ulan West Mine Modification
Longwalls 3 to 12

ULA4229

Strata Control Technology

Mining Research and Consulting Group
SCT Operations Pty Ltd PO Box 824 Wollongong NSW 2520 Australia
sctnsw@sct.gs

Report To	Ben Anderson Ulan Coal Mines Limited Private Mail Bag 3006 MUDGEE NSW 2850
Subject	Subsidence Assessment for Proposed Ulan West Mine Modification Longwalls 3 to 12
Report No	ULA4229
Prepared By	Ken Mills
Date	4 March 2015

Ken Mills
Principal Geotechnical Engineer

SUMMARY

The subsidence impacts associated with the modified layout are not expected to be significantly different from those described in the UCCO Project subsidence assessment for Ulan West. The main differences are that there is an increase in the mining footprint in the southwest that impacts a private landholder not previously impacted and four archaeological heritage sites in the Cockabutta Creek area that are assessed by SEA as being significant. There is a reduction in area mined by Ulan West in the north east. There are also some minor differences in actual area mined around the panel ends because of differences in panel widths, but overall these do not cause significant changes to surface impacts.

Ulan West Mine is located within the Ulan Mining Complex approximately 25 kilometres north-east of Gulgong in New South Wales. Ulan Coal Mines Limited (UCML) is proposing to modify the layout of Longwalls 3 to 12 at Ulan West Mine within substantially the same area that was assessed in detail and approved in the Ulan Coal Continued Operations Project (UCCO Project). UCML commissioned Umwelt (Australia) Pty Limited (Umwelt) to prepare an Environmental Assessment (EA) for the proposed modification to the UCML Project Approval (PA) 08_0184 pursuant to Section 75W of the Environmental Planning and Assessment Act 1979 (EP&A Act) and SCT Operations Pty Ltd (SCT) to prepare a subsidence impact assessment for this proposed modification. This report presents the subsidence assessment for Longwalls 3 to 12 (proposed modification) at Ulan West Mine in support of the broader environmental assessment being prepared by Umwelt with particular focus on the differences in impacts from the UCCO Project.

The key features likely to be impacted by subsidence movements have been identified from previous surveys, aerial reconnaissance, and subsequent ground surveys by SCT, Umwelt, South East Archaeology Pty Ltd (SEA), and others. The impacts of mining subsidence on most of these features are described in detail in the UCCO Project assessment presented in SCT Report ULA3367 (SCT 2009) and subsequent modifications and this current assessment should be read in conjunction with the earlier assessments for context and completeness. The main focus of the impact assessment presented in this report is on those sites where there are likely to be significant differences in impacts compared to those described in the UCCO Project.

In general, the subsidence impacts for the proposed modification are substantially the same as those reported in the UCCO Project assessment. The main difference relates to four archaeological heritage sites located in the Cockabutta Creek catchment that have been assessed as significant and are now likely to be impacted by the proposed modification whereas they were previously protected in the UCCO Project layout. Impacts are assessed as a probability of rock falls of up to 20% and a probability of perceptible changes of up to 70% at all four sites.

Most of the differences between the UCCO assessment and the assessment for the proposed modification are associated with changes in footprint. Other differences include refinements to the subsidence parameter estimates and changes in the types of impact based on monitoring experience at Ulan No 3 Mine since the UCCO Project was completed. The nominal mining height has been increased from 2.9m used in the UCCO Project assessment to 3.2m used in this assessment to account for possible variability in the actual seam thickness mined, particularly in shallow cover areas where the seam thickness is more closely reflected in the maximum subsidence.

The main differences in the mining footprint are in the southwest of the modified Ulan West mining area around Cockabutta Creek where privately owned land and four archaeological sites not previously impacted are now likely to be affected by mining subsidence. There is a reduction in area mined by Ulan West Mine in the north east. There are also some minor differences in actual area mined around the panel ends because of differences in panel position, but overall these do not cause significant changes to surface impacts.

This subsidence assessment indicates maximum subsidence across most of the modified Ulan West mining area is likely to be less than 1.8m and less than 2.1m for the shallow cover areas near the southern end of the first three and last two longwall panels. The higher magnitude maximum subsidence used for assessment purposes in this assessment compared to the approved Ulan West mine plan is not expected to have any practical significance because none of the features located above the area are particularly sensitive to the magnitude of maximum subsidence and actual maximum subsidence in the central part of each longwall panel is expected to be generally much less than maximum values typically in the range of 0.9-1.5m and 1.6-1.8m in the shallow cover areas. Subsidence over the chain pillars is expected to increase with overburden depth ranging from 0.2m in shallower cover areas up to approximately 0.5m in the deeper areas.

Maximum tilts of 20-40mm/m are expected across most of modified Ulan West mining area reducing to 15-20mm/m when the overburden is greater than 200m, and increasing to 120mm/m in areas where the overburden depth is least. Locally higher values of tilt are possible in areas where steps or compression overrides form.

Systematic horizontal ground movements of 150-200mm are expected to occur in a direction toward the goaf and then in the direction of mining once the longwall face has passed. Additional horizontal movements associated with surface topography of generally less than 300mm are expected to occur in a downslope direction with larger horizontal movements of up to 500mm expected in areas where mining is in the same direction as the slope.

Maximum horizontal strains are generally expected to be less than 20mm/m across most of the modified Ulan West mining area with systematic peaks of up to 30mm/m in tension and 50mm/m in compression in the shallow areas and less than 15mm/m at cover depths above 200m.

Surface cracks are expected to be generally isolated and increase in size inversely to overburden thickness ranging from 20mm wide in flat and gently undulating terrain and generally less than 100mm wide elsewhere but possibly up to 250mm wide in shallow cover areas.

There are numerous ephemeral watercourses located within the project area. Mining below ephemeral creeks is considered to have potential to reduce surface flows and the duration that pools retain water following a rainfall event.

Mining subsidence is expected to cause surface cracking and fracturing of the strata throughout the overburden section directly above each of the longwall panels. Surface and sub-surface fracturing is expected to increase the hydraulic conductivity of the overburden strata and allow a tortuous pathway to develop between the surface and the mining horizon through this fracture network.

Water bores and groundwater seeps located directly over the longwall panels are expected to dry up as a result of mining subsidence movements. Although it is possible that some of these may return, alternative arrangements are considered likely to be necessary to supplement water supplies that rely on any bores located over and within close proximity of the proposed Ulan West modification area.

Cliff formations within the project area range in height from a few metres to greater than 20m high in some locations with most in the 3-15m high range. Cliff formations located directly above the mining area are likely to be impacted by mining subsidence with potential for cracking, shear displacements, and rock falls. Based on previous experience of mining under similar sandstone cliffs at Ulan, rock falls on 10-20% of the sandstone cliff formations located directly above the mining area are expected. In general, cliff formations that are high, overhanging, re-entrant and laterally extensive are most likely to experience perceptible changes. Mining induced rock falls outside of the mining area are not commonly observed.

Cliff formations beyond the mining area to a maximum distance of about 0.4 times overburden depth (typically 40-60m at Ulan West) have some potential to be impacted by cracking and shear movements but the probability tends to reduce with distance from the panel edge.

A protection barrier based on an angle of draw of 26.5° (half depth) to the top of the cliff formations is expected to provide full protection against mining induced rock falls, but a high level of protection against mining induced rock falls (>99%) is provided wherever the cliff formations are outside the mining area. The barriers associated with the Brokenback Conservation Area are expected to provide full protection to archaeological heritage sites identified as significant by SEA and UCML as well as protection to many of the adjacent archaeological sites.

Mining subsidence is not expected to cause significant disturbance to the fish fossil beds in the Talbragar Fish Fossil Reserve because of their already fragmented nature.

Mining subsidence is not expected to significantly impact any of the European heritage sites identified within the modified Ulan West mining area. Several of the sites are likely to experience reduced impacts as a result of the modified layout compared to the layout assessed in the UCCO Project assessment.

As indicated in the previous assessment for the UCCO Project, subsidence movements from the proposed modification are expected to change the vertical and horizontal location of Ulan Trig and other permanent survey marks in the general vicinity out to a distance of up to 2km from the mining area.

Mining subsidence movements from the project mining geometry are expected to cause perceptible damage to the residential and farm buildings on privately owned properties identified as Property ID 57 “Billir” and Property ID 254 “Woodbury”. Buried services such as water and sewerage pipes are likely to be damaged. Telephone and power lines may require some mitigation works depending on their specific location relative to mining, but in most cases, subsidence impacts on these services is easily manageable. These impacts are consistent with those predicted as part of the UCCO Project.

Farm dams, fences and four wheel drive access tracks are not expected to be significantly impacted by mining subsidence movements. However, some minor remedial work may be necessary to fill in cracks and remove compression humps. Steps such as those observed over the North 1 Longwalls C, E, and F at Ulan No 3 Mine may occur and additional remediation efforts may be required if these occur in areas crossed by access tracks. Signage to warn of the potential for mine subsidence movements in active mining areas is recommended as a precautionary measure.

TABLE OF CONTENTS

PAGE NO

1. INTRODUCTION

Ulan West Mine is located within the Ulan Mining Complex approximately 25 kilometres north-east of Gulgong in New South Wales. Ulan Coal Mines Limited (UCML) is proposing to modify the Ulan West mine plan to provide access to additional coal resources within an existing exploration lease and allow for a realignment of approved longwall panels as a result of previous mine plan changes (hereafter referred to as the proposed modification). The proposed modification is substantially within the same area as the approved mining layout that was assessed in detail in the Ulan Coal Continued Operations Project (UCCO Project) and approved under Project Approval (PA) 08_0184. UCML commissioned Umwelt (Australia) Pty Limited (Umwelt) to prepare an Environmental Assessment (EA) for the proposed modification to PA 08_0184 pursuant to Section 75W of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and SCT Operations Pty Ltd (SCT) to prepare a subsidence impact assessment for the proposed modification.

The previous mine plan changes to Longwalls 3 and 4 undertaken under the provisions of Condition 25 of Schedule 3 of PA 08_0184. A subsidence assessment of the changes was undertaken at the time. For completeness, this report presents the subsidence assessment for Longwalls 3 to 12 at Ulan West Mine in support of the broader assessment being prepared by Umwelt with particular focus on any differences to the UCCO Project assessment.

The key features likely to be impacted by subsidence movements have been identified from previous surveys, aerial reconnaissance, and subsequent ground surveys by SCT, Umwelt, South East Archaeology Pty Ltd (SEA), and others. The impacts of mining subsidence on most of these features are described in detail in the UCCO Project assessment presented in SCT Report ULA3367 dated 14 August 2009. This current assessment should be read in conjunction with the UCCO Project assessment because the detail presented there for those features where there has been no change in impact are not repeated.

Detail of the subsidence behaviour expected from the revised layout is presented in this report across the full mining area. However, apart from changes in area that cause changes to which particular natural features are impacted and some refinements to the subsidence parameter estimates based on recent monitoring experience, the subsidence impacts are substantially the same as those reported in the UCCO Project assessment. The main focus of the impact assessment presented in this report is on those sites where there are likely to be significant differences in impacts compared to those described in the UCCO Project.

The report is structured as follows:

- Section 2 provides a general site description of the project area, the surface, surface features, overburden depth, seam thickness, and mine layout as well as a summary of the changes that have occurred.

- Section 3 presents the subsidence predicted in the project area based on the results of previous subsidence monitoring at the Ulan Mining Complex.

- Section 4 presents a summary of changes from the UCCO Project and the changes in subsidence impacts that are expected for natural features, heritage features, privately owned surface improvements, and other features located over the modified Ulan West mining area.

Appendix 1 presents a revised table showing the expected probability of impacts on all of the Aboriginal archaeological sites identified within the modified Ulan West mining area.

2. SITE DESCRIPTION

Figure 1 shows a plan of the proposed and existing longwall panels superimposed onto a 1:25,000 topographic series map together with the layout considered in the UCCO Project impact assessment.

The surface above the modified Ulan West mining area is predominantly undeveloped bushland straddling the Great Dividing Range. In the north and in several pockets elsewhere, the surface is open pasture with scattered trees. Some of the area is privately owned and there are three residences located in the modified Ulan West mining area.

The Ulan West longwall panels are aligned north south and extend from Longwall 1 in the east to Longwall 12 in the west. Longwalls 8 to 12 are split in the middle around the Brokenback Conservation Area. Longwalls 3 to 12 are the subject of this assessment. Longwall 1, which is currently being mined, and Longwall 2 are already approved and are not proposed to be changed as part of the proposed modification and consequently are not assessed in this document.

The current assessment area is generally similar to the area assessed and approved in the UCCO Project. The differences are:

- A 280 hectare area in the south west corner where the panels extend further to the south into an area not previously assessed.

- Changes around the Brokenback Conservation Area including the southern part of Longwalls 11A and 12A extending further to the south. The outline of the Brokenback Conservation Area has not changed since the UCCO Project but the changes in width to individual longwall panels means some adjacent areas will also be protected.

- Small areas at either end of the panels and above the chain pillars where sideways movements in the proposed panels compared to the Part UCCO Project alignment cause minor changes in the location of impact without significantly changing the total area impacted.

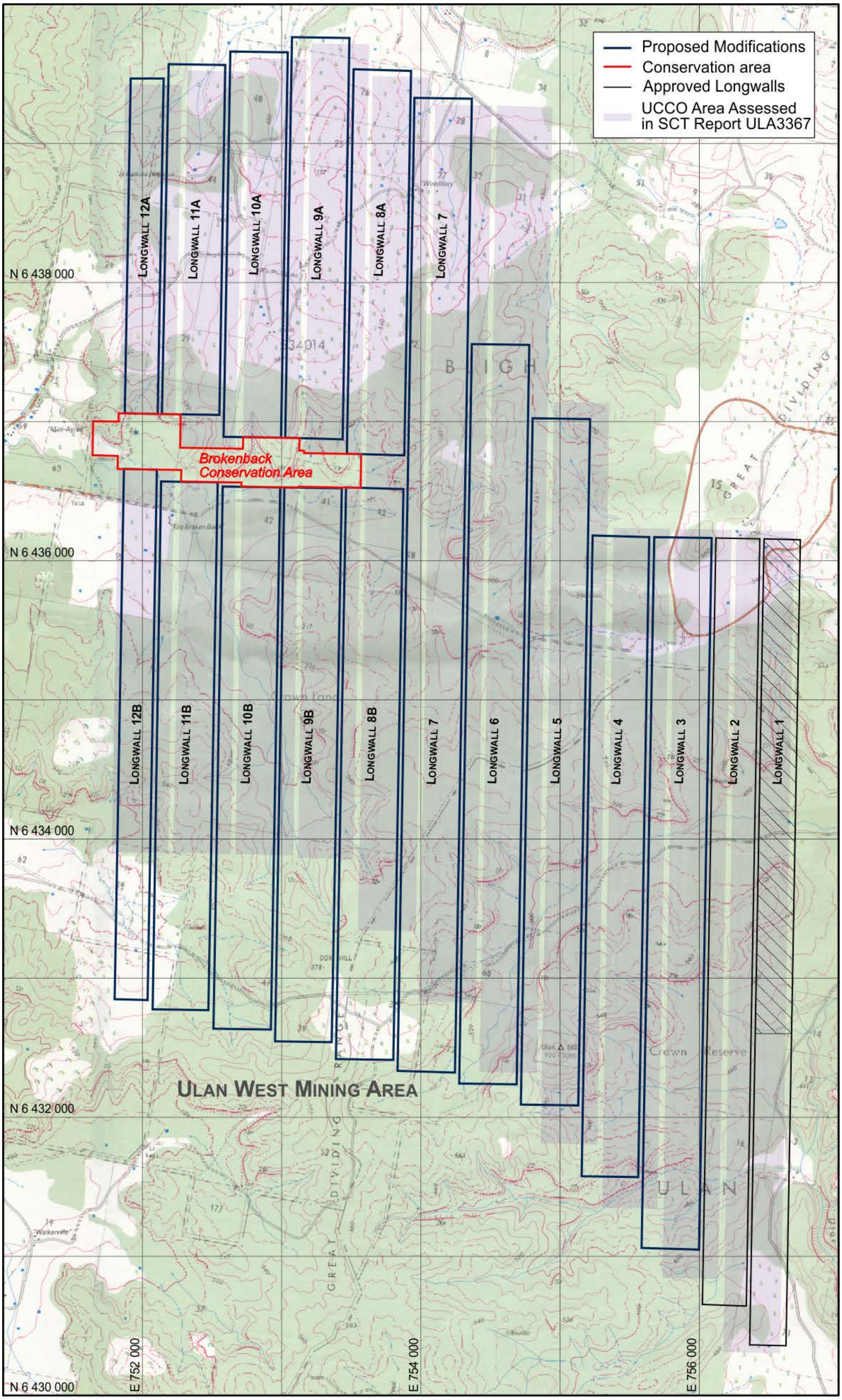

Figure 1: Site plan on a 1:25,000 topographic series map (reduced to 1:40,000), showing comparison of proposed modification with the approved mine plan for UCCO project and Longwalls 1 & 2.

- An area at the northern ends of Longwalls 5 to 7 where the area impacted by subsidence is reduced compared to the area assessed in the UCCO Project.

Figure 2 shows a plan of the overburden depth to the Ulan Seam. The modified Ulan West mining area is split diagonally by the Great Dividing Range. Overburden depths are greatest in the northeast and below the ridge lines associated with the Great Dividing Range. Most of the local variation in overburden depth is a result of surface topography but there is also a general increase to the northeast as the strata dips gently in this direction at an average gradient of approximately 1 in 70.

Overburden depth ranges from a small local high of about 250m at the north eastern corner of Longwall 3 to 80m at the southern end of Longwall 3 and ranges from 100m to 180m along the western edge of Longwall 12. Deeper areas are located at the northern end of the first longwall panels and above the central part of the split longwall panels. Shallower areas are located at the southern end of the first and last longwall panels. In general, the overburden depth ranges between about 110m to 210m over most of the modified mining area.

The surface of the modified Ulan West mining area drains south and east into the Goulburn River via Ulan Creek and north and west into the Talbragar River via a number of smaller creek systems. Cockabutta Creek drains the south western and central part of the modified Ulan West mining area around Brokenback Road and Mona Creek drains the northern part.

All the watercourses within the modified Ulan West mining area are ephemeral streams, although the lower part of Ulan Creek, to the east and outside the modified Ulan West mining area, is supported by flow from the mine's licensed discharge from the UCML owned Bobadeen Reverse Osmosis plant. There are several farm dams and numerous ponds along watercourses that retain water for extended periods after rain. Some of the ponds are retained behind rock and pebble bars, but most are associated with depressions in clay layers. There are some sections of creek channel with a solid rock base near the southern part of Longwalls 3 and 4.

The Ulan Seam is up to 7-10m thick but only the lower section is mined in underground operations. The mining height can vary depending on market conditions and other factors. For subsidence assessment purposes the mining section has been assumed to be 3.2m.

UCML is proposing to mine the Ulan Seam within the modified Ulan West mining area using the retreat longwall method of mining with 400m panel widths that create a final nominal void width of 411m for most of the panels and 238m in Longwall 12. The panels are separated by chain pillars that are 32-35m wide measured rib to rib.

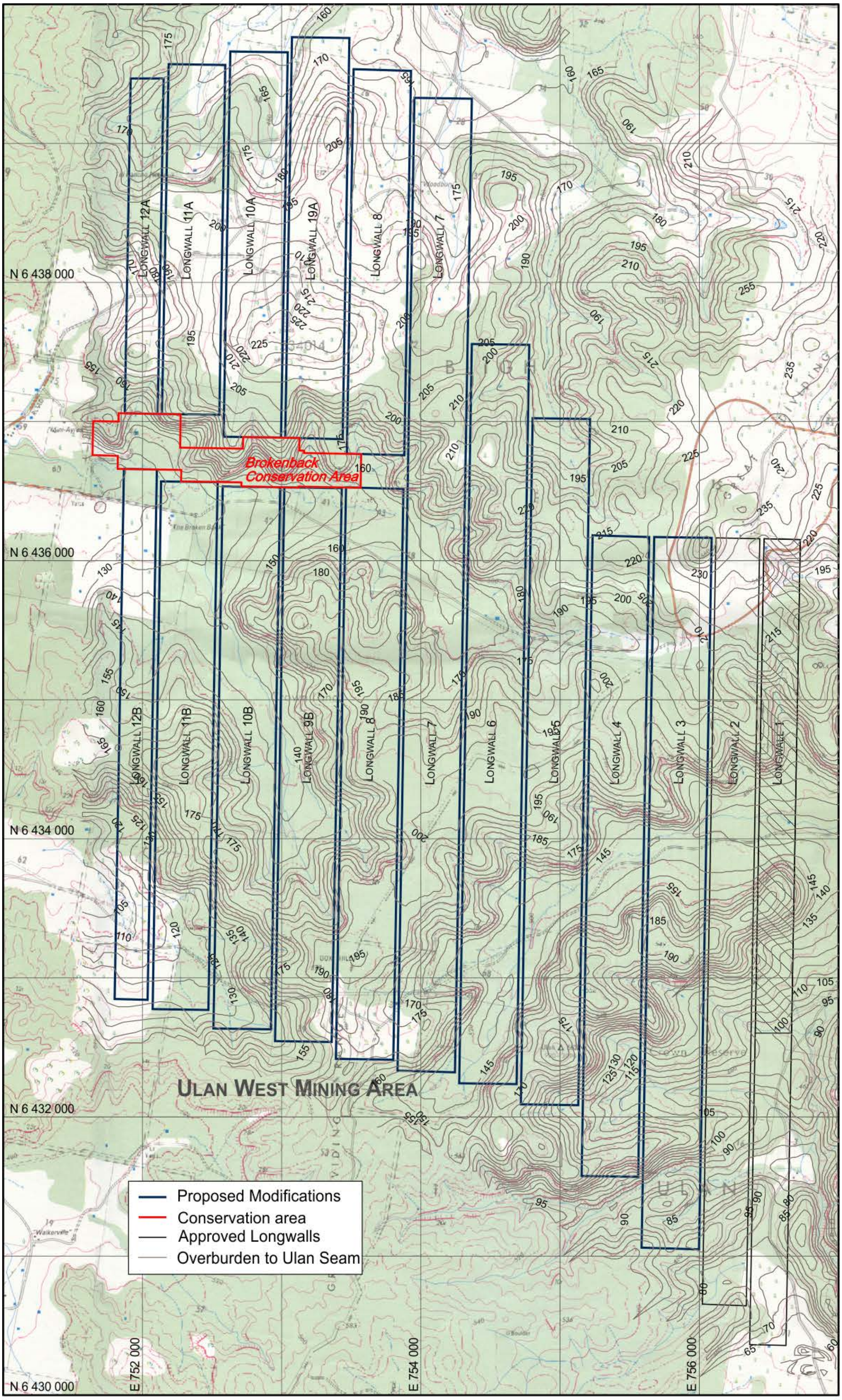

Figure 2: Overburden depth isopachs to the Ulan Seam mining horizon.

2.1 Project Context

UCML operations, collectively referred to as the Ulan Mine Complex, are located approximately 1.5 kilometres from the village of Ulan, within the Mid Western Regional Council Local Government Area (LGA). The UCML landholdings comprise approximately 18,000ha located at the headwaters of the Goulburn and Talbragar River catchments.

Mining in the Ulan area has been undertaken since the early 1920s, initially as Ulan No. 1 Colliery Holding. An exploration program undertaken in 1976 in the Ulan area proved the existence of extensive coal reserves, and mining operations at UCML expanded substantially in the 1980s. Longwall mining methods were introduced in 1986 with the commencement of Ulan No. 3.

The Ulan West mine commenced development in March 2012 within Mining Leases ML1468 and ML1341 and Consolidate Coal Lease (CCL) CCL741. The first coal was extracted from Ulan West in May 2014. The Ulan West mine is concurrently operating alongside the existing Ulan No.3 underground mine and the Ulan Open Cut mine.

The potential environmental impacts of the approved Ulan Coal Complex, including Ulan West, were assessed in the UCCO Project EA (Umwelt, 2009). UCML was granted PA 08_0184 under Part 3A of the EP&A Act for the UCCO Project on 15 November 2010. UCML also has an existing approval (EPBC No 2009/5252) under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) which was granted on 30 November 2010. Following granting of PA 08_0184, there have been a number of approved modifications to PA 08_0184 including changes to longwall widths within Longwall 1 to 4 at Ulan West.

UCML has an existing exploration lease (EL7542) which covers an area south west and an area to the north of the currently approved Ulan West mine plan. Since the approval of PA 08_0184 in 2010, exploration activities have been undertaken within existing mining leases and the southern portion of EL7542. This exploration process has further characterised the coal resource as well as provided additional detailed information on other geological features within this area.

At Ulan West a fault had previously been interpreted close to the western boundary of the existing mining lease. The location of this east-west trending fault was previously interpreted to limit the ability to mine south of the currently approved main headings of Ulan West. The further exploration activities completed in the southern portion of EL7542 have more accurately mapped the location of the fault and determined that the feature lies further south than previously interpreted. UCML have determined that there is a minable resource that can be accessed, and seek to modify the current project approval to enable access to this coal resource by adjusting the approved longwall layout in this area. A mining lease application (MLA475) has been lodged for the southern portion of the EL7542 with the NSW Trade and Investment – Division of Resources and Energy (DRE).

During 2013, UCML altered the approved Ulan West mine plan through the provisions of Condition 25 of Schedule 3 of PA 08_0184. The changes resulted in the widening of longwall panels Longwalls 3 and 4 by approximately 100m from 300m to 400m wide. Accordingly, the remaining Ulan West longwall panels will be repositioned to the west to accommodate the widening of Longwalls 3 and 4. The proposed modification will allow for the repositioning of Longwalls 5 to 12 that will be required from the previous changes to Longwalls 3 and 4. Some minor changes to the northern extent of the Ulan West longwall panels are also required through this realignment process. The repositioning of Longwalls 5 to 12 will result in changes to the previously assessed and approved Ulan West mine plan.

The changes to the Ulan West mine plan will also require repositioning of approved ventilation shafts and dewatering bores as well as the installation of additional ventilation shafts and associated infrastructure to provide ongoing support to underground mining operations.

UCML proposes to modify PA 08_0184 pursuant to section 75W of the EP&A Act.

2.2 Land Use and Ownership

The modified Ulan West mining area is predominantly undeveloped bushland dominated by sandstone outcrop and sandy soils. Grazing land in the north and small pockets in the northeast corner, south and west are of low to moderate land capability, varying soil quality, depth/rockiness, and erosion hazard potential.

The broader area is predominantly rural landholdings, native bushland and primary industries including agriculture, forestry and extractive industries.

UCML owns or leases the majority of land within the proposed Ulan West area. The approved Ulan West mine plan undermines five private landholdings and three private residences. The proposed modification will result in undermining one additional private landholding. No additional private residences will be impacted as a result of the proposed modification.

3. PREDICTED SUBSIDENCE BEHAVIOUR

In this section, the subsidence movements expected above the longwall panels at Ulan West are predicted on the basis of site specific monitoring at the Ulan Coal Complex over 33 previous longwall panels at Ulan No 3 Mine.

The subsidence profiles used in the predictions are based on previous subsidence monitoring over solid goaf edges. Systematic strains and tilts have been determined using the approach described by Holla (1991) for the Western Coalfield, adjusted slightly to take account of the site specific conditions and the results of previous measurements at the Ulan Coal Complex.

Subsidence monitoring has been conducted routinely at the Ulan Coal Complex since the commencement of longwall mining at Ulan No 3. The results of this subsidence monitoring and implications for mining are presented in end of panel reports and compilation reports for all the previous longwall panels at the Ulan Coal Complex. These results are considered to provide a strong basis for predicting subsidence for the modified Ulan West mine plan.

It should be recognised that none of the subsidence impacts anticipated are particularly sensitive to specific values of subsidence, strain or tilt, but rather to general trends in subsidence behaviour, so the focus of the prediction methodology has been on understanding the general nature of the subsidence behaviour and the impacts such subsidence is likely to have. The approach that has been adopted is considered appropriate to the types of impacts that are expected.

In general, the subsidence predictions presented are similar to those presented in the UCCO Project assessment. Individual longwall panels are the same width as those considered in the UCCO Project assessment. All but the last panel create a void that is approximately 411m wide. The overburden depth ranges between 110m to 210m over most of the modified Ulan West mining area so supercritical width subsidence behaviour is expected above each panel including Longwall 12. The term “supercritical width behaviour” means that full subsidence is reached in the centre of each longwall panel.

Compared to the UCCO Project assessment, the main changes to the subsidence predictions included in this assessment have been refinement of the subsidence profiles around the pillar edges, an increase in the magnitude of subsidence at overburden depths of less than about 130m where the bulking characteristics of the Triassic Sandstone are less dominant or completely absent and seam thickness is more critical, and recognition of the possibility of a step forming mechanism that was observed in the North 1 Longwalls C, E and F, subsequent to the UCCO Project assessment being completed.

Subsidence behaviour over most of the Ulan Coal Complex is dominated by the variable bulking characteristics of the Triassic Sandstone. This unit is up to 110m thick and its base is about 100m above the Ulan Seam. The sandstone is reduced in thickness by erosion where it outcrops in the landform across most of the site. The irregular bulking of the sandstone as it subsides causes maximum subsidence to vary randomly from about 0.9m to 1.5m in otherwise similar conditions of overburden depth and panel width. This bulking also means that the maximum subsidence is not strongly dependent on the mining height.

In contrast to the Triassic Sandstone strata, the 100m thick Permian coal measure strata located between the Ulan Seam and the base of the Triassic Sandstone behaves during subsidence in a manner that is more consistent with conventional subsidence experience. The variability in maximum subsidence is less with the maximum subsidence typically about 55% of the mining height but 65% of the mining height has been used for assessment purposes to account of any local variability that may occur.

3.1 Review of Previous Subsidence Monitoring at Ulan Coal Mine

Subsidence monitoring results from Ulan No 3 Mine are summarised in Table 1 and Figures 3 and 4. In this section, all references to longwall panels in this section relate to Ulan No 3 Mine unless otherwise noted. Table 1 summarises the subsidence parameters that have been measured on individual longwall panels at Ulan No 3 Mine up to the end of Longwall 27.

The subsidence behaviour over the modified Ulan West mining area is expected to be similar to the subsidence behaviour observed over previous longwall panels at Ulan No 3 Mine particularly the subsidence behaviour in those panels where the overburden depth ranges from 110m to 210m i.e. from Longwalls 1-17 and A-F. Subsidence monitoring from the recent longwall panels at Ulan No 3 Mine relates to overburden depths that are generally greater than 210m and while this subsidence monitoring is informative in terms of general subsidence behaviour at the site, higher values of goaf edge subsidence, angle of draw, and horizontal movements are observed at these greater depths.

Figure 3 shows the relationship between maximum subsidence as a proportion of seam thickness and the width to depth ratio of individual longwall panels based on previous subsidence monitoring at Ulan No 3. For reference, all of the longwall panels in the modified Ulan West mining area, except Longwall 12, are proposed to be 411m wide. Longwall 12 is proposed to be approximately 233m wide. The overburden depth is typically in the range 150-200m over most of proposed panels so the width to depth ratio is typically in the range 2.0-2.7 in the Ulan West mining area, with the maximum range 1.7-5.

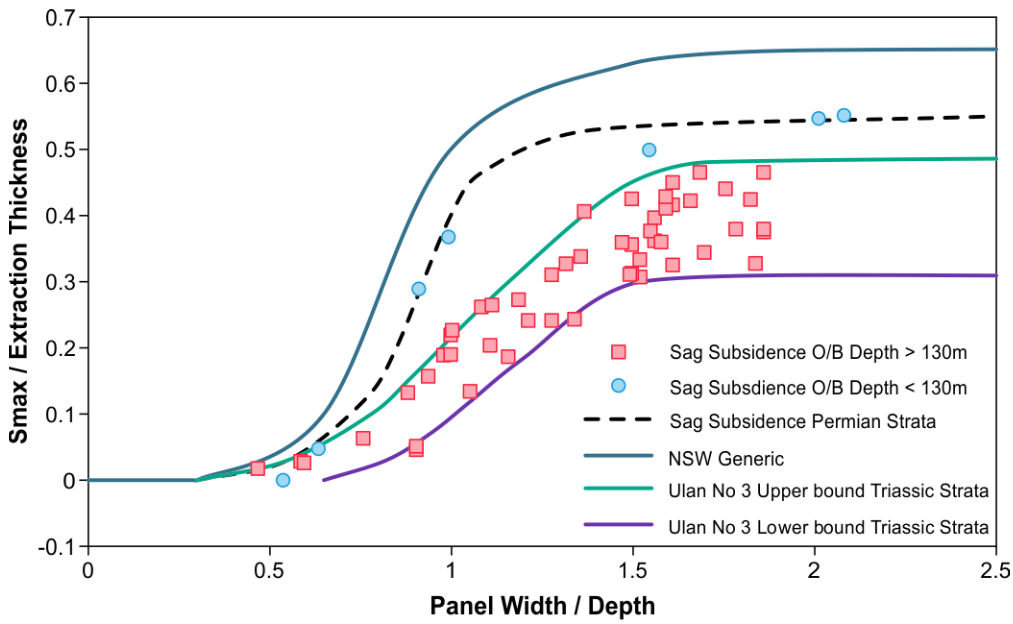

Figure 3: Sag subsidence behaviour observed at the UCML complex to date.

Maximum subsidence is reached once the ratio of panel width to overburden depth exceeds about 1.4 (a point referred to as critical width). At panel widths above critical width, the overburden depth in the central part of each panel is supported entirely on the longwall goaf (i.e. the mined out area) and does not transfer any load onto adjacent pillars or solid coal. Making the panel wider increases the central area of overburden strata fully supported on the goaf but does not increase the magnitude of subsidence.

Table 1: Summary of Previous Subsidence Monitoring at Ulan Coal Mines

LW	DEPTH (m)	MAX SUBS (m)	GOAF EDGE SUBS (mm)	ANGLE OF DRAW (°)	MAX TILT (mm/m)	MAX STRAIN (mm/m)	HORZ DISP (mm)
1	67-110	1.5-1.6	70	15	>50	N/A	N/A
5	130-190	1.0	51	10	20	10	400
A	130-150	1.2	85	13	35	20	500
B	150-170	0.93	107	14	25	10	300
6	180	0.13	54	15	5	3	100
7	170	1.0	63	26	30	7	200
8	160	1.0	87	29	15	9	300
9	150	1.2	45	19	20	9	350
10	140	1.3	99	20	20	8	200
11	150-160	1.4	85	17	40	20	350
11X	150	1.4*	-	-	32	6	200
11C	140-155	1.4*	-	-	30*	4	200*
12D	155-165	1.3	75	8	20	14	200
13D	170	1.3	-	-	20	14	250
14D	170	1.1	70	13	20	(25)	50
15D	170-180	0.96	102	39	17	7	150
16D	185-200	1.1	98	30	20	9	200
17D	200-215	1.2	64	17	14	7	200
18E	250-260	1.1	86	24	11	6	200
19E	230-240	1.2	102	27	13	3	300
22	220-285	0.8*	-	-	10*	3*	100*
23	250-280	1.4	121-206	16-41	12	6	270
24	240-280	1.4	137-154	30	15	5	220
25	240-260	1.4	110	-	17	8	200
26	240-250	1.4	222	44	14	6	800
27	250-280	1.5	290	45	13	3	600
C	180-190	1.3	100	>29	19	4	180
E	130-150	1.3	110	29	23	18	200
F	120-140	1.8	133	>35	31	27	400
W1	195-240	0.9-1.4	71	17	14	5	350
W2	230	1.4	140	72	27	10	400

** Based on estimate from incomplete subsidence records.*

Figure 3 also shows that the maximum subsidence is highly variable when the overburden depth is greater than about 130m ranging from 0.3 to about 0.45 times the extracted seam height or 0.9 to 1.5m. This effect is also illustrated in Figure 4 which shows a summary of the subsidence measured along the centreline of a 411m wide longwall panel at 200m deep in an area where the overburden depth varies only slightly and the panel width remains unchanged. The variability in maximum subsidence is attributed to the uneven bulking behaviour of the sandstone.

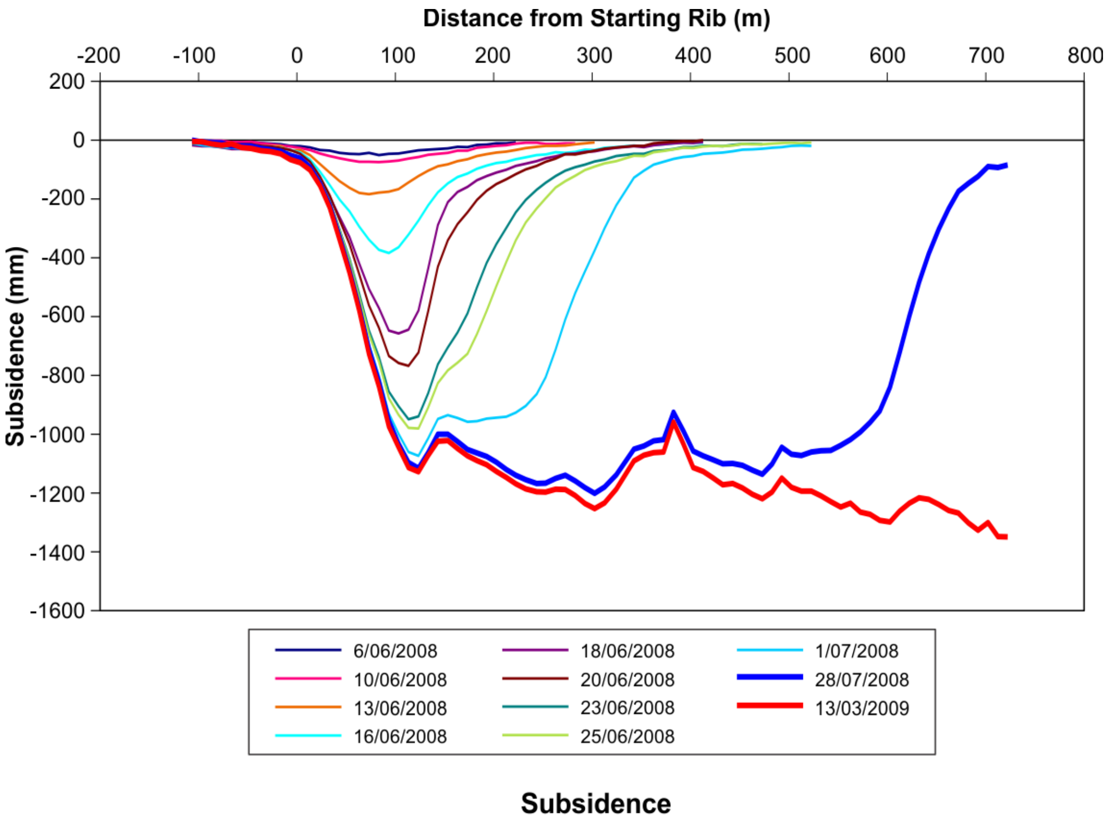

Figure 4: Subsidence profile along centreline of Longwall W1 at Ulan No 3 showing natural variability of maximum subsidence from 0.9m to 1.4m for same conditions of overburden depth and panel geometry.

The overburden strata at the Ulan Coal Complex subsides in a more regular fashion and is more consistent with general experience at other sites when the overburden depth is less than about 130m and the stronger Triassic Sandstone units are no longer significant in the subsidence processes. The maximum subsidence is also a greater proportion of the mining height reaching about 55% of the extracted mining height or a maximum of 1.8m in the two areas mined so far at Ulan No 3 where there has been less than 30m of Triassic Sandstone (Longwall1 and Longwall F).

Subsidence experience elsewhere in the Western Coalfield and in NSW more generally indicates maximum subsidence can reach up to 65% of the extracted seam thickness or 2.1m for a 3.2m mining section and this value has been used as the upper bound for prediction purposes in areas where the overburden depth is less than about 130m. Downward refinement of this estimate may be possible once the results from Longwall 1 at Ulan West become available.

Subsidence monitoring at Ulan No 3 indicates that the maximum subsidence has ranged between 0.9m to1.4m over most of the longwall panels, with slightly higher subsidence of between 1.5m to 1.6m over the first panel, Longwall 1, where the surface is located in the outcrop of the Permian Coal Measures.

Subsidence over the chain pillars has varied with the chain pillar size, the longwall width, and the overburden depth. At 150m overburden depth, subsidence over 25m wide chain pillars isolated in the goaf between 250m wide longwall panels has generally been less than 200-300mm. At 220m overburden depth, subsidence over 25m wide chain pillars is 550mm for the same mining geometry because of the increased pillar loading. Subsidence measured over 40m wide chain pillars between Longwalls 23 and 24 at Ulan No 3 was 530mm at an overburden depth of approximately 280m. These values are consistent with the pillar loading expected and the results of elastic strata compression above and below each pillar (Mills 1998).

Horizontal movements at the Ulan Coal Complex are typical of other longwall operations in moderately steep terrain. In addition to the horizontal subsidence movements typical of flat terrain, there may be up to several hundred millimetres of superimposed movement that occurs in a downslope direction where the surface topography is sloping. In flat terrain conditions, initial movements are toward the approaching longwall face (up to 100mm) followed by a reversal in direction to give a final offset in the direction of mining of up to 150mm. Closure across individual panels is typically in the range 200-300mm but up to 800mm of closure has been observed above Longwall 26 at Ulan No 3. In the central section of the longwall panel, horizontal movements are predominantly transitory in nature with a permanent offset in the direction of mining. Near the panel edges, horizontal movements are predominantly toward the goaf and the offset is permanent.

Far-field horizontal movements have been observed in recent subsidence monitoring programs where a broad and comprehensive survey control network has been established. These far-field movements have all been measured where the overburden depths is greater than about 220m. Such movements are relatively small in magnitude, typically less than 200mm (but occasionally up to 600mm) at the edge of the longwall panel, and taper gradually back to zero at a distance of approximately 1.5-2km as a linear function of distance from the goaf edge. The movements are considered to be a result of horizontal stress relief and may be influenced by geological features in the basement below the coal seam. Such small and gradual movements – equivalent to average strains of 0.13mm/m – are not expected to be of any practical significance or cause any perceptible change on any surface features but may have an influence on groundwater pressures.

Over Ulan No 3, maximum tilts ranging from 20mm/m to more than 50mm/m are typical of the longwall panels up to Longwall 11 and North 1 Longwalls A-F. From Longwalls 11-16 maximum tilts are typically 15-20mm/m when the overburden depth is in the range of 150-200m and decrease to 10-15mm/m as the overburden depth increases over Longwalls 23 to 27 to greater than 240m.

Maximum horizontal strains of up to 20mm/m have been measured in the southern panels up to Longwall 11 and North 1 Longwalls A-F decreasing in the northern panels to less than about 7mm/m as the overburden depth increases above 170m.

The angle of draw to 20mm of vertical subsidence measured at Ulan No 3 is typically in the range of 10-30° but has increased over recent panels to about 45° as the overburden depth has increased and improvements to survey control have been implemented to more accurately measure the full vertical and horizontal subsidence movements.

Goaf edge subsidence has typically been less than about 130mm at Ulan No 3 but has increased with overburden depth to almost 300mm over recent longwall panels at overburden depths of 280m.

Figure 5 shows a summary of the goaf edge subsidence profiles that have been measured over solid goaf edges at Ulan. All of these, except for the goaf edge profile over North 1 Longwall F, have a significant thickness of Triassic Sandstone. Within the bulk of the profiles, there are some small differences due to surveying, topography, variations in overburden stratigraphy, and longwall width, but the general form of the goaf edge subsidence profiles is essentially consistent. As the overburden depth decreases to less than 130m and the Triassic sandstone ceases to dominate the subsidence behaviour, the goaf edge profile steepens and is more consistent with subsidence profiles elsewhere in the Western Coalfield.

The goaf edge subsidence profiles can be divided into three parts:

1. The gradual subsidence that increases from over the solid coal to about 30m over the goaf with the Triassic sandstone and 20m without the Triassic sandstone.

2. An essentially linear section that extends from 30m over the goaf to full subsidence at a rate of up to about 10mm/m with the Triassic Sandstone and 30mm/m without the Triassic Sandstone.

3. A central section over each longwall panel associated with maximum subsidence, where the subsidence profile flattens out again.

The subsidence profiles measured over solid goaf edges can be used as the basis for subsidence predictions for Ulan West. The profile at overburden depths less than 130m has been scaled to allow for reduced overburden depth.

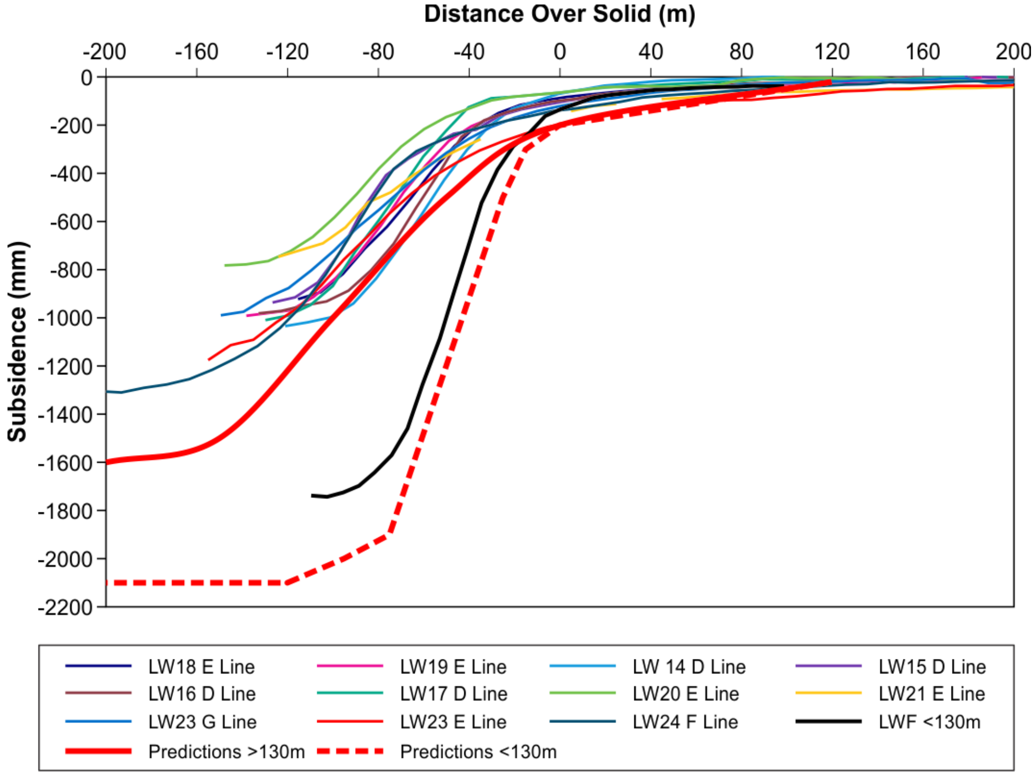

Figure 5: Goaf edge subsidence profiles measured at Ulan No 3 and used for subsidence prediction at Ulan West.

In addition to the conventional subsidence behaviour described above, two subsidence related phenomena have been observed at Ulan No 3 and have potential to occur again over Ulan West. Both have been observed at other sites and relate to particular stratigraphic conditions.

A phenomenon of horizontal shearing on a bedding plane has been observed at numerous sites in the Western and Southern Coalfields. A low strength horizon that is continuous across a large area can develop at a horizon where horizontal movements become localised. The result is all the horizontal movements above the shear horizon cause the near surface soils to roll over on themselves creating a wave like structure in the soil profile. This structure commonly has a steep front and a large tension crack a short distance behind it. The structure commonly meanders across the surface topography following the outcrop of the low strength bedding plane. These features are also known as ripples. Two such features have been observed in the vicinity of Longwall 26 on either side of Bobadeen Creek at Ulan No 3. They are considered likely to relate to the same low strength bedding plane located within the Jurassic mudstones and sandstones that overlie the Triassic Sandstone in this area.

A second phenomenon of stepping was observed over Longwalls C, E, and F. This phenomenon had not previously been observed at the Ulan Coal Complex but similar behaviour has also been observed at other sites in similar circumstances. This phenomenon causes a step change in the surface that was up to 0.8m high at the start of Longwall E. The phenomenon appears to occur where a plate of intact sandstone cantilevers out over the subsiding strata and before it breaks off, becomes locked in place as the already subsided strata moves forward as part of normal subsidence processes.

3.2 Subsidence Predictions

In this section, the maximum subsidence is estimated for the proposed longwall panels based on previous subsidence monitoring at the Ulan Coal Complex and elsewhere in the Western Coalfield. This previous monitoring is considered to provide a sound basis for subsidence predictions at Ulan West. However, it should be recognised that in a natural system there may be localised differences based on geological structures and other effects that are not necessarily predictable.

Previous subsidence monitoring indicates that the longwall panels are likely to be of supercritical width with the maximum subsidence controlled primarily by overburden caving behaviour and not panel geometry.

Predictions of strains and tilts are based on the empirical relationships developed from the results of subsidence monitoring at the Ulan Coal Complex and in the Western Coalfield (Holla 1991) more generally. Maximum strains and tilts are determined on the basis of proportionality to maximum subsidence and inverse proportionality to overburden depth. Previous monitoring experience provides a cross-check on the values determined and the approach appears to provide a reasonable basis for estimating the maximum values.

3.2.1 Vertical Subsidence

Maximum subsidence is expected to be controlled by the ability of the goaf to reconsolidate under the weight of overburden strata and bulking of the Triassic sandstone. In general, maximum subsidence is expected to be mainly in the range of 0.9-1.5m increasing in areas of lower overburden depth up to about 1.8m. However, where the overburden depth is less than about 130m and the Triassic sandstone is not present in sufficient thickness to dominate the subsidence processes, maximum subsidence of up to 65% of seam extraction thickness or 2.1m (for a 3.2m mining section) has been allowed for in the predictions of vertical subsidence. In areas where the Triassic sandstone is greater than 30m thick, i.e. overburden depth is greater than 130m, maximum subsidence in the range of 30-50% of extraction thickness or 1.8m (for a 3.2m mining section) has been used for assessment purposes.

Subsidence over the chain pillars is expected to increase with overburden depth ranging from less than 0.2m in shallow areas to a maximum of about 0.5m in areas where the overburden depth is greater than about 200m.

Goaf edge subsidence is predicted to be less than 130mm across most of the Ulan West mining area. Angles of draw ranging between 10-45° (with 20-30° typical) are expected but it should be recognised that angle of draw is very sensitive to small changes in survey tolerance. A greater or lesser angle of draw is not particularly significant because vertical subsidence outside the panel edges is so small it is considered to be insignificant for all practical purposes.

Subsidence over each panel is likely to be substantially complete once the panel has been mined, but additional subsidence is expected when the next longwall panel is mined, mainly within about 100m of the intermediate chain pillar.

Figure 6 shows contours of subsidence that are expected at the completion of the proposed longwall mining. These subsidence contours are based on goaf edge subsidence profiles measured previously at the Ulan Coal Complex with an upper limit of maximum subsidence of 1.8m over most of the area and 2.1m in areas where the overburden depth is less than 130m and the Triassic sandstone is not sufficiently thick to significantly modify subsidence behaviour. The actual maximum subsidence is expected to range between 0.9m and 1.5m over most of the area similar to the current approved mining. The contours shown are considered to be an upper limit.

A digital surface was generated from the contours of subsidence shown in Figure 6 for the purposes of stream gradient assessments and estimation of potential ponding areas. This surface was developed from the contour lines and re-gridded onto a 10m by 10m grid.

3.2.2 Tilt

Using the approach outlined by Holla (1991) which is based on experience elsewhere in the Western Coalfield, maximum tilts are inversely proportional to overburden depth. The Holla method indicates tilts of up to 120mm/m in the shallower areas in the south, with maximum tilts over most of the mining area in the range 15-40mm/m. These estimates are consistent with experience at Ulan No 3.

Maximum tilts are expected to range from 15mm/m in the deeper areas up to about 120mm/m in the shallow areas. Maximum tilts are expected to be in the range 20-40mm/m over most of the Ulan West mining area reducing to 15-20mm/m when the overburden depth is greater than 200m, and increasing to 120mm/m in areas where the overburden depth is 80m.

Over the centre of each longwall panel, tilt is likely to be transitory, although some low levels of residual tilt may remain as part of alternating zones of compression and tension, particularly in the shallower areas. Tilt is likely to be permanent near the solid goaf edges and may be greater near the start and finish of each longwall panel. As each subsequent longwall panel is mined, there may be some additional vertical subsidence over the intermediate chain pillar between panels so the permanent tilt near the chain pillar edge may reduce as a result of mining the adjacent panel.

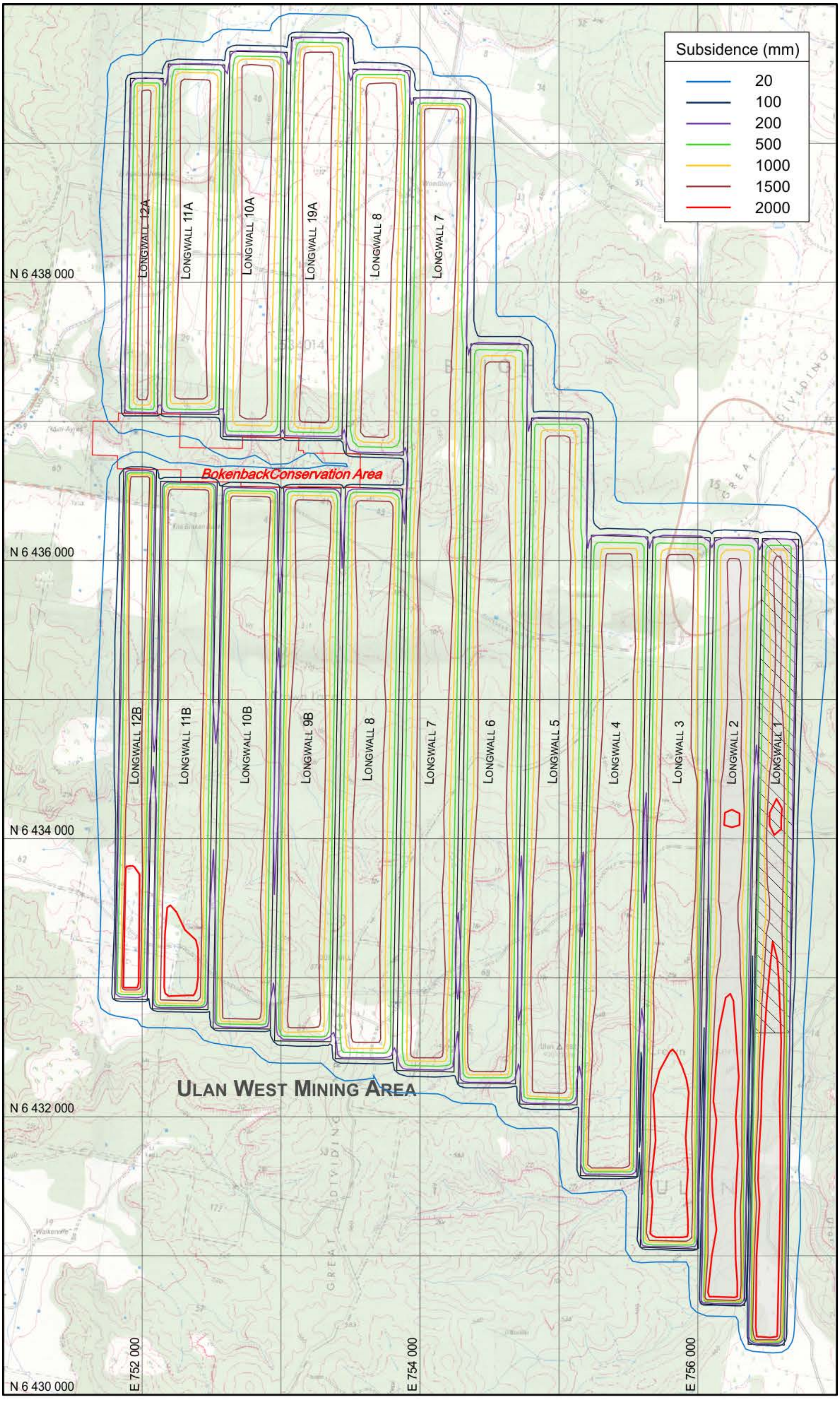

Figure 6: Contours of subsidence predicted for the proposed Ulan West modification area.

Locally high values of tilt may also occur in areas where steps or compression overrides form. In these areas, tilts may be locally higher than the systematic tilts described above.

3.2.3 Horizontal Movements

Horizontal ground movements occur at the surface in response to vertical subsidence movements within the overburden strata. There are three main components of horizontal movement, a systematic component that occurs as a result of vertical subsidence, a component that occurs as a result of horizontal stress relief, and a topographic component that occurs as a result of sloping terrain.

Systematic horizontal ground movements are expected to occur in a direction toward the goaf and then in the direction of mining once the longwall face has passed. The magnitude of systematic horizontal movements is typically less than 150-200mm.

Horizontal movements associated with horizontal stress relief have been observed to occur outside the mining area. In the Ulan West mining area, the magnitude of these movements is generally expected to be less than 200mm at the goaf edge tapering to zero at a distance of approximately 2km ahead of longwall mining. The gradual rate of change outside the mining area is generally so small as to be of no practical significance.

Horizontal movements associated with topography are expected to occur in a downslope direction with larger horizontal movements expected in areas where mining is in the same direction as the slope. The magnitude and direction of the topographic component is strongly dependent on surface topography, but is expected to be generally less than 300-500mm as indicated by previous monitoring.

3.2.4 Strain and Surface Cracks

For subsidence of 1.8m, Holla (1991) indicates compression strains of up to 50mm/m and tensile strains of up to about 30mm/m at the minimum overburden depth of approximately 80m. Experience at Ulan No 3 indicates that the maximum horizontal strains are likely to be generally less than 20mm/m at 160m overburden depth and generally less than 15mm/m at 200m overburden depth.

Strain is the rate of change of horizontal ground movements. Strain may be tensile (stretching) or compressive in nature. Compressive strains tend to be larger in magnitude than tensile strains. Tension cracks are expected to develop over the longwall panels and remain after the passage of mining in the vicinity of panel edges and along the tops of topographic highs. Tension cracks are expected to be greatest at the start of each panel and to be permanent all around the solid panel edges typically about 0.3 times overburden depth from the edge of each panel. Transient tension cracks may also occur at regular intervals above the centre of the panel typically just behind the longwall face. Remnants of these transient tension cracks are commonly interspersed with compression humps above the centre of each extracted longwall panel. Permanent compression humps are expected at regular intervals along the panel and compression is expected at topographic lows such as drainage channels where fracturing of stream channels flowing on bedrock is to likely to occur.

The magnitude of tensile strain at which surface cracking is detectable is sensitive to the nature of the surface terrain. Cracks are typically evident on hard surfaces such as roads and bare rock outcrops at strains of about 2-5mm/m and in bushland environments at strains above about 5-10mm/m. Cracks are typically less than about 20mm wide in flat or gently undulating terrain but may be larger, generally less than 100mm wide but possibly up to 250mm wide, in shallower areas. Tension cracks tend to be larger at the top of steep slopes and cliffs that are directly mined under. Tension cracks typically align with natural joint directions in the rock mass and may form en echelon type cracks along goaf edges.

With each subsequent longwall panel mined, there is likely to be additional vertical subsidence over the intermediate chain pillar. The tensile strains over the goaf edge may reduce as a result of this additional subsidence. The compressive strains are likely to generally increase as a result of the additional subsidence.

3.2.5 Unconventional Subsidence Effects

Recent experience at Ulan No 3 indicates that two styles of unconventional subsidence are possible in the modified Ulan West mining area. The first involves stepping of the surface with up to 0.8m steps possible. This style of behaviour is most likely to occur at overburden depths of about 130-140m and 180-190m in areas where thin slabs of sandstone strata outcrop near the surface. The second involves horizontal shearing and compression overrides with local humps of up to about 0.5m high forming as a ripple on the surface. These are most likely to occur where low strength bedding plane horizons interact with the surface. So far at Ulan No 3, this ripple effect has only been observed at an overburden depth of about 240m. Given that most of the modified Ulan West mining area is located in areas where the overburden depth is less than 240m, this effect is unlikely to occur unless another low strength bedding plane is mobilised lower in the overburden strata.

3.3 Reliability and Accuracy of Subsidence Predictions

The approach to estimating subsidence used in this assessment is based on a review of previous experience over 33 previous longwall panels at Ulan No 3 and estimating the maximum likely subsidence based on this data. This approach has been used by Holla and others in the past and is considered essentially sound. This method is an empirical approach suitable for providing an upper limit based on experience to date. Actual subsidence and subsidence parameters are expected to be generally less and in most cases significantly less than the upper limit values provided by an empirical approach. Nevertheless, an upper limit estimate of subsidence movements is considered appropriate for assessment purposes.

The approach taken in this assessment has been to provide conservative estimates of subsidence, recognising that in the particular circumstances at Ulan West, none of the impacts are likely to be particularly sensitive to the specific magnitude of subsidence, but rather to the general nature of the subsidence expected. Further refinement is expected to be possible as the subsidence database for shallower areas and observations of subsidence behaviour across multiple depth ranges increases with further high quality subsidence monitoring.

It is not credible that the magnitude of maximum subsidence could exceed predicted maxima by 100% or 200% because the seam thickness mined is much less than double the predicted subsidence. Therefore, this possibility has not been considered.

4. SUBSIDENCE IMPACT ASSESSMENT

This section presents a general summary of the surface features that are located within the modified Ulan West mining area and then an assessment of the specific subsidence impacts focusing on those features where the changes in mine layout associated with the proposed modification have potential to cause different impacts to the impacts described in the UCCO Project assessment.

4.1 Overview of Impacts

The locations of non-UCML owned residential dwellings, European heritage sites identified by SEA and others, significant natural features, and cliff formations inspected are shown in Figure 7 together with the modified Ulan West mine layout. The original layout assessed in the UCCO Project and subsequently approved is shown lightly shaded in the background as a reference to those areas that have been previously assessed and for which no substantive change in impact is expected.

The natural features impacted by mining subsidence include sandstone cliff formations, watercourses, natural seeps/springs, and the Talbragar Fish Fossil deposit. Most of the sandstone cliff formations located within the UCCO Project area have been visited on foot and inspected. A compendium of photographs of sandstone cliff formations is included in Appendix 2 of the UCCO Project subsidence assessment, SCT Report ULA3367, and is not duplicated here. Although there are additional cliff formations located in the south west of the modified Ulan West mining area that were not impacted by the layout assessed in the UCCO Project, there are no cliff formations located in this area that are considered to be particularly significant in their own right beyond their association with archaeological heritage sites.

Archaeological sites identified by SEA have been assessed generically on the basis of their location within the stratigraphic sequence and past experience of mining under similar formations. There are several additional sites impacted by the revised mine layout that were not impacted by the layout assessed in the UCCO Project. There are also several other sites that are no longer impacted by mining. These are not assessed in this report. A list of all the sites expected to be impacted by the revised mine plan including those previously assessed in the UCCO Project is presented in Appendix 1.

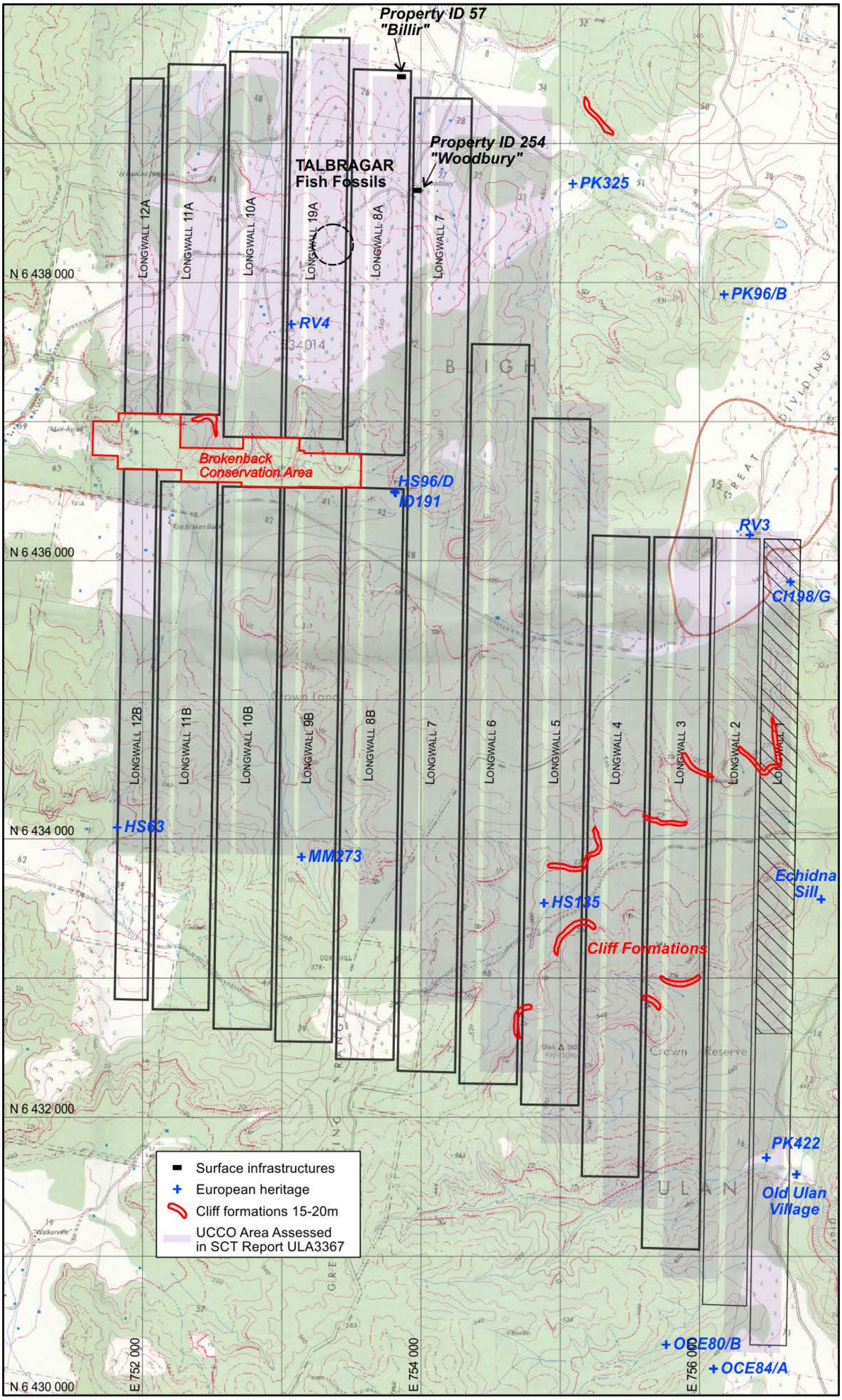

Figure 7: Locations of non UCML owned residential dwellings, European heritage sites and cliff formations greater than 15-20m high.

A site specific subsidence assessment has been conducted on four sites – 161, 162, 284, and CC28 – determined by SEA as being of high significance. The assessment indicates that without some form of mitigation, there is a high potential (estimated to be 70% probability) of perceptible impacts such as fracturing and shear movements and a 20% probability of rock falls.

European heritage features identified within the Ulan West mining area comprise remnant structures from timber getting operations and scattered artefacts including at two sites located below overhanging sandstone cliff formations. These structures are individually assessed in the UCCO Project and there are no new sites identified in the new areas that are now planned to be mined. Proposed changes in the mine layout do not significantly change the nature of impacts at most of the sites although at three of the sites, the impacts are expected to be reduced.

Surface improvements that have been identified include several power lines, Ulan Trig, dwellings and services associated with Property ID 57 "Billir" and Property ID 254 "Woodbury". Privately owned farm infrastructure such as outbuildings, dams and fences, and various access road and four-wheel drive tracks that traverse the surface have also been assessed generically.

None of the UCML owned infrastructure has been assessed although at present there is limited UCML owned infrastructure within the modified Ulan West mining area apart from fences, tracks, and various exploration / monitoring stations.

The SMP Guidelines (NSW DMR 2003 Appendix B) list a range of features that should be considered in a subsidence assessment. The features in this list that are either not located within the project mining area or would not be impacted in any perceptible way by longwall mining in the project area include: drinking water catchments, rivers, seas or lakes, shorelines, natural dams, major escarpments, national parks or wilderness areas, state recreation areas, state conservation areas, state forests, railways, public roads, bridges, tunnels, drainage culverts, water infrastructure, sewerage pipelines, sewerage treatment works, gas pipelines, liquid fuel pipelines, gas or fuel storage facilities, tanks, air strips, public utilities or amenities, poultry sheds, factories, industrial buildings, equipment or operations sensitive to surface movements, or any industrial, commercial or business activities.

Impacts on flora and fauna, threatened or protected species, and water related eco-systems, swamps and wetlands, aquifers, wells and bores, creeks, natural springs, and surface water have not been specifically assessed in this report, although SCT understands that these assessments have been undertaken by Umwelt and others based on the results of this subsidence assessment.

4.2 Sandstone Cliff Formations

There are numerous sandstone cliff formations located within the modified Ulan West mining area. Most of these cliffs are in the range 3-15m high and are associated with one of four cliff forming sandstone units within the Triassic Sandstone strata that extends from 100m to about 210m above the mining horizon. Most of the larger cliffs are associated with a particular stratigraphic unit that occurs about 160-190m above the Ulan Seam over Ulan No 3 and 130-160m in the western part of Ulan West.

All the large cliffs greater than 20m high were identified, inspected, and assessed in the UCCO Project (SCT Report ULA3367). Many of the smaller cliffs, the locations of which are shown in Figure 8, have also been visited and photographed. There are no cliffs greater than 20m high within the modified Ulan West mining area that were not assessed for the UCCO Project. Cliff formations located outside the UCCO Project area but within the modified Ulan West mining area have been inspected during aerial reconnaissance of the site and several associated with archaeological features have been visited. The size and character of these formations is similar to many of the outcrops and smaller cliffs assessed generically for the UCCO Project.

In the late 1990's, a survey was conducted of all the cliff formations at Ulan No 3 that had been mined under at that time, mainly over Longwalls 1-12. This survey indicated that about 20% of the undermined length of cliff formations formed in a cliff forming sandstone between 160m and 190m above the Ulan Seam experienced rock falls and cliffs over about 70% of the undermined length were perceptibly impacted.

Rock falls ranged in extent from complete destabilisation of the rock formation to localised falls of a few cubic metres. Rock fall frequency tended to be greatest in the central part of each panel, but there are also numerous examples of rock falls occurring over chain pillars where longwalls have been mined on both sides. Maximum subsidence over the 210m to 260m wide Longwalls 1-12 at Ulan No 3 ranged from 0.9-1.5m. The magnitude of subsidence movements at these sites is therefore generally similar to the movements anticipated at the location of the four archaeological sites of interest.

Figures 8 to 11 illustrate the range of impacts that have been observed at Ulan No 3 and are likely to be observed at Ulan West. These impacts range from no perceptible impact to total collapse of the rock formation with no part of the original cliff face intact. The spectrum of impacts ranges from minor cracking, shearing on low strength bedding planes possibly causing shear offsets, opening of larger tension cracks, possibly with minor rock falls, larger rock falls, complete disintegration of the entire rock formation.

It is difficult to predict with confidence exactly which formations are going to be impacted by mining subsidence. However, in general, cliff formations that are:

Figure 8: Examples of perceptible shear movements.

- part of longer formations
- high
- overhanging
- located in re-entrants (i.e. cut backs into the line of cliff line that forms nick points)
- located where there is potential for horizontal compression movements along their length

tend to be more vulnerable to subsidence impacts.

In general, cliff formations that are high, overhanging, re-entrant and laterally extensive are impacted more than low, isolated features such as boulders or pagoda formations particularly when these isolated features are less than 20m in lateral dimension and less than 3m high.

Most of the major cliff formations over the Ulan West mining area are formed within the main sandstone cliff forming unit located at 60-90m above the base of the Triassic sandstones equivalent to 160m to 190m above the mining horizon in the east and 130m to 150m in the western part of Ulan West. The large formations in the southwest of the modified Ulan West mining area and those around the Brokenback Conservation Area are formed within this unit. Cliff formations in these units are expected to sustain mining related rock falls along about 20% of the length directly undermined and perceptible changes such as cracking along up to 70% of their length.

Cliff formations in the lower Triassic series are expected to be generally more tolerant to subsidence impacts. Recent experience over Longwalls E and F indicates perceptible impacts such as cracks, shear movements, and minor rock dislocations on about 50% of the length of formation directly undermined and rock falls on about 5% of the undermined length.

Cliff formations located within the upper part of the Triassic sandstone sequence are located in the central part of the Ulan West mining area. These cliff formations are generally less than 5m high and tend to be isolated features or heavily fractured. There is limited experience on which to develop a probability rating, but their general form suggests a probability of rock falls of less than 5% and potential for perceptible cracking of less than 20%.

Sandstone features located outside of the mining area may experience perceptible tensile cracking up to a distance of approximately 0.4 times overburden depth (typically 60-80m) from the goaf edge, but perceptible changes and rock falls outside of the mining area are unusual and are generally associated with an extension of an impact initiated within the mining area or rock formations that were imminently unstable prior to mining.

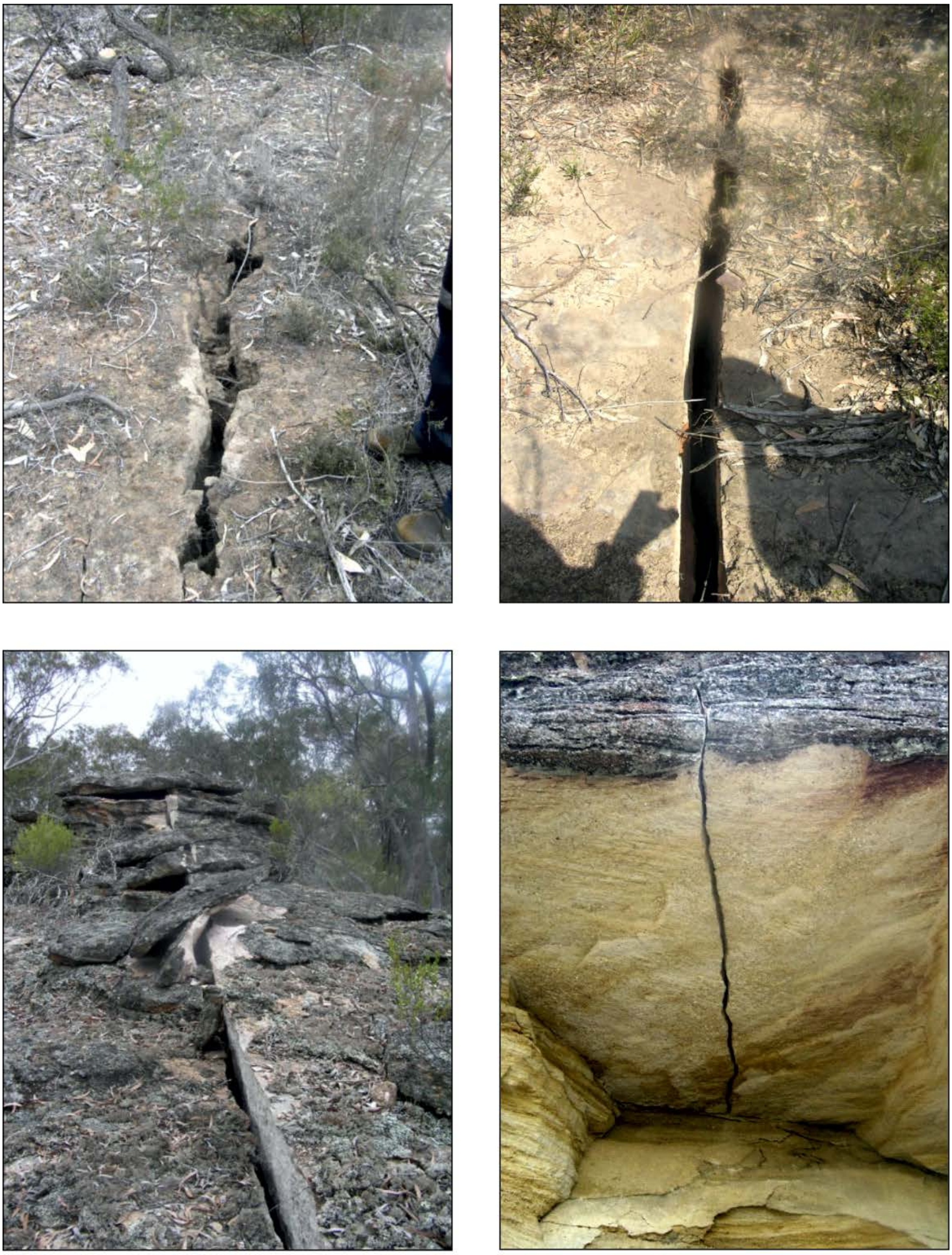

Figure 9: Examples of tension cracking.

Figure 10: Examples of rock disturbance causing minor rock falls.

Figure 11: Rock Falls.

A subsidence protection barrier based on an angle of draw of 26.5° is expected to fully protect cliff formations from any mining impacts. However, a high level of protection against rock falls (nominally greater than 99%) is provided if cliff formations are not directly mined under.

Some cracking and opening of existing joints may be observed over the solid coal out to a distance from the goaf edge of up to about 0.4 times overburden depth but at the Ulan Coal Complex perceptible mining induced changes are not common on the surface beyond the goaf edge.

There are several cliff formations located over the Ulan West mining area that are estimated to be greater than 20m high depending on how they are measured. Those located within the Brokenback Conservation Area are fully protected by a barrier equivalent to a 26.5° angle of draw. Others along the ridge adjacent to Ulan Trig are expected to experience the full range of subsidence movements with rock falls along about 20% of the length of cliff formation mined under and cracking, shearing, and minor dislocations along up to 70% of the length mined under.

4.3 Watercourses

There are numerous watercourses and drainage lines located within the modified Ulan West mining area, but because the area straddles the Great Dividing Range, they are all headwater catchments and of an ephemeral nature. The changes in mine layout have the effect of impacting a tributary of Cockabutta Creek in the southwest of the modified Ulan West mining area that was not previously impacted. Ulan Creek is located immediately to the east of Ulan West Longwall 1 and is well outside the modified Ulan West mining area. Impacts to other watercourses and drainage lines for the proposed mining layout are expected to be similar to those described in the UCCO Project assessment.

There are several minor watercourses that have short sections of the creek flowing over rock outcrop. Mining subsidence is expected to cause fracturing of this rock strata with potential for flow diversion into the substrata with the effect that pools of water in ephemeral streams will tend to drain away more quickly after rainfall events than prior to mining and low flows may not be evident as surface flow. In creeks with sandy bases, a similar trend is likely within the underlying bedrock, but cracking is less likely to be evident at the surface because of the masking presence of surface materials. Downstream flows are likely to be reduced as some surface flow is lost into the sub-surface fracture network, either directly through occasional surface cracks or indirectly as a result of reduced water tables.

4.4 Overburden Impacts to Groundwater

An extensive program of monitoring overburden behaviour directly above and in close proximity to extracted longwall panels has been undertaken at the Ulan Coal Complex over a period of several years. This monitoring indicates that the full section of overburden strata above each individual panel becomes more fractured as a result of subsidence related ground movements. The vertical connectivity of this fracturing varies depending on the nature of the rock strata, with the fracture network more tortuous in thinly bedded strata and more conductive in massive sandstone strata.

Monitoring indicates that the groundwater above each longwall panel is drawn down into the mine by drainage through the natural and mining induced fracture networks under the hydraulic gradient created by the zero pressure in the mine. Recharge from the surface may slow this process, but the evidence from monitoring has been that surface and any lateral recharge that may occur as been insufficient to stop complete depressurisation of the overburden strata even above a 260m wide longwall panel at 220m of overburden depth.

The tortuous nature of the fracture network within the Permian strata is such that full drawdown may take some years to complete. In areas where Jurassic strata is present on the surface, the rate of rainfall recharge appears to be sufficient to support a perched aquifer within the Jurassic strata despite the fracturing. This perch is considered most likely to be recharging the deeper groundwater and its presence is a reflection of the average surface recharge rate exceeding the outflow rate to the deeper groundwater. Groundwater within the deeper Triassic and Permian strata appears to be drawn down directly over each longwall panel and for up to several kilometres either side of each panel (MER 2009).

Ulan West Mine is proposing to mine Longwalls 3-12 in an area where the overburden depth ranges from about 250m to 80m. The longwall panels create a void that is nominally 410m wide with full subsidence expected in the central part of each longwall panel consistent with supercritical width subsidence behaviour. Where full subsidence occurs, a vertically interconnected fracture network is expected above each longwall goaf extending through to the surface. The vertically interconnected fracture network created by mining subsidence increases the permeability of the overburden strata but the tortuous nature of the fracture network means that the magnitude of any flow is relatively limited, increasing with area of extraction at an estimated rate of about 0.5 Ml/day/km^2 of extraction based on a broad brush estimate of the mine inflow rates.

Immediately following mining, the fracture network created by mining subsidence has potential to be substantially filled by groundwater. This groundwater acts as a barrier to air flow between the mine ventilation circuit and the surface. However, over time, the groundwater drains downward into the goaf allowing the fracture network to eventually become unsaturated. Once the fracture network is unsaturated, the groundwater barrier is likely to become ineffective and an airflow connection between the surface and underground becomes possible. The pathway is very tortuous and the pressure differentials between the mine ventilation system and the surface are low, so the volume of flow is typically low.

Experience of monitoring groundwater above Longwall 22 and in the vicinity of Longwalls 12 and 23 at Ulan No 3, indicates that, at an overburden depth of about 220 m, it takes several years for the groundwater within the Triassic Sandstone to drain downward into the mine and completely depressurise the sandstone. The rate of decrease in water level in the Permian coal measure strata is about an order of magnitude quicker than in the Triassic because of the lower storativity (fracture and connected matrix porosity) in the coal measure strata. Above Longwall 22, it took about three years to drain and desaturate 30 m of Triassic sandstone but less than six months to completely depressurise about 70 m of Permian strata.

On the basis of the experience over Longwall 22 at Ulan No 3, there appears likely to be complete desaturation of the overburden strata above each longwall panel within about six months of mining any particular location once there is no longer any groundwater within the Triassic sandstone. The base of the Triassic sandstone is located about 100 m above the Ulan Seam mining horizon. Assuming, the groundwater is at a level about 30 m below the surface, the potential for desaturation within six months appears likely to be greatest when the overburden depth is less than about 130 m. Connection over a longer timeframe is considered inevitable unless there is a significant source of surface recharge available.

As the overburden depth gets less than about 130 m, the timeframe for complete depressurisation and desaturation is expected to decrease. At similar mine sites, vertical connectivity is clearly apparent with significant inflow following rainfall commonly observed at overburden depths of up to about 140 m to 180 m and occasionally much greater.

Tammetta (2012) provides an empirical basis to estimate the height of depressurisation. At Ulan West, this empirical approach indicates the overburden strata above all the longwall panels will eventually be completely depressurised. This anticipated depressurisation is consistent with the monitoring experience at Ulan No 3 Mine.

4.5 Natural Seeps and Springs

The change in mining layout associated with the proposed modification does not cause any changes to impacts to the seeps or springs identified within the modified Ulan West mining area.

There are several locations where water is observed to seep out from sandstone formations. The volume of flow is typically slight, but enough to keep the ground moist in the immediate vicinity and, in some cases, to support surface flow for a few metres downslope.

Fracturing of the overburden strata above each panel is expected to reduce surface flows from these springs and the period after rain that downstream pools retain water. Over time, fine grained material may fill fractures within the overburden strata and reduce the hydraulic conductivity of the immediate surface strata, as has been observed in Ulan Creek where inflows in highwall failure cracks have reduced over time, but, until this happens, seeps and natural springs located over the mining area are expected to dry up as a result of mining.

4.6 Talbragar Fish Fossil Reserve

The changes to the mine layout associated with the proposed modification are not expected to have any significantly different impact on the Talbragar Fish Fossil Reserve compared to the impacts of the mining layout described in the UCCO Project. Mining subsidence is expected to cause lowering of the ground surface and possible surface cracking. However, given the fragmented nature of the chert beds and the low strength nature of the underlying strata, it is considered likely that mining subsidence movements would be accommodated without significant disturbance to the fish fossil beds.

4.7 Archaeological Sites

In this section, the changes in assessed probabilities of impacts to archaeological heritage sites associated with the proposed modification are presented and discussed. Change from the UCCO Project assessment are primarily a result of changes in the mining layout, but impacts on grinding grooves and sites located at valley heads have also been reassessed on the basis of recent experience of impacts at Ulan No 3. Four sites in the Cockabutta Creek catchment identified in the archaeological heritage assessment as significant have been specifically assessed.

4.7.1 Sites With Changed Impact Probability From UCCO

Table 2 presents a summary of the probabilities of impacts for those sites where the probability has changed from the UCCO Project assessment. The probability assessed in the UCCO Project is included in brackets for comparison. Some new sites beyond the area previously assessed are included.

An assessment of the probabilities of subsidence impacts on all the archaeological sites identified by SEA is included in the UCCO Project assessment report. For most of these sites, the impacts from the modified layout discussed in this report have not changed, however for completeness, an updated list of the probabilities of impacts expected is provided in Appendix 1.

Archaeological sites identified by SEA are shown in Figure 12 relative to the modified Ulan West mining layout. Those sites where the assessment has changed are highlighted. A range of different types of sites are distributed across the surface. They are particularly concentrated above the first seven Ulan West longwall panels, the periphery of the Brokenback Conservation Area, and the southern part of the last five longwall panels at Ulan West.

The Brokenback Conservation Area has not changed from that shown in the UCCO Project and the archaeological sites identified by SEA and UCML as being significant have a high level of protection based on a solid coal barrier equivalent to an angle of draw of 26.5° from each of the sites. The overburden depth to the top of the cliff formations is approximately 180m in this area, so the barriers are equal to approximately 90m in each direction

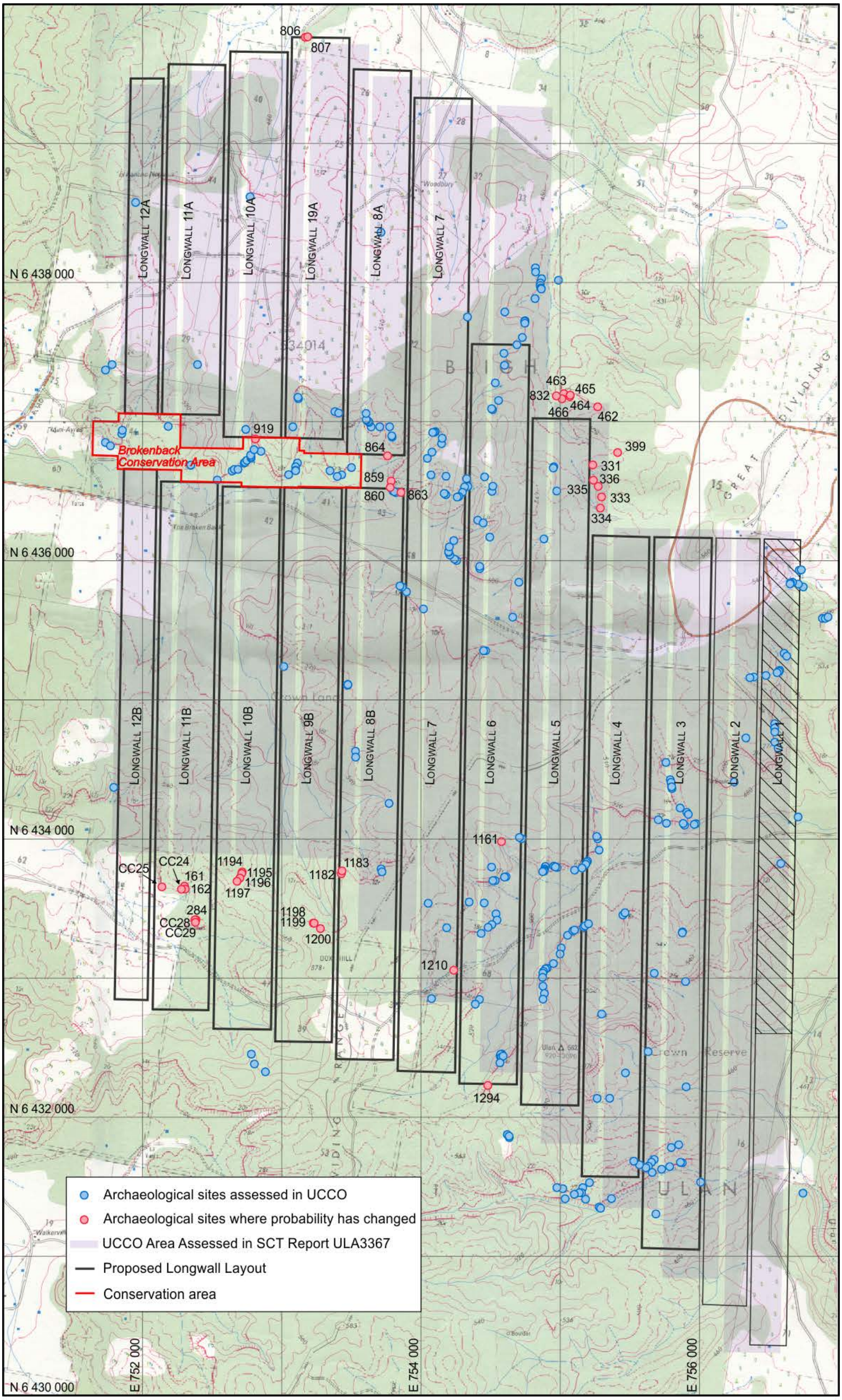

Figure 12: Location of known archaeological sites.

from the location given for each site. Numerous other sites located directly over or close to these conservation barriers will also be substantially protected from mining subsidence impacts. The subsidence impact assessment for Site 919 has changed as a result of its location at the head of a valley and reassessment following recent experience of cracking in a similar geometry at Ulan No 3.

Grinding groove sites are by their nature located on rock outcrops. Such outcrops tend to be sensitive to surface cracking. There is some potential for subsidence movements to cause cracking as a result of both horizontal compression and tension cracking. The fractures may cause perceptible change at grinding groove sites. Recent experience at Ulan No 3 of cracking at such a site is typical of the impacts that may occur.

Subsidence movements are not expected to have any practical effect on artefact scatters and isolated finds in open terrain. These types of sites are not considered in this report. There is a slight possibility of subsidence cracks causing disturbance to scar trees and stone arrangement sites located close to the edge of or directly over mining areas. However the magnitude and frequency of previous surface cracking at the Ulan Coal Complex has been so small that the potential for change at these sites is considered to be of no practical significance.

For archaeological sites located in or close to rock shelters along outcrop of the Triassic sandstone, the approach taken to assess subsidence impacts is to provide a generic assessment of the types of subsidence impacts that can be expected in each type of rock formation and a probability of impact. The sites have been assessed for rock falls and perceptible change. The term “perceptible change” refers to any changes in the rock formations that are associated with mining activity and subsidence movements. Such impacts include tensile cracking ranging from fine cracks to major fractures, shear movements on bedding planes and through intact strata, perceptible disturbance of any formations, and rock falls ranging from minor dislocation of material through to major falls.

The probability of perceptible change is a generic estimate based on the stratigraphic horizon in which the rock shelters are formed, rather than the specific geometries of individual sites. Large, continuous, overhanging formations are likely to be more susceptible to rock falls than pagoda features and isolated rocks, so there may be significant differences in potential impacts at individual sites that cannot be captured without a specific site assessment.

It should be recognised that the probability of impacts at any particular site are likely to be less than the probability of impacts somewhere on the cliff formations in the general area. If the integrity of a site is considered to be compromised by an impact in the general area, the probability of such an impact is likely to be greater than that indicated in Table 2 and Appendix 1.

Table 2: Assessed probabilities of impacts to archaeological sites in the modified Ulan West mining area

Ulan ID#	Site Name	OEH AHIMS #	Site Type	Probability of Perceptible Impact (Current Approved probability in brackets)	Probability of Rock Fall or Significant Rock Fracturing with Potential for Fall
161	Cockabutta Creek 19	36-3-1506	Rockshelter with Art and Artefacts	70% (0)	20% (0)
162	Cockabutta Creek 20	36-3-1507	Rockshelter with Artefacts	70% (0)	20% (0)
284	Cockabutta Creek 21	36-3-1563	Rockshelter with Artefacts	70% (0)	20% (0)
331	BB14/A PAD4	36-3-1605	Rockshelter with PAD	5% (50)	<1% (10)
333	BB14/C PAD5	36-3-1606	Rockshelter with PAD	0% (50)	0% (10)
334	BB14/D	36-3-411	Rockshelter with Artefacts	0% (50)	0% (10)
335	BB14/E	36-3-412	Rockshelter with Artefacts	0% (50)	0% (10)
336	BB14/F	36-3-413	Rockshelter with Artefacts	5% (50)	<1% (10)
399	MC33/A PAD3	36-3-1607	Rockshelter with PAD	0% (50)	0% (10)
462	MC39/A	36-3-768	Rockshelter with Grinding Grooves	0% (50)	0% (10)
463	MC40/A PAD	36-3-1608	Rockshelter with PAD	0% (5)	0% (1)
464	MC40/B PAD	36-3-1609	Rockshelter with PAD	0% (5)	0% (1)
465	MC40/C PAD	36-3-1610	Rockshelter with PAD	0% (5)	0% (1)
466	MC40/D PAD	36-3-1611	Rockshelter with PAD	0% (5)	0% (1)
806	MC318	36-3-1909	Rockshelter with PAD	10% (0)	<1% (0)
807	MC319	36-3-1910	Ochre Quarry	10% (0)	N/A
832	MC343	36-3-1935	Rockshelter with PAD	0% (5)	0% (1)
859	BB43	36-3-1962	Rockshelter with PAD	0% (70)	0% (20)
860	BB44	36-3-1963	Rockshelter with PAD	20% (70)	5% (20)
863	BB47	36-3-1966	Rockshelter with PAD	30% (70)	5% (20)
864	BB48	36-3-1967	Rockshelter with PAD	20% (70)	5% (20)
919	BB103	36-3-2022	Rockshelter with PAD	50% (10)	10% (0)
1161	UC183	36-3-2264	Grinding Grooves	70% (30)	N/A
1182	BB203	36-3-2284	Rockshelter with PAD	50% (0)	10% (0)
1183	BB204	36-3-2285	Rockshelter with PAD	50% (0)	10% (0)
1194	BB213	36-3-2296	Rockshelter with PAD	50% (0)	10% (0)
1195	BB214	36-3-2297	Rockshelter with PAD	50% (0)	10% (0)
1196	BB215	36-3-2298	Rockshelter with PAD	50% (0)	10% (0)
1197	BB216	36-3-2299	Rockshelter with PAD	50% (0)	10% (0)
1198	BB217	36-3-2300	Rockshelter with PAD	50% (0)	10% (0)
1199	BB218	36-3-2301	Rockshelter with PAD	50% (0)	10% (0)
1200	BB219	36-3-2302	Rockshelter with PAD	50% (0)	10% (0)
1210	UC199	36-3-2312	Grinding Grooves	70% (30)	N/A
1294	UC282	36-3-2395	Rockshelter with PAD	5%	<1%
CC24	Cockabutta Creek 24		Rockshelter with PAD	70%	20%
CC25	Cockabutta Creek 25		Rockshelter with Artefacts	70%	20%
CC28	Cockabutta Creek 28		Rockshelter with Artefacts	70%	20%
CC29	Cockabutta Creek 29		Rockshelter with PAD	70%	20%
CC45	Cockabutta Creek 45		Rockshelter with PAD	0%	0%
CC46	Cockabutta Creek 46		Rockshelter with PAD	0%	0%
CC47	Cockabutta Creek 47		Rockshelter with PAD	0%	0%

Table 3 shows the descriptive interpretation that can be placed on the probability categories.

Table 3: Probability Rating for Subsidence Impacts on Sandstone Rock Formations

Descriptive Term	Probability
Almost Certainly	> 90%
Likely	50-90%
Possible	11-49%
Unlikely	1-10%
Most Unlikely	<1%

4.7.2 Specific Assessment for Cockabutta Creek Sites

Four archaeological heritage sites, identified as 161, 162, 284, and CC28 have been assessed by SEA in the archaeological heritage assessment as being significant. This section presents a site specific subsidence impact assessment for these four sites. The assessment indicates that without some form of mitigation, there is a high potential (estimated to be 70% probability) of perceptible impacts such as fracturing and shear movements and a 20% probability of rock falls.

Figure 13 shows the locations of the four sites relative to the UCCO Project footprint and the proposed modification.

4.7.2.1 Site 161

Figure 14 shows a photograph of Site 161. Figure 15 shows a schematic of the site in plan, elevation and section. The formation is approximately 16m long and is located within a rock slope facing to the south. The cliff formation has an overhang of up to 5.1m that is up to 3m high with the deepest part of the overhang located at floor level. The face of the cliff line is oriented at approximately 85°GN. The site is located on a more extensive cliff line that extends about 130m to the west and 50m to the east. The overburden depth to the Ulan Seam is approximately 135m.

4.7.2.2 Site 162

Figure 16 shows a photograph of Site 162. A schematic of the site is included in Figure 15. The formation is approximately 21m long and is located within a rock slope adjacent to and immediately east of Site 161. The cliff formation has an overhang of up to 4.6m that is up to 3.5m high with the deepest part of the overhang located at floor level. The face of the cliff line is oriented at approximately 105°GN. The site is located on a more extensive cliff line that extends about 180m to the west and terminates near the eastern end of the formation. The overburden depth to the Ulan Seam is approximately 135m.

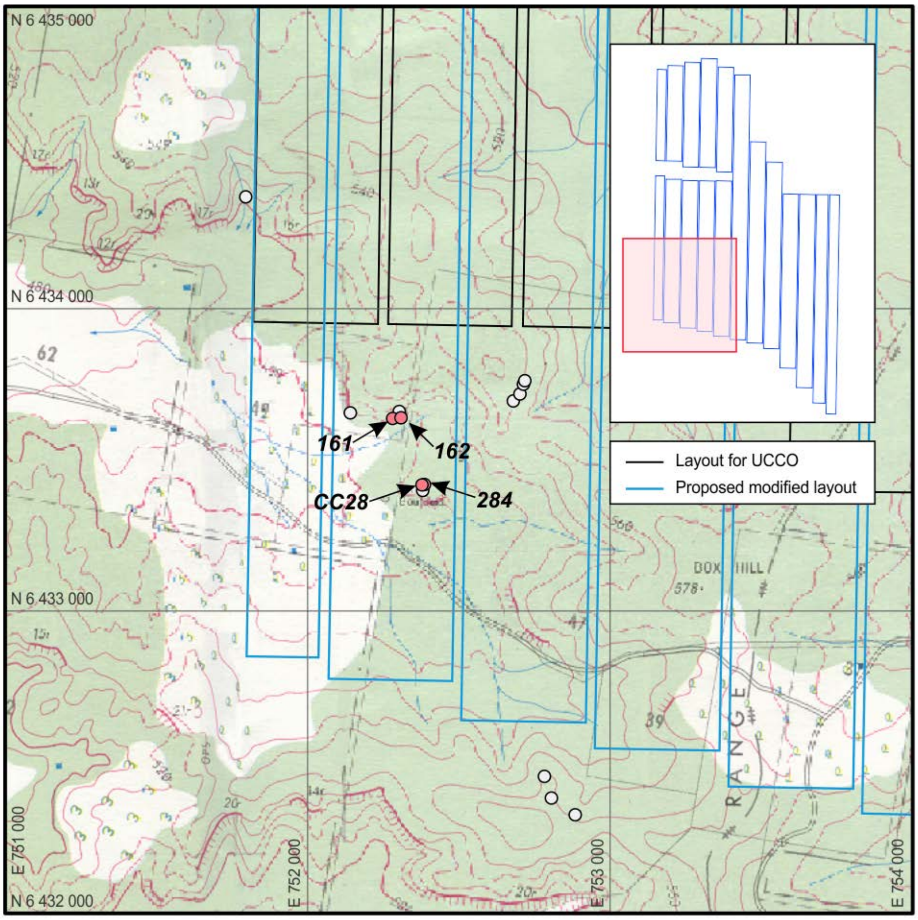

Figure 13: Site plan showing the locations of the four archaeological heritage sites of high significance.

Figure 14: Site 161 – camera view looking north west.

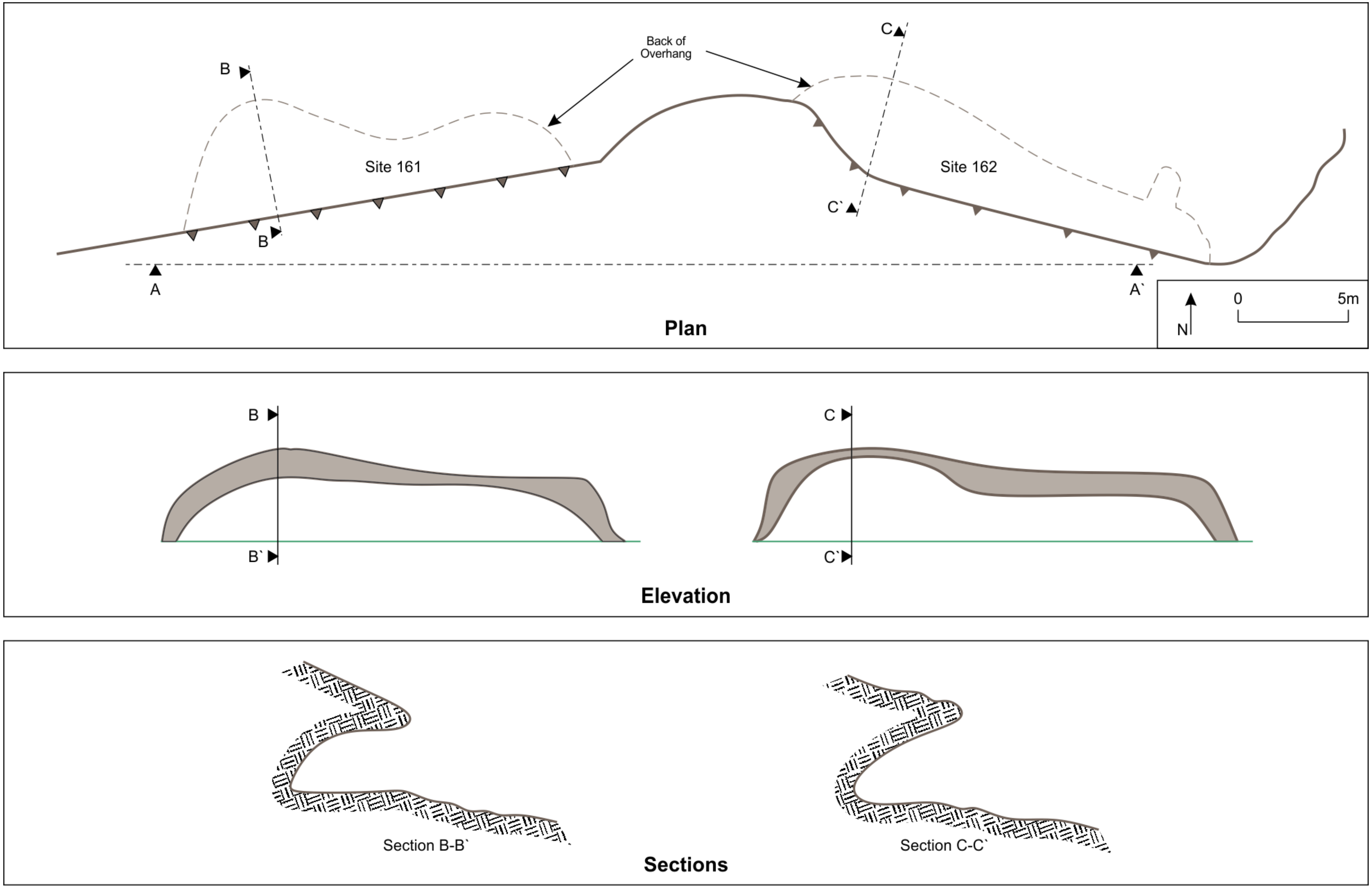

Figure 15: Schematic of Sites 161 and 162 in plan, and elevation and section.

Figure 16: Site 162 – camera view looking northeast.

4.7.2.3 Site CC28

Figure 17 shows a photograph of Site CC28. Figure 18 shows a schematic of the site in plan, elevation, and section. The formation is approximately 14m long and is located at the western end of a rock spur and faces to the north. The cliff face is aligned at approximately 70°GN. The cliff formation has an overhang of up to 3m that is up to 4m high with a prominent bedding plane approximately half way up that forms the deepest part of the overhang. There is a prominent joint set oriented at 175°GN at the eastern end of the overhang. This joint set is evident as a deeply incised valley on the southern side of the ridge about 20m to the south. The overburden depth to the Ulan Seam is approximately 130m.

4.7.2.4 Site 284

Figure 19 shows a photograph of Site 284. A schematic of the site is shown in Figure 18. The formation is approximately 5m long and is located immediately east of Site 284 facing to the northwest. There is a pile of rock debris in front of this formation that is interpreted as being rock fall debris from a previous collapse of the overhang during natural erosion processes. The cliff face is aligned at approximately 30°GN. The cliff formation has an overhang of up to 3m that is up to 4m high with a prominent bedding plane approximately half way up that forms the deepest part of the overhang. The prominent joint set oriented at 175°GN at the western end of the overhang separates the site from Site CC28. The overburden depth to the Ulan Seam is approximately 130m.

4.7.2.5 Estimated Subsidence Movements

The estimates of subsidence at the four sites 161, 162, 284 and CC28 are provided for context, but the relationship between subsidence parameters and perceptible impacts and rock falls on cliff formations is site dependent and not necessarily directly related to magnitude of subsidence movements. Nevertheless, it is helpful to have an estimate of the subsidence parameters as a basis to estimate the likely quantum of impact.

In the approved UCCO longwall geometry, all four archaeological heritage sites were fully protected from any mining subsidence impacts by a barrier of solid coal that is greater than 300m in size.

In the proposed modification layout, all four sites are located directly above a single longwall panel. All four sites are expected to experience vertical subsidence movements most likely to be in the range 0.9-1.5m up to a possible maximum of about 2.1m of subsidence for an extraction height of 3.2m if the sandstone strata overlying the Permian strata is not sufficiently strong to bulk up. This greater subsidence occurred over the start of Longwall F at Ulan No 3 Mine at an overburden depth of about 130m.

Using the approach outlined by Holla (1991), an approach which is based on experience elsewhere in the Western Coalfield, maximum tilts of up to about 70mm/m are expected at each of the four sites. The tilts are likely to be mainly transitory. Experience indicates that tilts are not a particularly critical parameter for estimating cliff instability.

Figure 17: Site CC28 – camera view looking west.

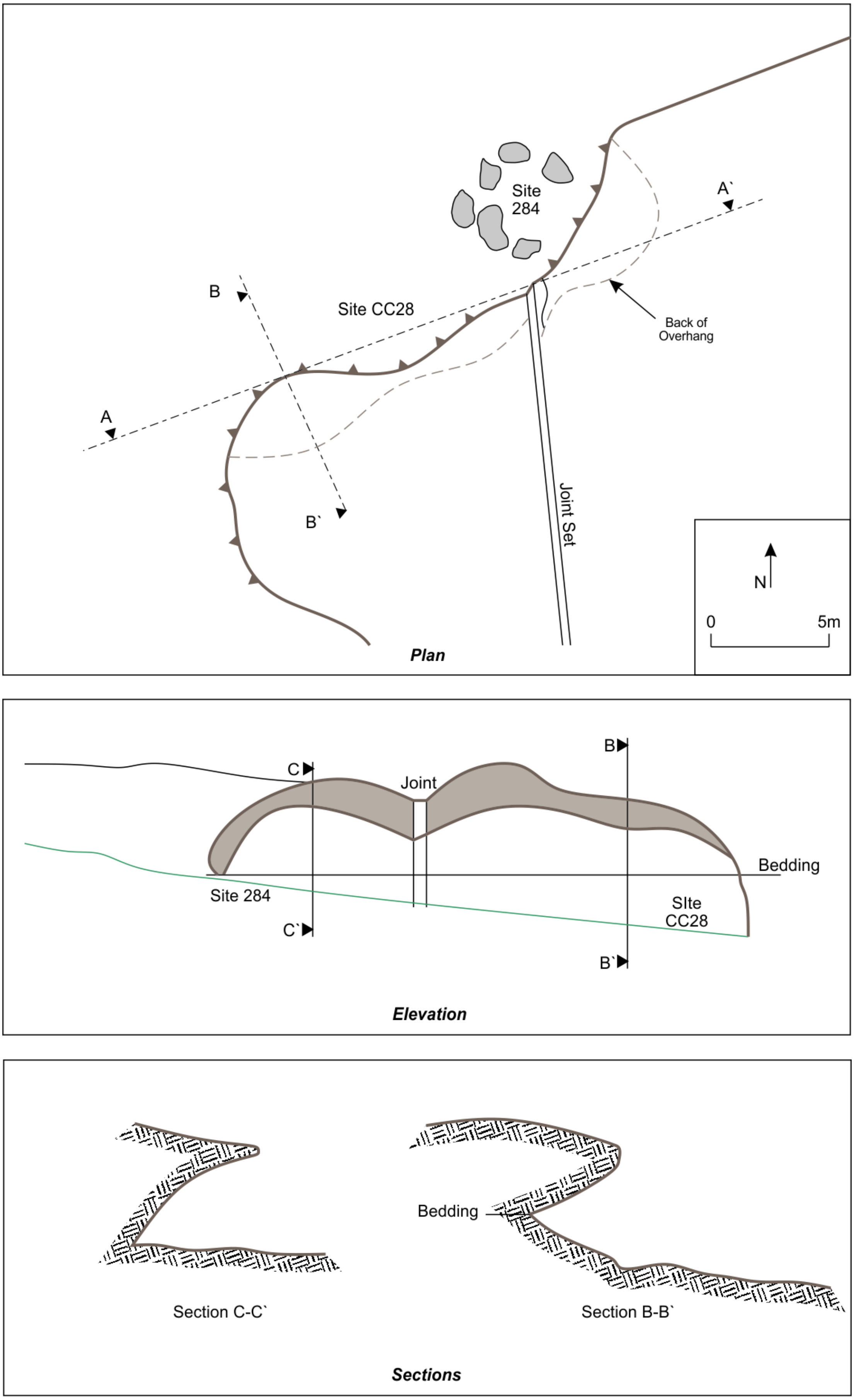

Figure 18: Schematic of Sites 284 and CC28 in plan and elevation and section.

Figure 19: Site 284 – camera view looking east.

The critical subsidence movements from the perspective of rock falls on cliff formations are the horizontal compression movements in a direction parallel to the line of the cliff formations. Horizontal movements parallel to the cliff face are the main cause of rock falls and rock formations that are laterally extensive, overhanging, and high tend to be most vulnerable. Horizontal movements perpendicular to the cliff face may cause perceptible fracturing, shearing, and fracturing, but of themselves are not typically the cause of rock falls.

Horizontal movements are made up of a number of components, but the largest of these is the horizontal movements associated with topography. These movements occur in a downslope direction with larger horizontal movements expected in areas where mining is in the same direction as the slope. The magnitude and direction of the topographic component is strongly dependent on surface topography, but is generally less than about 300-500mm. Horizontal movements of small magnitude may be perceptible up to about 400m in front of mining in steep terrain, but movements sufficient to cause significant impacts are typically limited to when the longwall face mines close to and directly under the site.

Strain is the rate of change of horizontal ground movements. Strain may be tensile (stretching) or compressive in nature. Compressive strains tend to be larger in magnitude than tensile strains. For subsidence of 1.8m, the method outlined by Holla (1991) indicates compression strains of up to about 30mm/m and tensile strains of up to 20mm/m at overburden depths of 130m.

Tension cracks are associated with tensile strains and are expected to develop over the longwall panels and remain after the passage of mining in the vicinity of panel edges and along the tops of topographic highs. Tension cracks are expected to be greatest at the start of each panel and to be permanent all around the solid panel edges typically at a distance of about 0.3 times overburden depth from the edge of each panel.

Transient tension cracks may also occur at regular intervals above the centre of the panel typically just behind the longwall face. Remnants of these transient tension cracks are commonly interspersed with compression humps above the centre of each extracted longwall panel. Permanent compression humps are expected at regular intervals along the panel and compression is expected at topographic lows such as drainage channels.

The magnitude of tensile strain at which surface cracking is detectable on sandstone rock formation is sensitive to the nature of the formation, but cracks are typically evident on rock outcrops at strains of above about 2-5mm/m and in the bushland environment more generally at strains above about 5-10mm/m. Cracks are typically less than about 20mm wide in flat or gently undulating terrain but may be larger, generally less than 100mm wide but possibly up to 250mm wide. Tension cracks tend to be larger at the top of steep slopes and cliffs that are directly mined under. Tension cracks typically align with natural joint directions in the rock mass and may form a series of en-echelon cracks that each align with the joint directions but more generally align with the goaf edges.

With each subsequent longwall panel mined, there is likely to be additional vertical subsidence over the intermediate chain pillar. The tensile strains over the goaf edge may reduce as a result of this additional subsidence. The compressive strains are likely to generally increase as a result of the additional subsidence.

4.7.2.6 Impacts Anticipated

The impacts of mining subsidence on the cliff formations at the four archaeological sites can be estimated with reasonable confidence based on the experience of mining below similar formations from the same stratigraphic sequence at Ulan No 3. These impacts are illustrated in Section 4.2 of this report based on examples from Ulan No 3.

The cliff formations associated with Sites 161 and 162 are both part of a longer cliff formation, have overhangs, and are located in an area where mining is proceeding from the high ground toward the lower ground. As a result, both sites are assessed as having significant potential to experience perceptible impacts and rock falls with the probability of perceptible impacts estimated to be 70% and the probability of rock falls is estimated to be 20%.

Site SG5 above Longwall 13 at Ulan No 3 provides a good analogue for the types of impacts that can be expected at Sites 161 and 162. Mining proceeded from the high ground toward the valley. The cliff is formed in the same cliff forming sandstone at an overburden depth of 160m. Some rock falls were observed and the sandstone formation was fractured. When last inspected in the late 1990's, the site was not considered safe to work under so that the archaeological deposit was, at least at that time, sterilised from a scientific perspective as well as being degraded from a cultural heritage perspective.

The cliff formations associated with Sites 284 and CC28 are part of a terminating ridge system, are overhanging but shorter in length, and mining is proceeding in a direction from the low ground toward the ridge. On this basis a lower potential for impact than at Sites 161 and 162 would be expected but there is not sufficient resolution in the database of experience to indicate other than 70% perceptible impact and 20% probability of rock fall.

4.8 European Heritage Features

European heritage features within the Ulan West mining area are listed in Table 4. The changes to the mine layout from the layout assessed in the UCCO Project are expected to slightly reduce the likelihood of perceptible impacts to ID191 and HS96/D and significantly reduce the likelihood of perceptible impacts to HS63. The impacts to the other sites remain unchanged.

Table 4: Summary of Potential Natural Heritage Sites Identified by Umwelt, South East Archaeology, and Others

Site Name	MGA Easting	MGA Northing	Site Type
ID191	753816	6436485	Overhang with historical artefacts[1]
HS96/D	753809	6436494	Overhang with historical artefacts
HS63	751816	6434081	Timber mill
MM273	753141	6433870	Logging mill
HS135	754883	6433538	Bottles
RV4	753069	6437698	Old stockyard with adjacent current stockyard.

[1] Artefacts include pieces of wood and metal derived from horse cart, oven with metal oven door and metal sheet oven walls, horse cart mud guard, swindle bar, cart metal bar, 2 x billy cans, 2 x copper barrel rings, wooden boards off the sulky, side rails on a horse cart, plough hook, spring metal hook to protect the hub, horse cart wooden seat (not a toilet lid as described in Haglund), glass bottles AGMIS106, AGM 1926 198I, whip hook, horse shoe, haymes, buckle with a floral design, rasp for grinding horse hooves, part of wheel-bolt, horse cart axle.

ID191 and HS96/D are both located close to the barrier for the Brokenback Conservation Area near the corner of the panel. There is considered to be a nominal 20% potential for rock falls on the overhanging cliff formations because the site is located directly above a longwall panel; but in the corner of the panel, the probability of impacts is likely to be less than it would be if the site were located in the centre of the panel.

In the approved mine layout, HS63 was located over the panel, but in the revised layout is now located on the edge of Longwall 12 where subsidence is expected to be less than about 100mm and no perceptible impacts are expected. Sites HS63 and MM273 are open sites that are not expected to be sensitive to subsidence movements and no perceptible impact is expected.

Bottles were found at HS135 at a site located about Ulan West Longwall 5. Although the full range of subsidence movements is expected to occur at the site as a result of mining, it is unlikely that subsidence movements will be perceptible or otherwise directly impact the site.

Former post and rail timber stockyards that have fallen into disrepair and disuse are located above Ulan West Longwall 9. The overburden depth to the coal seam at this location is approximately 225m. The site is located nearer to the chain pillar than it was in the approved mine layout, but the strains and tilts are expected to be of similar magnitude. The posts and rails are in an advanced state of disrepair. The subsidence movements of the magnitude anticipated are unlikely to be perceptible. The heritage site is considered unlikely to be affected in any perceptible way.

4.9 Surface Improvements

Changes to the mining layout associated with the proposed modification are not expected to significantly change impacts to surface improvements from those described in the UCCO Project assessment.

Surface improvements that have been identified in the vicinity of project area include several power lines, Ulan Trig, privately owned dwellings, privately owned farm infrastructure such as dams and fences, and various access road and four-wheel drive tracks that traverse the surface.

4.9.1 Power Lines

There are several low voltage power lines crossing the project area. These are all of single pole construction and subsidence impact is not anticipated, based on previous experience of mining under similar structures. Typically subsidence impacts can be managed by undertaking minor mitigation work such as placing conductors in sheaves and adjusting stays if there is potential for damage to support brackets or loss of clearance if the poles tilt. It is anticipated that this type of mitigation work would be undertaken on a longwall by longwall basis as required and could be managed without undue difficulty, consistent with the current approval.

4.9.2 Ulan Trig

Ulan Trig is located in the centre of Ulan West Longwall 5. Subsidence movements are expected to change the vertical position of Ulan Trig by up to about 1.8m and the horizontal position by up to about 400mm. The structure itself is unlikely to be affected by this subsidence, but its physical location will need to be resurveyed once mining subsidence movements are complete if the trig is required to remain serviceable as a survey marker. Small subsidence movements may start to occur up to 2km ahead of mining but movements are expected to be substantially complete once Ulan West Longwall 7 has finished.

UCML has installed and is planning to install multiple permanent survey marks in the general area. Any of these marks within an approximately 2km distance from the nearest longwall panel have potential to move but a protocol for notification and resurvey is well developed and has been used to successfully manage subsidence impacts at Ulan No 3.

4.9.3 Dwellings

There are two privately owned residences located within the Ulan West mining area: Property ID 57 “Billir” and Property ID 254 “Woodbury”. The subsidence impacts to these dwellings from the proposed modification are not expected to be significantly different to those described in the UCCO Project assessment.

It is noted that council approved structures located outside of proclaimed mine subsidence districts are automatically covered for compensation by the

Mine Subsidence Board in the event of any structural damage caused by mine subsidence.

There are several individual structures at each of the two privately owned properties. These are typically of light weight, timber frame, and corrugated iron construction, mainly on concrete slabs.

The main dwelling at Property ID 57 "Billir" is of brick construction, part on a concrete slab and part on piers. The structure is approximately 25m long by 12m wide. There are several adjacent buildings and a large water tank in the same vicinity. The site is located approximately 120m south of the start of Ulan West Longwall 9 above the panel. The overburden depth to the coal seam is approximately 170m.

The main dwelling on Property ID 254 "Woodbury" is approximately 21m long by 11m wide, including an earth floor garage area. The living area is on a concrete slab and the veranda is partly on timber bearers and partly on a concrete slab. There are several outbuildings of various light weight construction in the vicinity. The overburden depth to the coal seam is approximately 180m.

Ground strains of 5-15mm/m and tilts of 10-20mm/m are expected at both these sites and given the close proximity of both dwellings to longwall panel edges, most of the strains and tilts are likely to be permanent.

Strains and tilts of these magnitudes are expected to cause perceptible damage to the structures and remedial work is likely to be required to maintain the structures in a serviceable condition. Buried water and sewerage systems are likely to be impacted by subsidence. Connections to power and telephone services may need to be managed depending on particular details. Water bores are likely to be affected by lateral shear movements associated with subsidence. Smaller out buildings are less likely to be impacted by ground strains, but they may remain permanently tilted because of the close location of both sites to panel edges.

4.9.4 Fences

No significant changes to the impacts to fences described in the UCCO Project assessment are expected as a result of the change in mine layout associated with the proposed modification.

Fences above the Ulan West mining area are in various states of repair, ranging from new to no longer serviceable. Mining subsidence is likely to cause slackening of some sections of fence line and over tightening of other sections. In general, the effects are likely to be relatively minor and manageable through the use of temporary electric fences and re-tensioning of the fence wires after mining.

4.9.5 Farm Dams

No significant changes to the impacts to farm dams described in the UCCO Project assessment are expected as a result of the change in mine layout associated with the proposed modification.

There are several farm dams located within the Ulan West mining area. Most are shallow scrapes with small catchments feeding into them. The impact of mining subsidence on farm dams tends to be limited to subsidence cracks that pass directly through the dam wall or through the base of the dam affecting about one in three dams. These may cause scouring and loss of water, but resealing can usually be achieved with only minor earthworks. If mining occurs in a period when the dams are full, precautionary emptying of the dams is recommended to reduce the potential for scour of the dam wall that may require more substantial rectification.

4.9.6 Water Bores

No significant changes to the impacts to water bores described in the UCCO Project assessment are expected as a result of the change in mine layout associated with the proposed modification.

There are understood to be no private, licensed bores within the Ulan West mining area. Bores located directly over the mining area and out to a distance of several kilometres from the mining area may be affected by changes in groundwater level. Bores located directly over the mining area and within several hundred metres outside the mining area may also be physically impacted by shear movements in the rock strata below the ground surface.

Alternative water supply arrangements may be required for any bores located within several kilometres of the mining area.

4.9.7 Access Roads and Four Wheel Drive Tracks

Subsidence impacts to access roads for the changed layout are expected to be generally similar to those presented in the UCCO Project assessment, but step changes in the surface such as those experienced above Longwalls C, E, and F at Ulan No 3 have been recognised as a possibility since the UCCO Project assessment was prepared. This possibility is now recognised in the assessment as likely wherever thin, strong, sandstone bands are present just below the surface. These bands are most likely, based on the experience to date, to be at overburden depths of about 130m and about 185m but may also be present at other depths.

There are numerous four wheel drive access tracks located within the Ulan West mining area. In general, subsidence movements are not expected to cause impacts that are significantly out of character with the general nature of the access roads and tracks. Steps in the surface of up to 0.8m high such as those observed above Longwalls C and E at Ulan No 3 are considered possible. These are likely to occur relatively suddenly, but given

the remoteness and nature of most of the tracks and the low vehicle numbers, the risk of personal injury is considered low.
Some minor repair work may be required to smooth out irregularities and close up open cracks. Any steps that form across access tracks may require some greater effort with a backhoe to break up the sandstone overhang that has formed. Signage to warn of the potential for mine subsidence movements in active mining area is recommended as a precautionary measure.

5. CONCLUSIONS

This subsidence assessment indicates maximum subsidence across most of the Ulan West mining area is likely to be less than 1.8m and less than 2.1m for the shallow cover areas near the southern end of the Longwall 3 and Longwalls 11 and 12. The magnitudes of maximum subsidence are greater than was used in the UCCO Project assessment because of the nominal mining height used for assessment purposes has been increased from 2.9m in the UCCO Project assessment to 3.2m in the modification assessment.

The higher magnitude maximum subsidence used for assessment purposes is not expected to have any practical significance because none of the features located above the area are particularly sensitive to the magnitude of maximum subsidence and actual maximum subsidence in the central part of each longwall panel is expected to be generally much less than maximum values typically in the range of 0.9-1.5m and 1.6-1.8m in the shallow cover areas. Subsidence over the chain pillars is expected to increase with overburden depth ranging from 0.2m in shallow cover areas up to approximately 0.5m in the deeper areas.

Maximum tilts of 20-40mm/m are expected across most of Ulan West mining area reducing to 15-20mm/m when the overburden is greater than 200m, and increasing to 120mm/m in areas where the overburden depth is shallowest at 80m. Locally higher values of tilt are possible in areas where steps or compression overrides form.

Systematic horizontal ground movements of 150-200mm are expected to occur in a direction toward the goaf and then in the direction of mining once the longwall face has passed. Additional horizontal movements associated with surface topography of generally less than 300mm are expected to occur in a downslope direction with larger horizontal movements of up to 500mm expected in areas where mining is in the same direction as the slope.

Maximum horizontal strains are generally expected to be less than 20mm/m across most of the Ulan West mining area with systematic peaks of up to 30mm/m in tension and 50mm/m in compression in the shallow areas and less than 15mm/m at cover depths above 200m.

Surface cracks are expected to be generally isolated and increase in size inversely to overburden thickness ranging from 20mm wide in flat and gently undulating terrain and generally less than 100mm wide elsewhere but possibly up to 250mm wide in shallow cover areas.

There are numerous ephemeral watercourses located within the Ulan West mining area. Mining below ephemeral creeks is considered to have potential to reduce surface flows and the duration that pools retain water following a rainfall event.

Mining subsidence is expected to cause surface cracking and fracturing of the strata throughout the overburden section. Surface and sub-surface fracturing is expected to increase the hydraulic conductivity of the overburden strata and allow a tortuous pathway to develop between the surface and the mining horizon through this fracture network.

Water bores and groundwater seeps are likely to be impacted by mining subsidence movements. Water bores and natural springs located directly over the Ulan West mining area are expected to dry up as a result of mining. Alternative arrangements may also be required to supplement water supplies that rely on bores within the general vicinity of the project area consistent with the impacts described in the UCCO Project.

There are numerous sandstone cliff formations located within the Ulan West mining area. Based on previous experience of mining under similar sandstone cliffs at the Ulan Coal Complex, mining subsidence is expected to cause rock falls on 10-20% of the sandstone cliff formations located directly above the mining area. In general, cliff formations that are high, overhanging, re-entrant and laterally extensive are likely to experience perceptible changes the most. Sandstone features located outside of the Ulan West mining area may experience perceptible tensile cracking up to a distance of approximately 0.4 times overburden depth (typically 60-80m) from the goaf edge. Mining induced rock falls outside of the Ulan West mining area are not commonly observed.

Cliff formations within the Ulan West mining area are greater than 20m high in some locations, although most are in the 3-15m high range. Cliff formations located directly above the Ulan West mining area are likely to be impacted by mining subsidence.

Archaeological heritage sites assessed as significant and located within the Brokenback Conservation Area are protected by a protection barrier based on an angle of draw of 26.5° (half depth) to the top of the cliff formations. The extent of the conservation area is unchanged from the UCCO and is expected to provide full protection against mining induced rock falls at all the sites assessed as significant within the conservation area. A high level of protection against mining induced rock falls (>99%) is provided to other sites where cliff formations are located over solid coal beyond the mining area.

The four archaeological heritage sites – 161, 162, 284, and CC28 – also assessed as significant were protected by the UCCO layout but are expected to have potential for rock falls along 20% of their length and perceptible impacts along approximately 70% of their length for the modified layout.

Mining subsidence is not expected to cause significant disturbance to the fish fossil beds in the Talbragar Fish Fossil Reserve because of their already fragmented nature.

Mining subsidence is not expected to significantly impact any of the European heritage sites identified within the modified Ulan West mining area. Several of the sites are likely to experience reduced impacts as a result of the modified layout compared to the layout assessed in the UCCO Project.

Subsidence movements from the project mining geometry are expected to change the vertical and horizontal location of Ulan Trig and other permanent survey marks in the general vicinity out to a distance of up to 2km from the mining area. Recognised protocols for managing these small movements have been successfully used to manage similar impacts at Ulan No 3 and are expected to be suitable to manage impacts from the proposed mining.

Mining subsidence movements from the project mining geometry are expected to cause perceptible damage to the residential and farm buildings on privately owned properties identified as Property ID 57 “Billir” and Property ID 254 “Woodbury”. Buried services such as water and sewerage pipes are likely to be damaged. Telephone and power lines may require mitigatory work depending on their specific location relative to mining, but in most cases, subsidence impacts on these services is easily manageable.

Farm dams, fences and four wheel drive access tracks are not expected to be significantly impacted by mining subsidence movements. However, some minor remedial work may be necessary to fill in cracks and remove compression humps. Steps such as those observed over Ulan No 3 Longwalls C, E, and F may occur and additional remediation efforts may be required if these occur in areas crossed by access tracks. Signage to warn of the potential for mine subsidence movements in active mining areas is recommended as a precautionary measure.

6. REFERENCES

Holla L. 1991 “Evaluation of Surface Subsidence Characteristics in the Western Coalfield of New South Wales” The Australian Coal Journal, No. 31 1991 pp19-30.

Mackie Environmental Research (MER) 2009 Ulan Coal Continued Operations - Groundwater Assessment.

Mills K.W. 1998, “Subsidence mechanisms about longwall panels” in proceedings of International Conference on Geomechanics/Ground Control in Mining and Underground Construction (GGM98), 14-17 July 1998, University of Wollongong, Vol 2 pp. 745-756.

NSW Department of Mineral Resources 2003 "Guideline for Application for Subsidence Management Approvals" December 2003.

SCT Report ULA3367 2009 "Part 3A Subsidence Assessment Ulan Coal Continued Operations" 14 August 2009.