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**ULA4958**

Dear Robyn

**ASSESSMENT OF ROCK FALLS IN MONA CREEK CLIFF PROTECTION AREA**

Ulan Coal Mines Ltd (UCML) is committed to protecting an area, referred to as the Mona Creek Rock Shelter sites, from the effects of mining subsidence and other activities associated with mine infrastructure development. A rock fall within this area occurred on or around 18 March 2014. UCML commissioned SCT Operations Pty Ltd (SCT) to assess:

- The potential that the rock fall is from subsidence
- The potential that the rock fall is from blasting
- The stability of the cliff line following the rock fall
- The potential that rock falls on the cliff line will occur due to subsidence associated with MOD4 (UUG Longwall 8 extension or the other longwalls)
- The potential that the rock shelter sites (Cultural Heritage) will now be further impacted by the MOD4
- Any additional monitoring that ought to be established

This report presents the results of our assessment and recommendations for additional monitoring. The report has been prepared following a site visit to the area on 3 December 2018 in company with Mr Geoff Mitchell (the landowner) and Lucy Stuart from UCML.

Our assessment indicates that:

- the Mona Creek Rock Shelter sites are part of a sandstone formation that is naturally in a cycle of ongoing erosion whereby rock falls are expected to occur naturally from time to time unrelated to any mining related effects

- the rock fall that occurred in March 2014 is a natural event caused by tree root invasion into a natural joint, with the event itself most likely triggered by a high intensity rainfall event

- the remaining cliff is now more stable than it was prior to the rock fall event

- this rock fall and a smaller one that occurred approximately 25 years earlier further along the same line of cliff are part of the natural processes of erosion

- there is no potential for the rock fall to be associated with mining subsidence - the nearest mining (start corner of Longwall W2 at Ulan Underground Mine) was 2.6km away at the time of the rock fall and too far for there to have had any influence

- there is no potential for the rock fall to be associated with blasting – the nearest blasting was 10km at Ulan Opencut at the time of the rock fall and too far for there to have been any potential for impact from blasting

- there is no potential for the rock fall to be associated with recent construction activity at the ventilation shaft because construction activity had not commenced at the time of the rock fall

- the stability of the cliff where the rock fall occurred is improved as a result of the rock fall, but natural cliffs are always in a cycle of ongoing erosion that involves intermittent rock falls so other adjacent sections of the cliff line still have potential to become unstable

- there is no potential for subsidence associated with the MOD4 application submitted by UCML to increase the potential for cliff instability along the section of cliff line UCML are committed to protecting – experience at numerous sites in the Western Coalfield indicate that the barrier created by standing off the cliffs by more than half depth (26.5° angle of draw) is sufficient to prevent mining induced rock falls

- although the rock fall that occurred in March 2014 did not involve any of the cultural heritage sites, there remains a low-level potential for further natural rock falls to impact these sites, but this potential is not increased by mining subsidence associated with the MOD4 application

- a vibration monitoring system installed along the top of the Mona Creek Rock Shelter site would be helpful to confirm that there are no further vibrations occurring from shaft construction activities that have potential to impact the rock shelter sites – none are expected, but it would be helpful to have a record showing this to be the case

- a weather station at the shaft would be helpful to confirm local weather conditions at the site, in particular localised high intensity rainfall events that might be associated with a thunderstorm for instance.

## 1. SITE DESCRIPTION

Figure 1 shows the location of the Mona Creek Rock Shelter sites relative to the MOD4 mining areas and the half depth protection barriers.

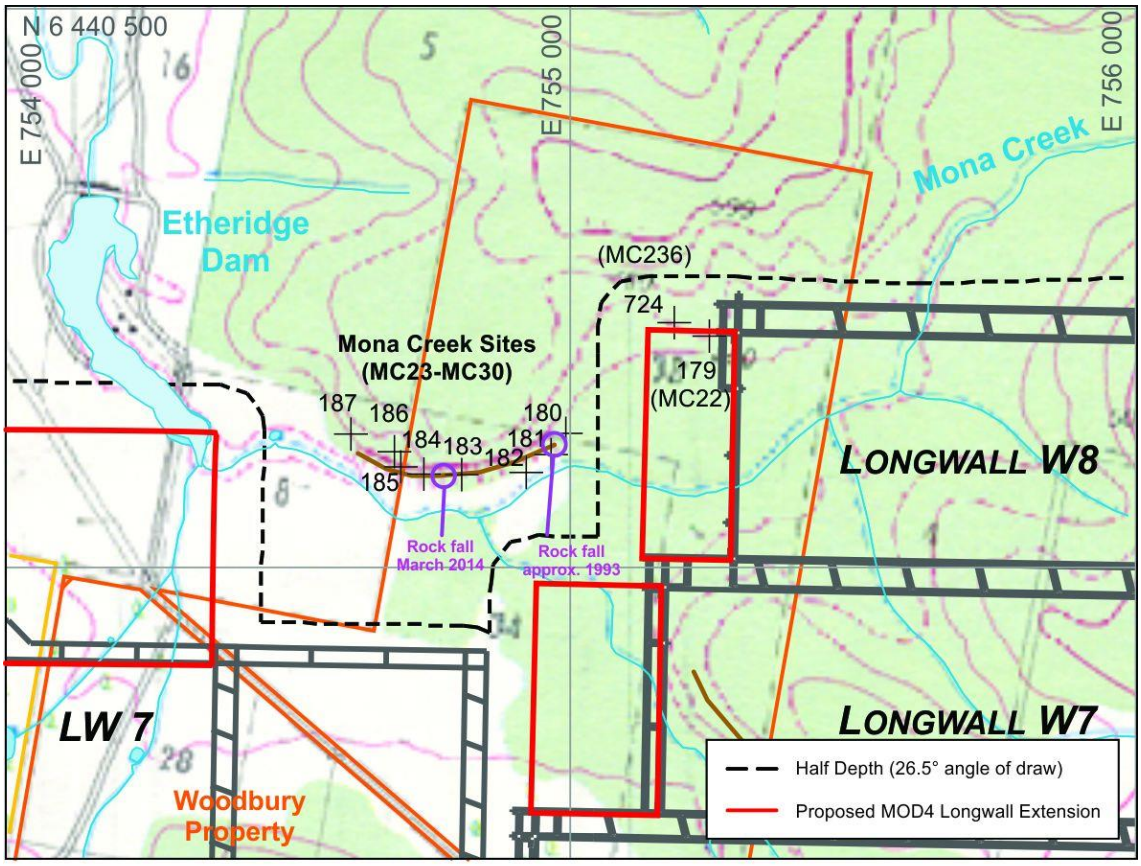


**Figure 1: Site Plan**

The depth to the mining horizon in this area is approximately 165m. All the rock shelter sites (MC23-MC30 or Ulan ID #170-187) are protected by a distance that is greater than 130m and, therefore, greater than 0.7 times the overburden depth (equivalent to 35°angle of draw).

Figure 2 shows a photograph of the site of the March 2014 rock fall. An estimated 300 tonnes of sandstone material detached from the cliff face along a surface that had been extensively invaded by tree roots. Two small areas of fresh rock appear to have fractured at the time of the rock fall leading to the event. It is considered likely that inflow into the top of the crack during a high intensity rainfall event allowed water pressure to build up in the joint wedged apart by tree roots. Although short in duration, this additional pressure is likely to have triggered failure of the remaining fresh rock leading to the rock fall.

**Figure 2: Rock fall that occurred on or around 18 March 2014**

The rock fall site is located a short distance to the east of Cultural Site #184. The cultural site does not appear to have been directly impacted, but it is likely that all the cultural sites in the area have natural joints in the rock strata behind and are similarly vulnerable to tree root invasion over time.

Figure 3 shows a photograph of a rock fall further to the east near Cultural Site #180. Mr Mitchell recalls this rock fall occurring some 25 years ago (around 1993). An estimated 60 tonnes of sandstone material detached from the cliff and rolled down onto the slope below as several large boulders.

## 2. MECHANISMS RECOGNISED TO CAUSE ROCK FALLS

The range of mechanisms observed to cause rock falls in the sandstone formations at Ulan and elsewhere in the Western Coalfield of New South Wales are discussed in this section. Natural rock falls cause the steep cliffs that are familiar in the landscape of the Sydney Basin, but mining induced subsidence movements are also recognised to cause rock falls.

Large sandstone cliff formations such as the Illawarra Escarpment are observed to retreat naturally at an average estimated rate of several millimetres to several tens of millimetres per year, although in practise retreat occurs in increments of several metres along limited sections of the cliff. The mechanism for retreat typically involves a combination of factors. The main factors include:

1) Accelerated erosion of fine grained material at the base of the cliff causing undercutting that leads to a sandstone overhang.

**Figure 3: Rock fall that occurred around 1993 further along the same formation as the March 2014 rock fall**

2) Toppling failure of sandstone blocks near the edge of the cliff typically defined by natural joints behind the cliff face.

3) Tree root invasion and jacking of natural joints, especially joints opened by toppling failure at the edge of the cliff.

4) Ingress of water during high intensity rainfall events at a rate greater than outflow leading to a rapid increase in water level in the open joint and an outward water pressure on the rock forming the cliff face.

Other natural processes are also recognised to contribute to instability of cliff formations. These include:

1) Diurnal and seasonal thermal variations that stress the rock on the cliff face causing micro-fractures in the rock to extend and link up.

2) Frost heave caused when wet surfaces freeze.

3) Artificially induced thermal effects such as building a fire below an overhanging formation.

4) High winds causing trees that have invaded the cracks behind the cliff to act as levers to force the rock on the face of the cliff outward.

5) Earthquakes causing lateral accelerations sufficient to destabilise marginally stable cliff formations.

6) Blasting that causes vibrations of a magnitude greater than about 50mm/s (human perception of vibrations is typically in the range 1-10mm/s)

Mining induced subsidence has characteristics that can also contribute to rock falls. There are two main sources of impact on cliff formations from mining induced subsidence movements. The first is tensile or stretching in nature and the other is compressive or squashing in nature.

Tensile or stretching ground movements tend to open existing joints within the rock mass or generate fresh fractures that remain open. Tensile or stretching subsidence movements occur both directly over the panel being mined and for a short distance outside the boundaries of the panel. Cracks in rock are typically perceptible to a distance of up to about 0.4 times the depth outside the panel and tend to be greatest at a distance of 0.1-0.2 times depth from the panel edge directly over the panel. Although small stretching movements typically occur beyond 0.4 times depth from the panel edge, these tend to be so small as to be imperceptible for all practical purposes. These far-field, low-level movements are associated with unloading of ground stresses and do not lead to rock failure.

Compressive or squashing ground movements have a much more significant effect on cliff formations. Compressive movements that occur along the line of the cliff have the capacity to generate large compressive stresses within the rock strata that comprises the cliff formation. These compressive stresses can lead to rock failure. Once previously intact rock strata fails and material becomes detached, the action of gravity typically leads to a rock fall.

Compressive subsidence movements occur predominantly over the central part of extracted longwall panels. Mining induced rock falls therefore tend to be concentrated in the central part of longwall panels. There are a few instances where mining induced rock falls have developed on the edge of panels or just outside them, but these situations tend to be associated with extensions of existing rock falls along tensile fracture zones.

Compressive movements tend to become concentrated at the head of small valleys or re-entrants in the cliff face and their effect on rock stability is greatest when there are overhang rock structures present. In both situations, the potential for rock falls tends to be increased.

The combined experience of 30 years of monitoring rock falls over longwall panels indicates that mining induced rock falls occur almost exclusively over extracted panels or the chain pillars between extracted longwall panels. Tensile cracking is evident over extracted longwall panels and for a short distance outside the panel, but this cracking does not typically lead to rock falls.

Effective protection of cliff formations from the effects of mining induced subsidence movements is able to be achieved by maintaining a distance of at least half depth between the edge of the extracted panel and the cliff formation.

## 3. LIKELY CAUSE OF RECENT ROCK FALLS

There have been two recent rock falls along the cliff line where the Mona Creek Rock Shelters are located. These both occurred remote from mining subsidence effects, the nearest panel at the time of the second rock fall in 2014 was Longwall W2, 2.6km away. The sites are also remote from blasting effects, the opencut is more than 10km away.

Both events are considered to initially caused by toppling failure. Toppling failures open up natural joints parallel to the face of the cliff. Tree root invasion of the open joint then causes further jacking. The triggering event is likely to have been a high intensity rainfall event that instantaneously adds water pressure to the back of cliff to destabilise it.

The rainfall records from the mine offices some 11km away do not indicate that March 2014 was a particularly wet period or that there were any high intensity events on the 18 March 2014. It is possible that a thunderstorm event occurred at the rock fall site that was not registered as rainfall at the mine offices. It may also be possible that the rock fall occurred earlier during a period of higher intensity rainfall events indicated at the mine office or that there was some other cause such as high winds in combination with tree root invasion causing the cliff face to become detached.

The consequence of the rock fall is that the remaining cliff is now more stable than it was prior to the event. The greater than 0.7 times depth protection barrier afforded to the cliff by the MOD4 mining proposal is expected to be more effective now than it would have been prior to the rock fall because the cliff formation is now more stable than it was prior to the rock fall.

The March 2014 rock fall occurred prior to any construction work being undertaken adjacent to site so vibration from this activity could not be the cause of the rock fall. Although no significant vibration is expected during construction of the ventilation shaft, it may be prudent to install a vibration monitoring system near the cliff line along which the rock falls have occurred so that it can be demonstrated that no significant vibrations have occurred for this or any other reason. Installation of a weather station at the ventilation shaft may also be prudent for similar reasons.

## 4. RISK OF ROCK FALLS ASSOCIATED WITH MOD4

There is a background risk of rock falls occurring naturally on almost all sandstone cliff formations in the Sydney Basin. The presence of a cliff formation is evidence that one of more rock falls has occurred during the period of its development. The background risk makes it impossible to eliminate the potential for rock falls. It is, however, possible to reduce the potential to background levels by providing a barrier of greater than half depth from the nearest extraction panel. This strategy has been found to be effective for protecting cliffs and other sandstone formations throughout NSW from mining induced rock falls.

The MOD4 mining geometry provides a level of protection to the cliff line on which the Mona Creek Rock Shelters are located that is greater than 0.7 times depth, equivalent to 35° angle of draw. There will remain a residual risk of rock falls along this cliff line prior to, during and after mining. The two recent rock fall events that occurred around 1993 and in 2014 occurred prior to any mining in the area and are evidence of this ongoing risk. Nevertheless, the protection provided to this cliff line and the Mona Creek Rock Shelters located along it is considered more than enough to provide a very high level of protection against mining induced subsidence impacts.

If you have any queries or require clarification of any of the information presented, please do not hesitate to contact me.

Your sincerely

Ken Mills
Principal Geotechnical Engineer