Our Ref: JMA Solutions 20220203:

Review of DGS Report No. NAR-005/2: Mine Subsidence Assessment for the Narrabri Underground Mine Stage 3 Extension Project

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25 February 2022

I am a Chartered Professional Engineer (NPER 63044), Director and General Manager of John Matheson & Associates Pty Ltd trading as J M A Solutions. I practise in the field of Civil and Structural Engineering, and I have been involved in the assessment of mine subsidence impacts on buildings (e.g., residential, commercial & industrial) and infrastructure (e.g., bridges, viaducts, tunnels, and drainage culvert structures within embankments) since 2000.

I am conversant with the type of numerical models used by subsidence engineers to predict the subsidence, horizontal ground movement, curvature and strain that occurs above the goaf and around the periphery of longwall mines in the Southern, Newcastle and Western coalfields.

At the request of Environment Defenders Office acting on behalf of Lock the Gate (my expert brief is attached as Appendix 1), I have read the Subsidence Assessment Report (referred to hereafter, as the SAR) prepared by DgS and I have prepared this expert report dated 25 February 2022. The report has been prepared to address the following issues:

a. Summary of any key subsidence and/or geotechnical impacts predicted to arise because of the Project,

b. What consequences, if any, are likely to arise for affected landholders and the environment as result of any impacts identified by you in response to question a),

c. Any further observations or opinions which you consider to be relevant.

In this report, there may be some overlap between the way the report has been prepared considering key subsidence and/or geotechnical impacts, which may have consequences for landowners. The report does not assume to understand each landowners' particular needs or sensitivities but simply tries to convey what may be of substance to a landowner.

I hereby confirm that I have read the Expert Witness Code of Conduct and agree to be bound by it.

Summary of key subsidence and/or geotechnical impacts

Relevant background information

The proposed extraction height of Longwall (LW) panels LW203-LW209 is 4.3m, which is the same as the extraction already conducted under ML 1609. Extraction is also proposed at a similar level within in the Hoskisson Seam due to the presence of stone bands in the upper part of the seam.

It is noted in the SAR that some of the top coal above the proposed extraction height caved whilst mining of LW101-108A was conducted, effectively increasing the height of extraction above 4.3m. The SAR states that the predictions for LW203-LW209 have been made to allow for this possibility to reoccur.

The SAR has presented a massive amount of data, which to the uninitiated, is daunting to read. As a high-level synopsis, the SAR explains the background to the empirical method of determining subsidence, and the sources of mine survey data and other measurements such as ground surface crack widths, borehole extensometer (assessed fracture zones, see **Figure 3**), and vibrating wire piezometers (groundwater response to mining). It has been noted in the report that the parameters used in subsidence, tilt, curvature, and ground strain calculations have been derived by conducting regression analyses on the relevant data to correlate curves of best fit corresponding to 50% and 95% confidence intervals.

By way of background, from a statistical perspective, a 95% CL (or confidence limit) is an interval estimate for the mean across the data sample (e.g., the Newcastle crack width data). If many samples are collected (e.g., Newcastle and other similar longwall panel mining data) and the confidence interval is calculated, eventually about 95% of these intervals would contain the true mean. Effectively, the confidence level measures how confident you are that the mean of your sample (the sample mean) is the same as the total population from which your sample is taken (the population mean). In simple terms, you adopt parameters for empirical crack width prediction, which over-predict crack width around 95% of the time.

The SAR does not define the exceedance probability[1] for the crack widths that have been predicted for the proposed longwall panels LW203-LW209. However, **Table 12** of the SAR, summarises measured crack widths v. predicted subsidence effects that were measured above steep slopes in the Newcastle Coalfield, which has been used to calibrate the empirical model used to calculate crack width above the proposed longwall panels LW203-LW209 at Narrabri. The SAR reports the following findings from the Newcastle Coalfield on page 68 and Longwall Panels LW101-108A in Narrabri :

i. Measured crack width in the Newcastle Coalfields was less than predicted crack width at 68% of locations where cracking was observed, or 32% of crack widths exceeded predictions, using mean values (SAR does not state that this is the 50%CL),
ii. Measured crack width in the Newcastle Coalfields However, was less than predicted crack width at 96% of locations where cracking was observed, or 4% of crack widths exceeded predictions, using 95% CL values,
iii. The measured crack widths and tensile strains above LW101 to 108A at Narrabri exceeded the predicted values (at these locations) and warranted further review when more data became available. Further discussion on crack width estimates is given in Section 10.2 of the SAR.

I note firstly on page 26 of the SAR that "*measured strains and crack widths over LW101-LW108A exceeded predicted values*" and, secondly on page 43 of the SAR that "*it was decided to increase the crack width estimates for future longwalls (LW203-LW210)*…" and thirdly, that "..*more cracking geometry data (width, depth, length and spacing is required to allow median and 95th percentiles to be estimated accurately*". This indicates that steps have been taken to improve the 95% CL crack width predictions based on crack width data recorded over LW101-LW108 in Narrabri, and to paraphrase the SAR, it appears less likely that crack widths will exceed predictions based on crack widths predicted empirically using data at the 95% Confidence Limit. However, in my opinion, the predicted severity of cracking that has been reported in **Table 12** of the SAR, even if it occurs at mean value level, could impact the steep slopes and minor cliffs, artifact locations, and surface infrastructure, adversely.

Geology and possible connective subsurface cracking

The area of the mine site is located on the eastern side of a plateau of low relief, which is dissected by ephemeral (non-permanent) water courses that drain in a north-easterly direction towards the Namoi River. An extract of a three-dimensional model of the surface topography and subsurface geology rock in the general area has been reproduced courtesy of Herr et al[2], see **Figure 1**. The rock strata are shown to clearly dip towards the west.

[1] Exceedance probability is referred to as the probability that a specified value will be exceeded in a predefined future time-period.
[2] Herr A, Northey J, Mitchell PJ, Aryal SK, Merrin LE and Slatter E (2018) Conceptual modelling for the Namoi subregion. Product 2.3 for the Namoi subregion from the Northern Inland Catchments Bioregional Assessment. Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia. http://data.bioregionalassessments.gov.au/product/NIC/NAM/2.3.

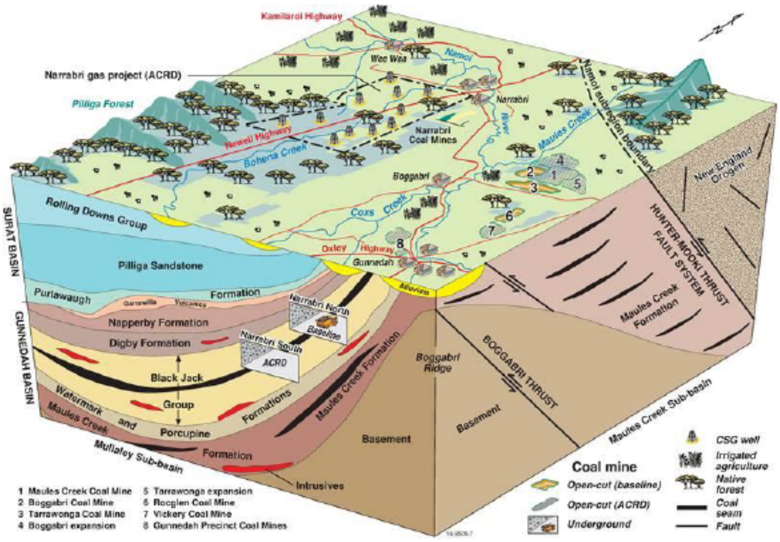

Figure 1 Three-dimension model of surface topography and subsurface geology reproduced courtesy of Herr et al.

The subsurface geology is described in the SAR, with a key figure reproduced in this report as **Figure 2**. The SAR variously notes that the rock strata dips to the west or southwest at up to 3°-5° or up to 52mm/m-87mm/m (that is a dip of 52-87mm for every metre of distance). Borehole NRI-13 is located approximately 1,020m from the tailgate or eastern edge of longwall panel LW203 (to the east) and approximately 2,275m from the maingate or western edge of longwall panel LW209 (to the west). The dip of the Pilliga Sandstone is assumed to continue in a westerly direction beyond borehole NRI-13, as shown by me in **Figure 2.** The approximate location of longwall panels LW203-LW209 are shown in **Figure 2** by a red-coloured rectangular shape superimposed on the Hoskissons Seam.

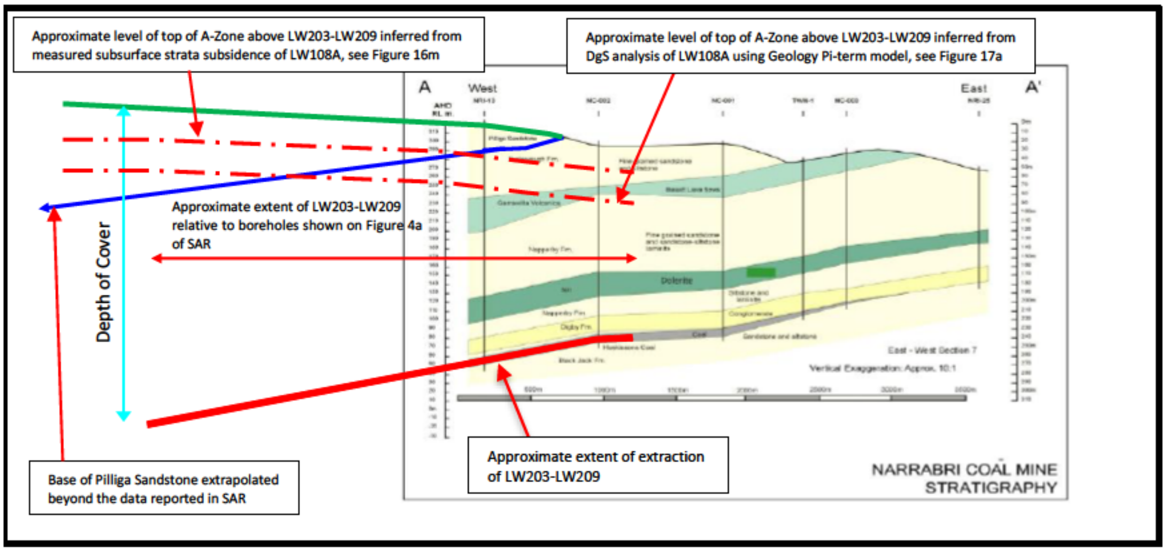

Figure 2 Approximate extent of longwall panels LW203-LW209 shown as a red-coloured rectangular shape superimposed on the Hoskissons Seam, Figure 3c reproduced courtesy of DgS.

The Pilliga Sandstone and to a lesser degree, the overlying Rolling Downs Group, contain aquifers, which drain towards the Coonamble Embayment of the Great Artesian Basin (Herr et al). The interface between the Pilliga Sandstone and the underlying Purlawaugh Formation has been shown extended and dipping further to the west of borehole NRI-13, see **Figure 2**. This provides a clearer understanding of the increasing thickness and depth of the Pilliga Sandstone above LW206-LW209 than has been provided by **Figure 3** of the SAR (reproduced here as annotated in **Figure 2**), which is consistent with the subsurface geology shown in **Figure 1**.

The strata underlying the Pilliga Sandstone, being the Purlawaugh Formation and much of the underlying strata down to the Hoskisson Seam are regarded as Aquitards, except for the Napperby Formation, the Ulinda Sandstone (Digby Formation) and the Clare Sandstone (Black Jack Group overlying the Hoskissons Coal Seam), which are potential or poor aquifers. These additional potential or poor aquifers lie within the A-Zone and could be impacted by connective cracking.

Based on the subsidence mechanisms described by Peng & Chiang and presented in **Figure 15a** of the SAR, (see **Figure 3** of this report), continuous fractures could develop in the fully fractured A-Zone. The SAR reports that the height of the A-Zone could range up to between 0.8- to 0.9-times the depth of cover at the 95% CL, see extract copies of **Figures 16m and 17a** of the SAR, in **Figure 4**. This means that the probability that the top of the A-Zone could be higher than predicted (i.e., between 0.8- to 0.9-times the depth of cover), is low.

I have superimposed the height of the A-Zone estimated from **Figures 16m** and **17a** reported in the SAR, on **Figure 2** of this report as a pair of nearly parallel red dashed curved lines on the extract of the Narrabri Coal Mine Stratigraphy. Noting that all the data is not available to use in this review, it is possible, if not likely, that A-Zone connective cracking could extend up into the Pilliga Sandstone. The uppermost red dashed line (A/H=0.9) [3] derived from **Figure 16m** of the SAR and shown in **Figure 2** above, does not appear to encroach within 20-metres of the ground surface and connective cracking, therefore, could extend up into the Pilliga Sandstone above LW205-LW209 and impact an area estimated to measure approximately 10.5km x 1.8km depending on the limit of the outcrop. The SAR notes on page **ES-4** that A-Zone connective cracking is considered **unlikely** to encroach within 20-metres of the surface.

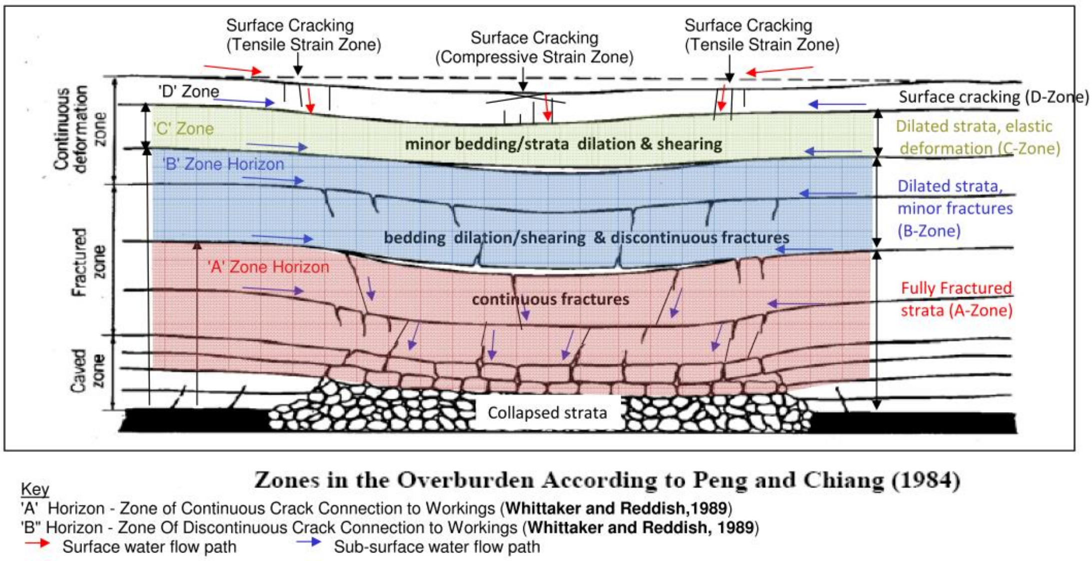

Figure 3 Extract copy of Figure 15a of the SAR

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[3] A/H is the ratio of the height of the A-Zone divided by the depth of cover

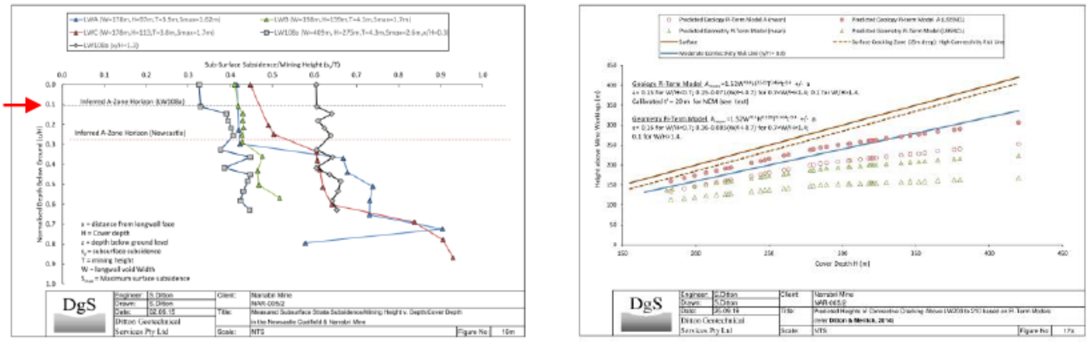

Figure 4 The A-Zone horizon above LW108A derived from subsurface strata subsidence measurements above LW108A (indicated by the red arrow) in the left frame and as predicted by the Geology Pi-term model upper 95% confidence interval in the right frame.

The SAR states that B-Zone sub-surface fracturing in the constrained zone, which contains aquitards like the Purlawaugh Formation immediately below the Pilliga Sandstone, is likely to interact with surface cracks (D-Zones) in the Pilliga Sandstone, where cover depths are < 300 m above the 306 m wide panels and < 375 m above the wider longwalls, which includes LW203-LW209. The SAR further states that based on a depth of surface cracking of 15-metres and possible connectivity between A- and B-Zones, that there is up to a 25% probability that connective cracking could impact the surface. The SAR does not refer to the potential impact of the A-Zone cracking on the Napperby Formation, Ulinda or Clare Sandstone strata.

Regarding the hydrogeological response to longwall mining, Guo et al[4] noted that "Breaching of aquitards is seen as a significant issue in Australia, but there do not seem to be Australian studies addressing this problem, apart from discussions of minimum mining depth that account for sufficient height of the constrained zone (e.g., Forster and Enever 1992)[5] to ensure no connection between the surface zone and the fractured zone." The writers noted, furthermore, that "Although groundwater levels may fall due to drainage into the mine, Booth (2006)[6] concluded that this is usually prevented by an intermediate aquitard and only causes problems for deep wells that get water from the fractured zone. These wells do not generally recover".

The theoretical stress distribution and hydrogeologic model proposed by Forster and Enever indicates that increased vertical permeability could be expected in the constrained zone of the rib area, which is located generally above the sides and ends of the longwall panel, see **Figure 7**. A decrease in vertical permeability is expected in the surface zone whilst horizontal and vertical permeability are expected to increase or not change, respectively, in the constrained zone if the A-zone does not extend to within 20metres of the ground surface. The statement on ES-5 of the SAR that "Discontinuous fracturing would normally be expected to occur above the proposed mining area, causing an increase in rock mass storage capacity and horizontal permeability, without direct hydraulic connection to the workings. Groundwater levels would be lowered in the medium to long terms as a consequence of these impacts", is reasonable, if the discontinuous fracturing generally occurs in the Purlawaugh Formation, a known Aquitard.

I broadly agree with the SAR that it is possible, if not likely, that creek flows could be temporarily rerouted to subsurface pathways and resurface downstream, however, after the findings of Herr et al, it appears likely that water in the Pilliga Sandstone aquifer could provide baseflow to watercourses draining towards the Namoi River at the eastern extent of the outcropping. The baseflows to the watercourses are most likely fed by rejected recharge, which

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[4] Guo, H. Adhikary, D. P. and Gabeva, D. ACARP Project C14033 Hydrogeological Response to Longwall Mining. CSIRO Exploration and Mining Report P2007/692 October 2007
[5] Forster, I., Enever, J. (1992): Hydrogeological response of overburden strata to underground mining. Office of Energy Report, Vol. 1, pages 104.
[6] Booth, C.J. (2006): Groundwater as an environmental constraint of longwall coal mining. Environmental Geology. Vol. 49, 796-803.

occurs where water is restricted from entering the aquifer, because of geology and topography and is discharged at the surface. It is uncertain whether water rerouted to subsurface pathways because of surface cracking would follow the same flow path.

Far-field ground movement

Far field or regional horizontal deformation of the ground surface occurs at comparatively large distances away from the mining area, after the findings of Hebblewhite[7]. In 1998, Reid[8] reported that "horizontal movements of up to 25mm occur even when underground coal mining is about 1.5km from survey movements". Furthermore, Reid states that "results also show that horizontal movements are typically at least as great as the vertical component, that the maximum horizontal movement occurs soon after mining, and that the movements are generally directed towards the goaf." A description of far field ground movement from the SAR (**Figure 20a**) is reproduced in **Figure 5** of this report.

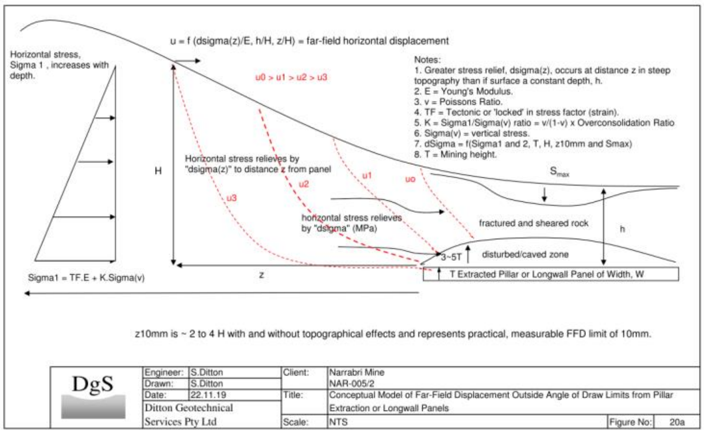

Figure 5 Description of far-field movement described in the SAR

I am currently involved with monitoring ten (10) structures located in the Southern Coalfields at offset distances from the nearest longwall panel of between 0.9km-1.2km. Potential areas of impact include horizontal valley closure displacement, vertical upsidence displacement and sideways racking[9] displacement of structures, and the potential for far field movement to concentrate at one location and cause significant opening of pre-existing fault zones, rock joints or cracks, which could impact overlying structure, whether geological or built.

According to **Figure 20a** of the SAR, inwards far-field movement of up to 10mm could occur at up to twice the depth of cover when allowing for topographical effects and four-times the depth of cover without topographical effects, see **Figure 6**. The inwards horizontal ground movement should progressively increase towards the 20mm subsidence contour or where the angle of draw intersects with the ground surface increasing horizontal stress.

The sloping rock faces and minor cliff lines beyond the southern end of LW205-LW207 are located within 0.3km of the end of the longwall panels LW205-LW207, which is much closer to the proposed longwall panels than the structures that are monitored in the southern coalfields (0.9km-1.1km).

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[7] Hebblewhite B.K. Waddington, A. Wood, J. Regional horizontal surface displacements due to mining beneath severe surface topography. 19th International Ground Control in Mining Conference (2000).
[8] Reid, P. Horizontal movements are Cataract Dam, Southern Coalfield. Mine Subsidence Technological Soc., Proc. 4th Triennial Conference, Newcastle, July 1998.
[9] Racking displacement occurs when one bridge abutment moves sideways relative to the other bridge abutment causing a rectangular shaped bridge structure to distort into a parallelogram shape.

The SAR notes that the exposed strata on the minor cliff faces and steep rocky slopes consist of blocky, medium bedded Quartzitic Sandstone beds of low to medium strength. Furthermore, small to large sandstone boulders and weathered sandstone exposures form steep, rocky talus slopes below the minor cliff faces.

The SAR notes on page 42 that undermining ridges can also result in surface cracks migrating upslope and outside the limits of extraction for significant distances due to rigid block rotations. Depending on topography and rock jointing cracks can migrate outside the limits of longwall extraction in Newcastle for distances up to 0.2 times the depth of cover.

If far field movement concentrates at one location around the steeply sloping rock faces and small cliffs, and the type of cracking that occurred in Newcastle, re-occurs in Narrabri, it is possible for rock joints between the blocks that comprise the minor cliffs to open and propagate in depth and length as described above, which could impact rock face stability.

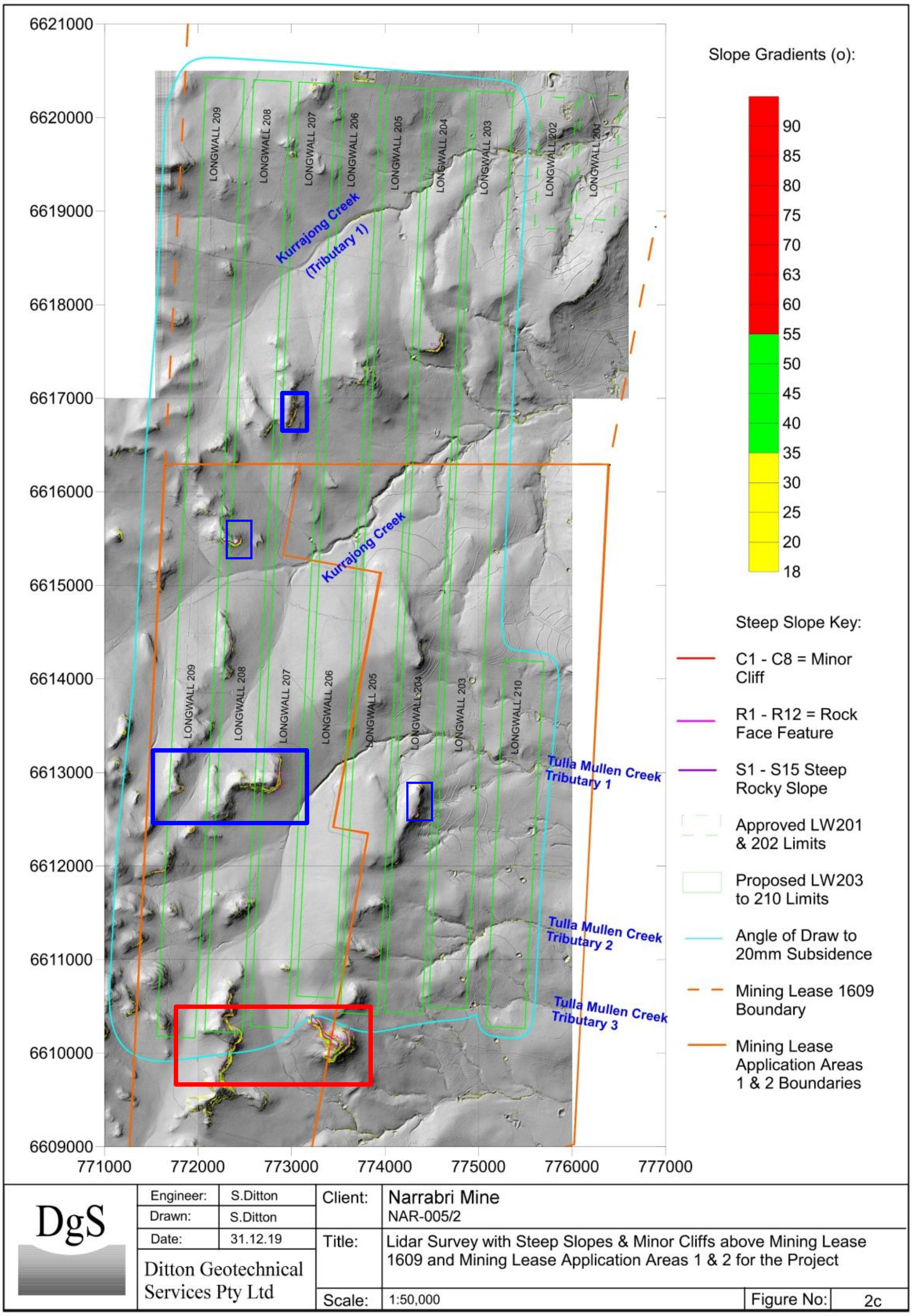

Figure 6 Lidar survey showing steep slopes and cliffs

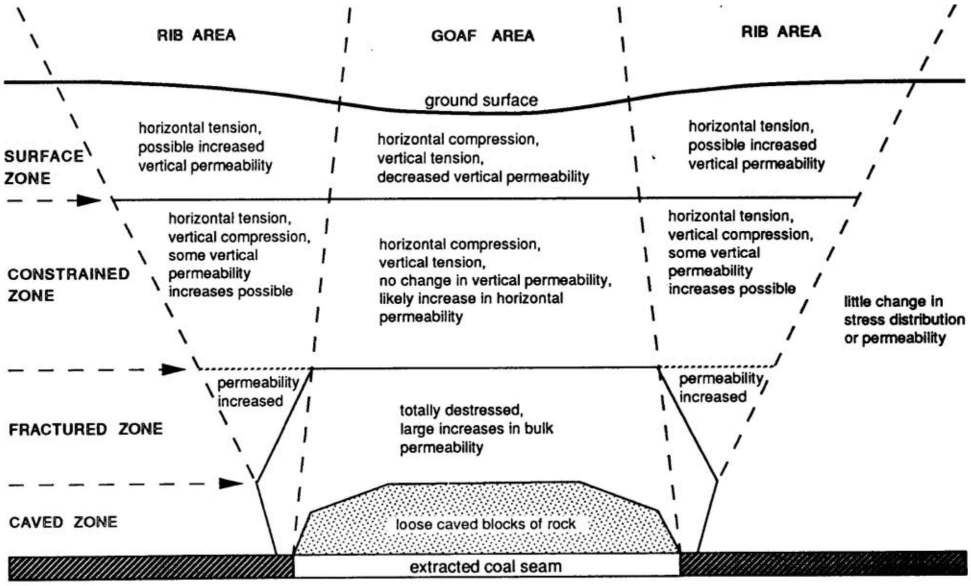

Figure 7 Theoretical stress distribution and hydrogeological model above and adjacent to longwall panel extraction after Forster and Enever (1992)

Predicted versus actual Subsidence

As background, of all the predictions made by subsidence engineers, subsidence predictions tend to match actual measured subsidence more closely, than firstly tilt, and then curvature and ground strain.

Predictive subsidence models, like **Figure 6h** of the SAR, typically show that subsidence develops in smooth triple-curvature across the width of the longwall panel. However, because of the blocky and non-homogeneous nature of the overburden above the longwall panels, curvature and strain on the ground surface can concentrate along short intervals and the determination of crack width can be difficult to predict with any precisions. Therefore, it is more usual to present a range of predicted crack widths to cover the statistical variation in possible outcomes so that the frequency that predicted crack widths are exceeded is low.

Subsidence for a single longwall panel has been calculated using the empirical subsidence prediction curves developed for the Newcastle Coalfield and published in ACARP, 2003. In essence, the subsidence profile for a longwall panel is derived by fitting mathematical functions to the mining data base, which has been updated since 2003, applying some key boundary conditions (see page 19 of SAR). Total longwall panel subsidence is then calculated by superimposing the influence of subsequent longwall panels on the initial single-panel predictions. These predictions include chain pillar subsidence.

The SAR describes in detail how subsidence has been predicted.

In summary, the SAR provides the following information:

- There is proposed to be a general increase in longwall panel width (W) in future mining noting that all proposed panels range from 399.7m to 415.4m in width; whereas longwall panels LW101 was 306.1m, LW102-106 were 306.4m and LW107-108A were 408.9-408.9m in width, respectively, (see **Tables 2A & 3** in the SAR).
- In reference to **Tables 2A & 3** of the SAR, the depth of cover (H) for proposed LW203-210 ranges between 180m & 400m with an average of around 290m, which is a noticeable increase above the average depth of cover above LW101-108A, which ranges between 160m & 280m with an average of around 210m. Therefore, based on the panel widths W quoted in **Tables 2A & 3** of the SAR, the ratio of longwall panel width to depth of cover (W/H) for proposed longwall panels LW203-210 ranges between 1.02 (LW209) and 2.31 with an average of 1.46 compared with LW101-108A where W/H ranges between 1.2 and 1.91.

- Total subsidence is predicted as a function of the longwall panel geometry (described above) and the potential for reduced subsidence (SRP) because of the presence of massive or very hard layers within the rockmass strata, see **Figures 10a-10c** of the SAR.
- Generally, around 2.75m of vertical subsidence is predicted at mid-panel for proposed longwall panels LW203-209, which is generally in line with the predictions for longwall panels LW101-108A, e.g., see **Figure 9a** of the SAR.
- **Figure 9a** shows that subsidence measured at mid-panel and at the chain pillars along the A-Line and H-Line (red- and green-trace) was slightly less than predicted. Based on the data as presented, it appears that subsidence along the chain pillars was less than predicted, and consequently, so too was total subsidence, see **Figures 7a to 7h** of the SAR.
- The SAR compares the predictions of two methods of computing subsidence (DgS & ACARP), with subtle and relatively insignificant differences being observed, see **Figure 12** of the SAR.
- Slightly greater subsidence has been predicted across the proposed LW203-209 than was predicted for LW202-203 already approved. The SAR notes that some top coal caved from the mine roof and was recovered during extraction, meaning that the real extraction height was slightly greater than 4.3m. DgS has accounted for this in the subsidence predictions for the new application.
- The magnitude of measured subsidence above LW101-108A was generally less than predicted, noting that some slight exceedances were recorded near the ends of LW106 & LW108, see Figures **7a-7h** of the SAR, which is not significant.

In review, I note that longwall panels LW107 and LW108A were 408.8m and 408.9m wide respectively, with depths of cover ranging from 240m to 280m, with panel geometry W/H[10] = 1.72 and 1.47-1.64, respectively. The proposed longwall panels LW203-LW209 have relatively similar (W/H) geometry with W/H ranging from between 1 and 2 and in my opinion, similar levels of ground strain are possible. Longwall panel LW210 has a panel geometry W/H of up to 2.31 and more severe grout tilt and strains are predicted to occur above and immediately surrounding LW210 than elsewhere above and immediately surrounding LW203-LW209, which is reasonable.

Potential impact on Landholders

The possible impact of subsidence on landholders is summarised in the following sections of the report, intended to highlight what could occur if subsidence develops as predicted.

Impact of Subsidence & Tilt on the Ground Surface

Extraction of each longwall panel will cause the ground surface to subside and tilt in towards a predicted 2.75m deep subsidence trough that will be expressed on the ground surface as the longwall face retreats.

The ground surface is predicted to tilt in towards the centre of each longwall panel by up to 70mm/m above LW201 and 50mm/m above LW202. Ground tilt is predicted to progressively reduces in magnitude as the depth of cover increases, towards LW209. To put the predicted ground tilt into perspective, the road pavement on the Kamilaroi Highway most likely has a cross fall of 3.5% or 35mm/m, which is half of maximum predicted ground tilt.

Surface water ponding could develop where the current ground surface slope is less than the predicted ground tilt. The SAR has identified several areas where ponding might increase, which appears to be a reasonable interpretation. However, based on an assessment of the contour drawings presented in **Figures 14a-14b and 19c-19d** of the SAR there is an increased risk, in my opinion, of increased ponding in the waterholes along the ephemeral Tulla Murren Creek tributary 1 above longwall panels LW205-206 and at D7 & D40 above LW203, which should be investigated further. The SAR notes that 9 of the 41 farm dams identified could have the inflow affected by subsidence. Furthermore, ground strain could impact the dams by cracking the base and walls causing water leakage.

[10] W/H is the ratio of longwall panel width divided by the depth of cover

Impact of Tensile Ground Strain

Tensile ground strain or ground extension typically develops in the cross-panel direction above barrier and chain pillars, and in the long-panel direction, above barrier (starting and finishing end) pillars and the retreating longwall face, which generates a travelling subsidence wave along the panel.

After longwall panel retreat commences, tensile ground strain gradually develops in the long-panel direction above the retreating longwall face. From the perspective of an observer anywhere along the panel centreline, the travelling a subsidence wave will be observed to gradually approach the observer and the ground will tilt in towards the subsidence wave and will extend into the goaf behind the longwall face. This generates tensile strain, which could generate severe ground surface cracking, as predicted (e.g., up to 920mm on Steep Rocky Slopes).

As the longwall face retreats past the observer, the ground tilt begins to flatten out in the long-panel direction and ground shortening is then expected to occur. This could cause closure of ground surface cracks generated by the travelling wave, depending on how the rockmass responds to subsidence and whether the crack has filled with loose or fractured material. It is possible that these cracks may not completely close. Therefore, crack widths above the longwall panel measured at the end of extraction are unlikely to accurately represent maximum crack width above the travelling wave.

For the reasons stated above and noting that surface crack widths ranging from 300mm to 1,000mm were recorded on the exposed rock surface along the sides of a topographic spur extending across Longwall panel C (Newcastle), see **Figure 14e** of the SAR, it seems very likely that similar cracking could occur on the steeply sloping rock faces or cliff lines above LW203-209. This opinion is reinforced by **Table 14** of the SAR, which notes that crack widths up to 466mm could develop around the identified cliff lines and crack widths up to 919mm could develop on the steeply sloping rock faces, see **Photos 10-14** in the SAR for images of cliff lines and steeply sloping rock faces. Section 10.2.2 of the SAR reports four cracks measuring 400mm in width and another measuring 1.0m to 1.8m in width, although the SAR notes a possible contribution to the cracking width of runoff erosion.

Of concern here is the development of wide cracks up to 466mm behind and/or through a minor cliff line, such that the cracking could exacerbate pre-existing movement that may already be occurring at rock joints. In my opinion, it is possible for mechanisms to develop that could lead to rock face instability or block separation that could damage a rock overhang, possibly leading to collapse. Given the foregoing and the possibility of infrequent visual and/or survey monitoring, access to these areas should be tightly controlled until after mining and possibly beyond, in my opinion.

The SAR notes that 7.5Ha of steep slopes that are 6m to 22m high would subside by up to 2.8m. Given that a significant proportion of this area could be impacted by convex curvature and tensile ground strain near or above chain pillars or could be impacted by the travelling subsidence wave, causing tensile and compressive ground strain, the proportion of the total area of steep slopes that was assessed in the SAR as likely to be impacted by subsidence seems to be very low.

I note in the SAR that cracking up to 920mm in width could develop in the steep slopes area, which is assumed to be a single crack affecting a localised area. However, if a swarm of smaller cracks develops, then the affected area could be more extensive.

It is notably difficult to predict where a crack will develop on the ground or on a brittle structure when it is subjected to tensile strain (ground extension) caused by subsidence. However, since the travelling wave will subside the steep slopes and ground extension will move along the length of the longwall panel, it is possible that a single wide crack or group of smaller cracks could develop, depending on how the near surface geology responds to the ground extension, which could impact a more extensive area of the steep slopes.

I hold a similar opinion for the minor cliff lines, which the SAR states are approximately 124metres in length. If a single crack or a group of cracks, of the length shown photo 19 of the SAR, intersected a minor cliff line at a shallow angle (slightly sub-parallel to the cliff line) or occurred behind the cliff line, the stability of the cliff face could be adversely impacted, and/or blocks of sandstone could move and overhangs could be damaged, which could ultimately lead to collapse. In my opinion, it is possible, given the short length of the minor cliff lines, that up to 50% of the cliff lines could be impacted although I note that none was recorded in Newcastle.

Significant tensile cracking has been recorded on the alluvial creek bed along a Pine Creek tributary above LW107-108A into which the ground along the sides of the crack has partially collapsed. The development of this type of cracking could present a hazard to stock, foot traffic and vehicles and should be risk assessed by the applicant.

I agree with the statements in the SAR that tension cracking of bedrock across creek beds can drain surface water down into the underlying rock strata, which should normally drain in the same direction of other groundwater in the locality. However, noting that the rock strata dip in the project area towards the west at up to 3° to 5° rather than the east (the direction of the creeks that receive rejected recharge, as described above), the assumption that existing ground water will drain towards the east, whilst having a simple logic, should be verified.

The grinding grooves located at Mayfield and Longsight, see **Figures 1e-1f** in the SAR for location, could be significantly impacted by tensile and compressive ground strain, particularly where the artifacts have been worked into the bedrock. Exposed bedrock is susceptible to the impact of ground strain along exposed bed joints and where weathering has initiated surface exfoliation not yet apparent on the rock surface.

The predicted subsidence effects at Mayfield and Longsight are presented in **Table 23** of the SAR. I have separately interpolated values of the strain from **Figures 13e & 13f** of the SAR. Some comments are presented as follows:

i. No compressive strain is predicted in the long-panel direction at both Mayfield and Longsight behind the longwall face when I would normally expect this to occur.
ii. Tensile strain above the longwall face appears a bit lower than expected or around 50% of estimated value derived from predicted strain near the end of the longwall panels.

I concur with the cracking strains presented in section 11.7.2 of the SAR. I note that ground tension needs to cause decompression to generate tensile stress in a rockmass. In-situ rock compressive stress is one explanation for the higher rock tensile cracking strains recorded in Newcastle. If the in-situ stress in the Pilliga Sandstone is around 20% of the Unconfined Compressive Strength[11] (UCS ranges between 5MPa and 20MPa as stated in the SAR), then I estimate an apparent tensile cracking strain ranging from 1.0mm/m to 2.7mm/m, which would ultimately depend on the engineering properties of the sandstone.

Based on my interpretation of **Figures 13e & f** in the SAR I conclude the following:

i. Tensile strain up to 4mm/m is estimated at Mayfield and cracking is possible on the rock surface at or around the artifacts. I concur with a 10-50% likelihood of ground surface cracking occurring.
ii. Compressive strain up to -12mm/m is estimated at Mayfield and I believe that compression damage is very likely at rock joints, notches and along bedding planes that find surface expression at or around the artifacts.
iii. Tensile strain up to +12mm/m is predicted in Table 23 of the SAR and tension cracking is very likely on the rock surface. I note that these artifacts have been worked into boulders and may not be impacted by tensile ground strain. If significant strain developed, the connection between the boulders and bedrock could be severed to alleviate strain transmission into the boulder if it became apparent.
iv. Compressive strain up to -29mm/m is predicted in Table 23 of the SAR and compression damage is almost certain at rock joints, notches, and along bedding planes that find surface expression at or around the artifacts. Localised compression failure of the rock surface beneath a boulder could cause some movement of the boulders.

It is normal practice to monitor subsidence and valley closure across creek beds in the southern coalfields. Given the existence of the artifacts, it is recommended that a grid of survey targets should be installed around the artifacts to monitor for the development of ground strain. However, it is unlikely that an additional response measure could be implemented at Mayfield if it was triggered during active subsidence, in time to limit the impact of ground strain around the artifacts. Therefore, the rate of longwall progress may need to be reduced to enable additional response measures to be implemented. It may be preferable to implement intervention

[11] The unconfined compressive strength (UCS) is the maximum axial compressive stress that a right-cylindrical sample of a material can withstand under unconfined conditions, i.e., there is no confining stress is zero.

measures designed to limit the amount of ground strain that can be transmitted into the bedrock surrounding the artifacts before subsidence occurs.

Ground-extension could increase tension in fencing wires or cause timber rails to pull away from the fence posts thereby reducing the effectiveness or ultimately damaging the fencing. Gates could also be impacted by strain and may be difficult to close. In either case of tensile or compressive strain, the fences and gates should be monitored to ensure they continue to remain safe and serviceable.

The farm dams could be impacted by the magnitude of tensile strains reported in Table 18 of the SAR. I concur with the SAR that tensile and compressive strains of this magnitude could breach dam walls or damage the base causing leakage.

Impact of Compressive Ground Strain

Compressive ground strain or ground shortening develops across the middle half of the longwall panel in the cross-panel direction and following the retreat of the longwall face in the long-panel direction. However, the SAR reports that surface ground movement anomalies were not recorded above LW101-108A during panel extraction.

Ground surface movement anomalies can occur where high compressive ground strain interacts with unusual near surface geological features, cross bedded sandstone, fault zones, and clay-filled dykes. The SAR notes that much of the area is covered by 1-4 metres of alluvial material, which is likely to conceal any visual evidence that anomalous movement have occurred on the underlying rock surface. If compressive ground heave does occur, it could be a potential hazard to stock, foot traffic and vehicles and should be risk assessed by the applicant.

High levels of compressive strain are generally predicted across the longwall panels and similar levels of compression stress can be expected to occur in the steeply sloping rock surfaces or cliff lines above the longwall panels after the subsidence wave has travelled past the exposed rock formations, which has been reported above.

Ground-shortening could de-tension fencing wires or cause timber rails to buckle between fence posts thereby reducing the effectiveness or ultimately damaging the fencing. In either case, the impact of compressive strain should be visible in the form of sagging wires or buckling rails, which should trigger additional response measures by the applicant.

I agree with the SAR that valley closure and upsidence can occur when valleys are subsided. Valley closure occurs across a valley partly because of the severity of the valley incision, partly due to near-surface geology and partly because the valley has most likely incised into a major rock joint, which can focus compressive strain. The likelihood that bed joint shearing will outcrop on the side walls of a creek valley seems remote.

The farm dams could be impacted by the magnitude of compressive strains reported in Table 18 of the SAR. I concur with the SAR that tensile and compressive strains of this magnitude could breach dam walls or damage the base causing leakage.

Subsidence Impacts on Surface Infrastructure

The key surface infrastructure that has been identified in the SAR is outlined as follows:

i. Residential dwellings
ii. Sheds
iii. Rainwater tanks
iv. In-ground potable water pipework
v. In-ground sewage pipework
vi. Septic tanks
vii. Power & telecommunication poles and wires

Residential dwellings & infrastructure

If subsidence occurs as predicted, structures could retain a residual tilt of up to 25mm/m. A residual tilt of this magnitude is well beyond normal serviceability limits and the dwelling would need to be re-levelled and possibly re-stumped, depending on ground strain impacts on the timber posts and any sub-floor bracing.

It is possible to jack up structures against increasing subsidence to maintain the structure within a desired level of maximum tilt, whilst being subsided, if the dwelling is occupied. This was carried out on a large single-storey residential dwelling near the Bulga Colliery in the Hunter Valley with my involvement.

The dwellings are likely to be impacted by differential subsidence, tilt, and ground strain to varying degrees, however, there are practical limitations to the remote assessment of subsidence impacts on structures unseen. However, in general, where ground curvature of up $1.5km^{-1}$ is possible, damage to clad timber frames, lined with plasterboard could reach Category 3 damage in accordance with AS2870:2011, with crack widths exceeding 5mm. Moreover, it is likely that the dwelling structures will need to be re-levelled and re-stumped, depending on the nature and severity of damage imposed on the substructure by ground strain. With ground tilt ranging up to 50mm/m, residual floor tilt is unlikely to be acceptable and gutter fall will be adversely impacted, however this is of academic interest given that re-levelling of the structures is almost certain, and the gutter would likewise be re-levelled in the process.

In-ground pipework and tanks are likely to be damaged by ground strain and interim alternative above-ground pipework and water storage may be required if the dwellings are occupied during active subsidence.

Poles supporting aerial power and telecommunications above the longwall panels are likely to tilt and move apart or toward each other depending on where they are located above the longwall panels. Ground strain can increase cable sag if the poles are drawn together, and minimum clearance heights should be monitored to manage public risk. If the poles are pulled apart, cables could be subject to increasing tension and this should also be monitored during active subsidence to maintain the power supply in a safe and serviceable condition.

Yours faithfully,
John Matheson & Associates Pty Ltd

[redacted]

John Matheson BE (Hon), CPEng, MIEAust, NPER

Director

Environmental Defenders Office

4 February 2022

Mr John Matheson
John Matheson & Associates
Consulting Engineers (T/as J M A Solutions)

By email: [redacted]

CONFIDENTIAL AND PRIVILEGED

Dear Mr Matheson

Brief to Expert – Narrabri Underground Mine Stage 3 Extension Project (SSD 10269) Public Hearing

1. We act for Lock the Gate in relation to the proposed Narrabri Underground Mine Stage 3 Extension Project (SSD 10269) (**Project**) by Narrabri Coal Operations Pty Ltd.

2. The Narrabri Coal Mine is an existing underground thermal coal mine located approximately 25 kilometres (**km**) south-east of Narrabri and approximately 60 km north-west of Gunnedah. Coal production using bord and pillar and partial extraction methods commenced in 2010. Stage 2 of the existing mine has been extracting coal by longwall methods since June 2012 and allows for the production and processing of up to 11 million tonnes per annum (**Mtpa**) of run-of-mine (**ROM**) coal until 26 July 2031. The Project proposes to continue longwall mining in a major southern extension area until 2044. The Project also seeks the continued use of existing underground and surface infrastructure, including use of the existing Coal Handling and Preparation Plant (**CHPP**) at 11 Mtpa.

3. The Project has now been referred to the Independent Planning Commission (**IPC**) for determination with a public hearing. Our client wishes to ensure the IPC receives independent expert advice on the Project. Accordingly, our client wishes to retain your services to act as an expert, to provide an expert report for submission to the IPC and to present your expert views to the IPC public hearing.

Primary purpose to provide independent expert advice

4. We note as a preliminary matter that our primary purpose in briefing you to prepare your report is to provide independent expert advice in your area of expertise. We do not ask you to be an advocate for our client. You are requested to prepare an independent report that is clear and well-written.

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5. In this respect, we draw your attention to Division 2 of Part 31 of the *Uniform Civil Procedure Rules 2005* (**UCPR**), and the Expert Witness Code of Conduct (**Code of Conduct**) contained in Schedule 7 of the UCPR, both of which govern the use of expert evidence in NSW Courts (**attached**). We understand that the IPC public hearing is not a Court proceeding, however, we are of the view that the same Code of Conduct should be adhered to in this instance.

6. In particular, clause 2 of the Code of Conduct states that:

> *"An expert witness is not an advocate for a party and has a paramount duty, overriding any duty to the party to the proceedings or other person retaining the expert witness, to assist the court impartially on matters relevant to the area of expertise of the witness."*

7. Your expert report must contain an acknowledgment that you have read the Expert Witness Code of Conduct and that you agree to be bound by it.

8. Your expert report will be used as evidence in chief of your professional opinion. Information of which you believe the decision maker should be aware must be contained in your expert report.

9. In providing your opinion to the decision maker you must set out all the assumptions upon which the opinion is based. This may include, for example, facts observed as a result of fieldwork or 'assumed' facts based on a body of scientific opinion. If the latter, you should provide references which demonstrate the existence of that body of opinion.

10. Your expert report must also set out the process of reasoning which you have undertaken in order to arrive at your conclusions. It is insufficient for an expert report to simply state your opinion or conclusion reached without an explanation as to how this was arrived at. The purpose of providing such assumptions and reasoning is to enable the decision maker and experts engaged by other parties to make an assessment as to the soundness of your opinion.

Overview of work requested

11. We request that you undertake the following work:

    a. review the documents listed below;
    b. prepare a written expert report that addresses the issues identified below ('Issues to address in your expert report'), and ensure that the work is prepared in accordance with Part 31, Division 2 of the UCPR; and
    c. appear as an expert witness at the IPC public hearing for the purpose of giving oral evidence.

Documents

12. We enclose the Code of Conduct and Part 31 Division 2 of the UCPR.

13. Full Project documentation is available at the following websites:
    a. NSW Government Planning Portal: https://www.planningportal.nsw.gov.au/major-projects/project/10731
    b. IPC: https://www.ipcn.nsw.gov.au/projects/2021/12/narrabri-underground-mine-stage-3-extension-project-ssd-10269.

14. The following documents relating to the Project are provided for your particular consideration:

Environmental Impact Statement

a. Executive Summary: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120201023T021123.529%20GMT
b. Table of Contents: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120201023T021124.977%20GMT
c. Section 1 - Introduction: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120201023T021125.593%20GMT
d. Section 2 - Project Description: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120201023T021126.211%20GMT
e. Section 6 - Assessment of Impacts (pp. 6-7-- 6-17): https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120201023T021129.246%20GMT
f. App A - Subsidence Assessment: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120201023T021139.762%20GMT

Response to Submissions

a. Submissions Report (pp. 44-45): https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=EXH-10425089%2120210531T070053.430%20GMT.

Amendments

a. Narrabri Stage 3 Project - Amendment Report (Appendix A): https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120210531T065545.008%20GMT.

Additional Information

a. IESC - Advice on EIS: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120201215T041319.148%20GMT
b. NCOPL response to IESC advice: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120220119T060415.097%20GMT

c. RFI - Mining Panel Advice - Sep 21: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120210927T073812.640%20GMT

d. NCOPL Response to DPIE Water - Submission & Amendment Reports Advice - 20 Sep 21: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120210927T065529.875%20GMT

Relevant Agency Advice

a. SA NSW - Advice on EIS: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-10521218%2120201211T054825.691%20GMT

b. SA NSW - Advice on Submissions and Amendment Reports: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-21182861%2120210701T053133.587%20GMT

c. DPE Water - Advice on EIS: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-10521206%2120210117T233808.869%20GMT

d. DPE Water - Advice on Submissions and Amendment Reports: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-21182850%2120210811T223934.014%20GMT

e. DPE Water - Supplementary Advice on Submissions and Amendment Reports: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-28882133%2120211029T045639.756%20GMT

f. MEG - Advice on EIS: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-10521212%2120201204T054427.145%20GMT

g. MEG Attachment A - Advice on EIS: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-10521212%2120201204T054409.029%20GMT

h. MEG - Advice on Submissions and Amendment Reports: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PAE-21182856%2120210615T072058.991%20GMT

Department’s Assessment Report

a. Department's Assessment Report (pp. vi-xv, 25-28): https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120220119T051727.890%20GMT

a. Recommended Conditions: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-10269%2120220119T051728.236%20GMT.

15. Please let us know as soon as possible if you require further information for the purpose of giving your expert opinion.

Issues to address in your expert report

16. We ask that your report address the following issues:

    a. Please summarise any key subsidence and/or geotechnical impacts predicted to arise as a consequence of the Project.
    b. In your opinion, what consequences, if any, are likely to arise for affected landholders and the environment as result of any impacts identified by you in response to question 16a)?
    c. Provide any further observations or opinions which you consider to be relevant.

Key dates

17. The IPC public hearing will be held remotely from **Monday 14 February 2022**.

18. The IPC will accept written comments on the Project until **5pm AEDT on Monday 21 February 2022**.

19. To assist our clients to prepare for the public hearing, we request a draft of your expert advice by **Friday 11 February 2022**.

20. Please provide your final expert advice by **Friday 18 February 2022**.

Duty of confidentiality

21. Please treat your work as strictly confidential until your expert report is provided to the IPC, unless authorised by us.

Fees and Terms

22. Thank you for agreeing to provide your advice in this matter for a capped fee of $6,000. EDO relies on experts such as you to assist in matters with very little financial compensation.

23. Please note the following terms:

    a. your work will only be used by EDO to relation to this matter;
    b. our client may choose to make your expert advice publicly available. Any public release of your report, whether by our client or by way of publication on the IPC's website, may result in disclosure of any works in your report over which you may claim copyright;
    c. EDO will take all reasonable steps to prevent your work being used for purposes other than that mentioned above, but we accept no responsibility for the actions of third parties;
    d. regardless of the above points, EDO may choose not to use your work; and
    e. you will not be covered by the EDO's insurance while undertaking the above tasks.

24. If you would like to discuss this brief further, please contact the author on (02) 9262 6989 or email [redacted]

We are grateful for your assistance in this matter.

Yours sincerely
Environmental Defenders Office

[redacted]

Matt Floro
Special Counsel

Reference number: S2602