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Supplementary Report

INDEPENDENT ASSESSMENT

HUME COAL PROJECT

Prepared for:

NSW DEPARTMENT OF PLANNING AND ENVIRONMENT

Report No. 1716-12/2b

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Report to: Mr C Preshaw
Director
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Title: Supplementary Report
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Signature:

…   …………………….

Emeritus Professor JM Galvin

22/8/18	Draft Supplementary Report Submitted	Report No: 1716-12/2a
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EXECUTIVE SUMMARY

In December 2017, Galvin and Associates Pty Ltd (GAPL) submitted a report to the Department of Planning and Environment (DPE) on the Hume Coal Project in response to the following Scope of Works:

> ***Scope***
>
> *The Department requires to engage independent experts to give advice on aspects of the EIS.*
>
> <u>*Mine Plan and Subsidence Risks*</u>
>
> *The EIS describes the conceptual "pine feather" mining method, which is yet to be used in NSW. The Department requires expert advice:*
>
> - *to confirm that the levels of subsidence resulting from this method would be as predicted in the EIS;*
> - *about the underground safety aspects of using this method; and*
> - *about the risk of subsidence impacts and environmental consequences to natural and built features, including groundwater aquifers.*

Subsequently, Hume Coal provided a draft response to the GAPL report and to another report by Professor Canbulat, leading to DPE commissioning Emeritus Professor Ted Brown AO to facilitate a meeting (the "experts meeting") between the various stakeholders and their advisors to discuss the mine design and associated issues; to identify real issues; and to promote a strong, fair and quick project assessment. The DPE produced a 'Record of Meeting' that was endorsed by Professors Brown, Canbulat and Galvin. Hume Coal used the DPE document as a base for recording the collective notes and recollections of its four representatives.

One outcome of the review process was the commissioning of Dr Keith Heasley to undertake numerical modelling of the mine layout to assist in estimating coal pillar loads. This was a work in progress at the time of the experts meeting.

On 11 July 2018, Hume Coal provided a report to DPE that included the outcomes of the numerical modelling and responses to Professor Canbulat's and GAPL's reports of December 2017. DPE requested GAPL to deal with Hume Coal's report by means of a supplementary report by 24 August 2018 and confined to whether Hume Coal's response of 11 July addressed issues raised in GAPL's December 2017 report and to whether it identified any residual issues that required further information from Hume Coal.

This supplementary report:

1. Provides a summary overview of the key issues.

2. Compares DPE's and Hume Coal's record of the experts meeting, reconciles areas of agreement and disagreement and identifies areas that could benefit from clarification or further discussion.

3. Raises a number of queries associated with the construction of the numerical model which need to be addressed before GAPL can adopt the outcomes of the modelling.

4. Responds to a range of residual matters raised in Hume Coal's report of 11 July 2018.

The Scope of Works for GAPL effectively requires consideration of regional, local and workplace mine stability in order to advise on levels and impacts of ground subsidence and underground safety aspects. Regional stability is generally concerned with overall mine stability; local stability with ground response and its consequences on a mining panel-by-panel basis; and workplace stability with ground stability and its consequences on a pillar-by-pillar and roadway-by-roadway basis.

The mining method involves delineating a series of, nominally, 60 m wide by 120 m long compartments. Roadways of 4 m width, referred to as 'drives' or 'plunges', are driven within each compartment by mean of a remote controlled continuous miner so as to form up a series of 120 m long strip pillars, referred to as 'web pillars' or 'panel pillars', which range in width from typically 3.5 m to 6.0 m. The concept relies on the overburden transferring some of its weight from the panel pillars to the perimeter pillars of each compartment, thus enabling the use of narrower and, therefore, weaker panel pillars than would otherwise be the case.

The method is novel. To Hume Coal's knowledge, there is no previous experience of driving 120 m, narrow drives by remote control means in underground coal mining. The proponent refers to the method as constituting bord and pillar first workings but acknowledges that the panel set-up is similar to that for the Wongawilli Method of pillar extraction.

A critical issue is the likely behaviour mode of the web pillars which, because they have a width of less than $1/10^{th}$ depth or 10 m, whichever is greater, classifies them under current NSW legislation as 'non-conforming' and, therefore, their formation as a 'high risk activity'. High risk activities are required to be notified to the regulator in advance of being undertaken and may lead to intervention from the regulator. Both Hume Coal and GAPL have provided examples of mining layouts employed in NSW that involve non-conforming pillars but in all cases they are associated with pillar extraction operations and not bord and pillar first workings.

The stability of web pillars does not appear to be critical to controlling surface subsidence but could be for ensuring a safe place of work and may have implications for interference with groundwater aquifers. The mine layout is intended to ensure that if the peak load carrying capacity of the web pillars were to be exceeded, surface subsidence would be restricted to low and manageable levels by the bridging action of the overburden across each panel. Hume Coal relies on the web pillars yielding in a gradual and controlled manner in these circumstances, rather than in a sudden, dynamic (violent) manner.

Irrespective of whether web pillars fail partially or totally and in a gradual or sudden manner, web pillar instability can give rise to a range of health and safety risks associated with factors such as falls of ground and the inability to maintain a respirable mine atmosphere. Roof instability and convergence can also jeopardise mine planning objectives of preventing relaxation effects in the overburden and restricting the height of groundwater drainage to within 2 m of the roof.

The height to which fracturing may extend in the event of the web pillars totally yielding cannot be accurately predicted. Based on percentage areal extraction, the mine layout approximates to totally extracting a 1.9 m thick seam at a depth of 80 m and a 1.5 m thick seam at a depth of 90 m. These values need to be discounted to account for the fact that failed pillars will not flatten out completely and will continue to provide some support to the overburden and retard fracturing. Surface subsidence measurements suggest that the presence of the failed coal pillar could restrict surface subsidence by 50% or more. Based on that figure and the Tammetta Equation (Tammetta**,** 2013), a first pass estimate of the mean height of complete groundwater drainage would be a maximum of about 20 m over the centre of a panel (and decreasing towards the panel abutments).

Given the small absolute width and small width-to-height ratio of the web pillars, their stability can be very sensitive to geology and to small changes in mining dimensions and ground conditions. It was noted in the December 2017 report of GAPL that the mine plans do not show the throw and displacement direction of faults and the thickness of dykes and that the EIS refers to geological structures as 'inferred'. It was also noted that cleating and jointing are not discussed in the EIS and that the nature of the mine layout for the Hume Coal Project is such that it is almost inevitable that cleats and joints will be sub-parallel to pillar sides in some parts of the mine, creating conditions conducive to rib spall (and, therefore, reductions in pillar width and strength).

Hume Coal has responded that mines do not typically present detailed geological information on conceptual mine designs in the planning and assessment phase of a project. GAPL concurs but notes that the Hume Coal mine layout is not typical of other mine designs and that its acceptance by the regulator and its safe and successful execution may be quite dependent on the presence, nature and density of geological structure and how this impacts on stability, especially in the workplace and locally, and on the safe disposal of water into old workings while the mine is still operational. In comparison to conventional bord and pillar mining, the proposed mining method is constrained in its flexibility to deal with geological structure other than by leaving coal unmined. The assessment of the EIS would be aided if it was supported by a geological plan and a mining plan showing the sequence of panel extraction and the sequence and timing of the filling of panels with coal reject and water.

Against the preceding background, the operation of the mining method in a confined underground setting needs to be supported by robust risk assessment. The likelihood of some of the more critical hazards materialising, the magnitude of the consequences should they materialise, controls for eliminating or mitigating them, and emergency responses and contingencies, all rely to some considerable extent on pre-empting if web pillars may yield, what form any yielding may take, and how conditions in a workplace maybe impacted by yielding. As advised in the December 2017 report of GAPL, numerical modelling is recommended to assist in addressing these issues.

The choice of LaModel as the modelling technique and of Dr Heasley to construct the models is supported. As in all numerical modelling, it is important before relying on the outputs to understand the construct of the model and its input parameters and to be satisfied that they are appropriate. Clarification is required, therefore, on the points that follow. This is not an unusual situation in numerical modelling. On this occasion, clarification is particularly important since the mining situation is complex to model; the assessment of the stability of web pillars is likely to be very sensitive to the selection of pillar strength formulations, constitutive laws and calibration factors; and the reliability of the outcomes is likely to be critical to the project assessment.

1. <u>Imbedded uncertainty in the Mark-Bieniawski formula</u>. The Mark-Bieniawski formula utilised in the numerical model to calculate pillar strength was derived from the Bieniawski pillar strength formula. A range of queries arise as to whether the uncertainty associated with the parent Bieniawski equation has been carried over into the Mark-Bieniawski equation and what additional degree of uncertainty may have been introduced in that process.

2. <u>Strength of a low width-to-height pillar based on the Mark-Bieniawski formula.</u> The strengths of web pillars predicted by the Mark-Bieniawski formula are 17% to 40 % greater than predicted by alternative mainstream strength formulae for pillars of such low width-to-height ratio. This feature generates further queries, including could this account for the finding that the web pillars will not fail and, therefore, is this finding

sound (especially when the unreliability embedded in the derivation of the strength formula is also taken in account).

3. Pillar constitutive law. By using an elastic-plastic constitutive law to define pillar response to load, the web pillars are prevented from unloading and so cannot fail. That is, the pillars cannot spall or yield and, instead, they continue to sustain peak load indefinitely.

The outcomes of the numerical modelling are unlikely to be seriously impacted by the above factors for the case where the model was run with all web pillars effectively removed. That model basically confirmed the expectations of the December 2017 report by GAPL, being that if the web pillars proved to be unstable, surface subsidence is still likely to be and manageable.

However, the factors can significantly affect the reliability of numerical modelling outcomes when applied to assessing workplace and local stability. Further consideration should be given to the appropriate pillar safety factor formula, pillar constitutive law and acceptable probability of instability associated with pillar factors of safety in order to properly assess the significance of the numerical modelling outputs to date and whether the input parameters and constitutive law need to be modified to better account for web pillar behaviour. If so, the numerical models will need to be rerun. GAPL has deferred assessing the outcomes of the numerical modelling in relation to web pillar behaviour until these matters are clarified.

Although GAPL requires clarification on a number of aspects of the recent numerical modelling, it remains of the opinion that in the absence of adverse geological conditions, surface subsidence is unlikely to seriously impact surface features. The extent of height of fracturing and its impacts on groundwater aquifers is difficult to quantify and definitive conclusions cannot be drawn by GAPL.

1.0 INTRODUCTION

In December 2017, Galvin and Associates Pty Ltd (GAPL) submitted a report under my authorship to the Department of Planning and Environment (DPE) on the Hume Coal Project in response to the following Scope of Works:

> ***Scope***
>
> *The Department requires to engage independent experts to give advice on aspects of the EIS.*
>
> *Mine Plan and Subsidence Risks*
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> - *to confirm that the levels of subsidence resulting from this method would be as predicted in the EIS;*
> - *about the underground safety aspects of using this method; and*
> - *about the risk of subsidence impacts and environmental consequences to natural and built features, including groundwater aquifers.*

Hume Coal issued a draft response, dated 26 February 2018, to the GAPL report as well as a draft response to a report prepared by Professor Ismet Canbulat who is also providing expert advice to the DPE on aspects of the Hume Coal Project. Emeritus Professor Ted Brown AO was commissioned by DPE to facilitate a meeting (the "experts meeting") held on 28 March 2018 between Hume Coal and its geotechnical consultant (Dr Russell Frith) and peer reviewer (Professor Bruce Hebblewhite), DPE, Professor Canbulat and Emeritus Professor Galvin (GAPL) to discuss key aspects of the reports prepared by the respective parties.

Subsequently, on 11 July 2018, Hume Coal produced a document entitled:

> *Response to reviews of the Hume Coal Project by Galvin and Associates, and Professor Ismet Canbulat.*

On 16 July 2018, DPE requested GAPL to prepare a supplementary report that clarifies whether Hume Coal's response of 11 July addresses issues raised in GAPL's December 2017 report and whether there are any residual issues which require further information from Hume Coal. This report has been prepared in response to that request. Given the complexity of some issues and the nature of work in progress, it is not possible to fully satisfy DPE's request. This supplementary report is focussed on:

- Providing a summary overview of the key issues
- Outcomes of the experts meeting
- Clarifying aspects of the numerical modelling undertaken to date; and
- Responding to residual issues arising of Hume Coal's response of 11 July 2018.

2.0 SUMMARY OVERVIEW

The Scope of Works for GAPL effectively requires consideration of regional, local and workplace mine stability in order to advise on levels and impacts of ground subsidence and underground safety aspects. Regional stability is generally concerned with overall mine stability; local stability with ground response and its consequences on a mining panel-by-panel basis; and workplace stability with ground stability and its consequences on a pillar-by-pillar and roadway-by-roadway basis.

The mining method involves delineating a series of, nominally, 60 m wide by 120 m long compartments. Roadways of 4 m width, referred to as 'drives' or 'plunges', are driven within each compartment by mean of a remote controlled continuous miner so as to form up a series of 120 m long strip pillars, referred to as 'web pillars' or 'panel pillars', which range in width from typically 3.5 m to 6.0 m. The concept relies on the overburden transferring some of its weight from the panel pillars to the perimeter pillars of each compartment, thus enabling the use of narrower and, therefore, weaker panel pillars than would otherwise be the case.

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A critical issue is the likely behaviour mode of the web pillars which, because they have a width of less than 1/10th depth or 10 m, whichever is greater, classifies them under current NSW legislation as 'non-conforming' and, therefore, their formation as a 'high risk activity'. High risk activities are required to be notified to the regulator in advance of being undertaken and may lead to intervention from the regulator. Both Hume Coal and GAPL have provided examples of mining layouts employed in NSW that involve non-conforming pillars but in all cases they were associated with pillar extraction operations and not bord and pillar first workings.

The stability of web pillars does not appear to be critical to controlling surface subsidence but could be for ensuring a safe place of work and may have implications for interference with groundwater aquifers. The mine layout is designed such that if the peak load carrying capacity of the web pillars were to be exceeded, surface subsidence would be restricted to low and manageable levels by the bridging action of the overburden across each panel. Hume Coal relies on the web pillars yielding in a gradual and controlled manner in these circumstances, rather than in a sudden, dynamic (violent) manner.

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Hume Coal has responded that mines do not typically present detailed geological information on conceptual mine designs in the planning and assessment phase of a project. GAPL concurs but notes that the Hume Coal mine layout is not typical of other mine designs and that its acceptance by the regulator and its safe and successful execution may be quite dependent on the presence, nature and density of geological structure and how this impacts on stability, especially in the workplace and locally, and on the safe disposal of water into old workings while the mine is still operational. In comparison to conventional bord and pillar mining, the proposed mining method is constrained in its flexibility to deal with geological structure other than by leaving coal unmined. The assessment of the EIS would be aided if it was supported by a geological plan and a mining plan showing the sequence of panel extraction and the sequence and timing of the filling of panels with coal reject and water.

Against the preceding background, the operation of the mining method in a confined underground setting needs to be supported by robust risk assessment. The likelihood of some of the more critical hazards materialising, the magnitude of the consequences should they materialise, controls for eliminating or mitigating them, and emergency responses and contingencies, all rely to some considerable extent on pre-empting if web pillars may yield, what form any yielding may take, and how conditions in a workplace maybe impacted by yielding. As advised in the December 2017 report of GAPL, numerical modelling is recommended to assist in addressing these issues.

3.0 OUTCOMES OF THE EXPERTS MEETING

DPE prepared a *Record of Meeting* for the expert meeting of 28 March 2018 and this was subsequently adopted by Professors Brown, Canbulat and Galvin. The Executive Summary of Hume Coal's response draws the reader's attention to its version of the Record of Meeting derived from the collective notes and recollections of its four representatives. GAPL has compared both records and annotated Hume Coal's record with GAPL's understanding of the proceedings. These are included as Attachments 1 and 2 to this supplementary report.

4.0 CORE ISSUE #1 - NUMERICAL MODELLING

Local and workplace stability require careful assessment. An important element of this assessment involves comparing the predicted strength of pillars with the load predicted to act on them, with the ratio between the two predictions being referred to as the *factor of safety* or *safety factor*. As discussed in the December 2017 review by GAPL, because of the relatively extreme ranges in pillar sizes and shapes associated with the proposed Hume Coal mining layout, it is very challenging to assess the actual load acting on the various coal pillars without the aid of sound sensible numerical modelling. Even then, an error range is still associated with numerical modelling predictions of pillar load.

Of particular concern is the potential for web pillars to exceed their peak load carrying capacity and yield to some extent. This presents added challenges in satisfying the statutory requirement for a Strata Failure Management Plan to consider *'the strata support requirements for the mine and the pillar strength and stability required to provide that support and the probability of instability of any pillar taking into account the pillar's role.'*[1]

The adaption of the highwall mining method to an underground setting changes the risk profile of the method. The risk associated with some hazards may be reduced or increased and a range of new hazards may be introduced. For example, from a regional stability perspective, the adaption of the surface mining system to an underground environment should benefit regional stability due to the overburden now being confined on all four sides rather than only on three sides. This can also offer benefits for local stability.

However, as apparent from the preceding discussion, the operation of the method in a confined space requires additional hazards to be risk assessed. The likelihood of some of the more critical hazards materialising, the magnitude of the consequences should they materialise, controls for eliminating or mitigating them, and emergency responses and contingencies, all rely to a considerable extent on pre-empting if web pillars may yield, what form any yielding may take (controlled or uncontrolled), and how conditions in a workplace may be impacted by yielding. This concern is yet to be fully resolved despite the numerical modelling undertaken to date.

Hume Coal engaged Dr Keith Heasley to undertake 2-D and 3-D numerical modelling of the mine design utilising the numerical modelling technique 'LaModel'. Dr Heasley's report (Heasley**,** 2018) is presented in Appendix 7 of the proponent's response. This modelling technique was developed in part by the late Professor Miklos Salamon for his PhD in submitted in 1962 (Salamon**,** 1962) and extended into a hybrid modelling technique by Dr Heasley for his PhD (Heasley**,** 1998) under Professor Salamon's co-supervision. Subsequently, Dr Heasley has made a number of significant extensions and refinements to LaModel. Based on the author's experience in working with Professor Salamon for over 3 decades and utilising both his original laminated model and LaModel, the model is considered to be fit-for-purpose for assessing pillar load distribution in the Hume Coal mining layout. GAPL has a high regard for Dr Heasley's specialist knowledge with this type of modelling.

As in all numerical modelling, it is important before relying on the outputs to understand the construct of the model and its input parameters and to be satisfied that they are appropriate. Dr Heasley reports that the numerical modelling study was split into five distinct stages. GAPL agrees with his approach. If its understanding is correct, Dr Heasley has calibrated LaModel to reproduce pillar strength as predicted by the Mark-Bieniawski pillar strength

[1] Schedule 1, Clause 1, Work Health and Safety (Mines) Regulation 2014 [NSW].

formula; attempted to calibrate the model against subsidence outcomes reported for Berrima Colliery but found that the resulting calibration factors are not sensible for the Hume Coal project and so applied heavily discounted values for the thickness of overburden laminations; assessed on the basis of pillar safety factors being greater than one (1) that web pillars will not fail; and used that outcome as the basis for describing pillar behaviour by an elastic-plastic constitutive law whereby once pillar elements reach their maximum load carrying capacity, they continue to sustain that load without failing while undergoing continuing compression.

On the basis of that understanding, clarification is required on the points that follow. This is not an unusual situation in numerical modelling. On this occasion, it is particularly important since the situation is complex to model; the assessment of the stability of web pillars is likely to be very sensitive to the selection of strength formulations, constitutive laws and calibration factors; and the reliability of the outcomes is likely to be critical to the project assessment.

1. Imbedded uncertainty in the Mark-Bieniawski formula. The Mark-Bieniawski formula (Mark & Bieniawski**,** 1987) utilised in the model to calculate pillar strength was derived from the Bieniawski pillar formula (Bieniawski**,** 1983) as described by Dr Heasley in the numerical modelling report. In a perfect world in which material properties and load and strength formulations are precisely known, a safety factor marginally greater than one (1) implies stability. However, in the real world, factors such as natural unknown variability in material properties, unknown and/or approximated material properties, and incomplete engineering knowledge bases mean that a degree of uncertainty is associated with pillar load and pillar strength values. Bieniawski accounted for the uncertainty associated with his pillar strength formula by recommending that the safety factors shown in Table 1 be applied when utilising it.

Table 1: Summary of safety factor recommendations of Bieniawski (1983, 1992) when using the Bieniawski formula.

Situation	Safety Factor
Bord and pillar first workings	1.5
Pillar extraction	2.0
Main development pillars	2.0
Barrier pillars	2.5
Tailgate chain pillars	1.3
Pillars in bleeder roadways	1.5 to 2.0

Query 1. Is the uncertainty inherent in the foundation Bieniawski equation embedded in the Mark-Bieniawski equation?

Query 2. If not, should it be carried over?

Query 2. What level of (additional) uncertainty in the Mark-Bieniawski pillar strength equation arises from the assumptions and approximations associated with its derivation?

Query 3. As a result of queries (1) to (3), what factor of safety value should be used when assessing the stability of the web pillars on the basis of the numerical modelling outcomes?

2. Strength of a low width-to-height pillar based on the Mark-Bieniawski formula. The Mark-Bieniawski formula is characterised by not being premised on a minimum pillar width-to-height ratio at which the beneficial effects of being confined in its long dimension begin to influence pillar strength. That is, the formula predicts an increase in the strength of a rectangular pillar no matter how slender or narrow the pillar. In practice, when pillars are narrow relative to their height, failure progresses from the longitudinal sides of the pillar through to the pillar core well before benefits are realised from the extra confinement due to the rectangular shape of the pillar. Based on practical mining experience, Salamon et al (1996) adjudged that rectangular shaped pillars do not start to experience an increase in strength due to their shape until their width-to-height ratio approaches three (3) and that the full benefit is not realised until width to height ratio reaches six (6).

   Table 2 shows a comparison between the strengths of 120 m long, 3.5 m wide and 5.5 m wide web pillars as predicted by the Mark-Bieniawski formula and by four other mainstream pillar strength formula that have had likelihoods of success assigned to their outcomes. The Mark-Bieniawski formula predicts strength increases that are 17% to 40 % higher than alternative mainstream formulae.

   Query 4. Could the reason for the numerical modelling predicting that the safety factor of the web pillars is greater than 1 be due to the higher pillar strength predicted by the Mark-Bieniawski pillar strength formula?

   Query 5. Is the reasoning correct that the safety factors produced by the numerical modelling to date need to exceed a value of 1.5*1.17 = 1.76 for 3.5 m wide web pillars, to 1.5*1.22= 1.83 for a 5.5 m wide web pillars in order to satisfy Bieniawski's safety factor recommendations for bord and pillar workings?

   Query 6. How are the analysis outcomes and their interpretation impacted if pillar strength is defined by the UNSW power (rectangular) formula and the minimum acceptable safety factor for pillar stability is set at 1.55 (corresponding to a minimum probability of stability of 1 in 1000, which is a common standard in NSW)?

Table 2: Comparison between strengths of a 3.5 m wide and a 5.5 m wide, 3.5 m high, 120 m long web pillars as predicted by mainstream pillar strength formulae.

	Web Pillar Width = 3.5 m		**Web Pillar Width = 5.5 m**	
Pillar Strength Formula	**Strength (MPa)**	**% Increase in Strength Associated with using Mark-Bieniawski Strength Equation**	**Strength (MPa)**	**% Increase in Strength Associated with using Mark-Bieniawski Strength Equation**
Mark & Bieniawski, 1987	7.28	-	9.15	-
UNSW Power Salamon et al., 1996	5.69	28 %	7.16	28 %
UNSW Linear Salamon et al., 1996	5.12	42 %	6.42	43 %
Bieniawski, 1983	6.20	17 %	7.5	22%
Salamon & Munro, 1967	5.60	30 %	6.9	33 %

3. Pillar constitutive law. By using an elastic-plastic constitutive law to define pillar response to load, the pillars are prevented from unloading and so cannot fail. That is, the pillars cannot spall or yield and, instead, continue to sustain peak load indefinitely.

   Query 5. How realistic is it to use an elastic-plastic constitutive law if pillar strength is based on other mainstream pillar strength formulae and design takes into account that failure can occur at safety factors less than or greater than 1. For example, if the modelling was re-run based on pillar strength defined by the UNSW power strength formula and a minimum acceptable probability of failure of 1 in 1000 (which corresponds to a safety factor of around 1.55 if the UNSW power pillar strength formula is invoked), would it still be appropriate to utilise an elastic, perfectly plastic constitutive law and, if so, why?

4. Calibration. Based on Dr Heasley's extensive experience and expertise in using LaModel, does he have a feel for how well the assumed lamination thicknesses and moduli values may represent the overburden stiffness in the shallow western area of the mining lease where weathering is reported to extend to within 5 to 10 m of the Wongawilli Seam roof?

The outcomes of the numerical modelling are unlikely to be seriously impacted by the above factors for the case where the model was run with all web pillars effectively removed. That model basically confirmed the expectations of the December 2017 report by GAPL, being that if the web pillars proved to be unstable, surface subsidence is still likely to be at the lower end of the range and manageable.

However, the factors can significantly affect the reliability of numerical modelling outcomes when applied to assessing workplace and local stability. Further consideration should be given to the appropriate pillar safety factor formula, pillar constitutive law and acceptable probability of instability associated with pillar factors of safety in order to properly assess the significance of the numerical modelling outputs to date and whether the input parameters and constitutive law need to be modified to better account for web pillar behaviour. If so, the numerical models will need to be rerun. GAPL has deferred assessing the outcomes of the numerical modelling in relation to web pillar behaviour until these matters are clarified.

5.0 CORE ISSUE #2 – THE PILLAR SYSTEM

A number of the points raised in this section by Hume Coal were discussed at the experts meeting and captured in the Record of Meeting (Attachment 1). Noteworthy residual matters are:

1. Re:

   'The experts generally agreed that the stability of the system as a whole is the key consideration as to whether the proposed layout designs are fit for purpose or not, not the strength and stability of individual pillars.'

   GAPL concurs. However, the strength and stability of individual pillars are also very important considerations for managing safety in the workplace and as a matter of due diligence, the potential for web pillars to yield, the extent to which they may yield and the location in the mining cycle where they are more prone to yield still need to be assessed.

   The mining cycle includes all activities after the formation of web pillars, such as supporting drives, conducting stowage operations backbye and filling the panels with water. Local pillar yielding need not of itself present an unacceptable risk to safety. However, the secondary consequences of yielding could if not anticipated and sufficiently understood to enable the associated risks to be managed effectively.

2. Re:

   'Focussing on the factor of safety of an individual pillar is only applicable in the case of a regular array of pillars under full-tributary area loading, where it can be demonstrated that the overburden has the potential to become sufficiently softened to drive the pillars to a state of complete collapse which is defined by exceeding a level of compressive strain'[2]

   Caution is advised. The statement is referring to an uncontrolled mode of pillar failure associated with a deadweight loading system where the full load continues to act on a pillar as it yields and fail. However, pillars can also exceed their peak load carrying capacity (or fail) and still yield and unload in a controlled and non-violent manner. Full tributary area loading is not required to cause failure of an individual pillar or a system of pillars. Any pillar can fail once the load acting on it, be it full tributary load or a fraction of full tributary load, exceeds the strength of the pillar. In the case of Hume Coal, the crux of the matter is to predict if the strength of any individual pillars will be exceeded and if so, how will they behave in yield. This is similar to assessing pillar behaviour on a goaf line in a pillar extraction panel or chain pillar behaviour in a longwall panel. As in both partial and full pillar extraction operations where low width-to-height pillars are formed at the working face, it is important to understand if and how individual pillars may fail in order to identify associated hazards and how they may be controlled. In the case of Hume Coal, this has added importance because persons are still required to access backbye areas adjacent to web pillars and to enter drives flanked by web pillars.

[2] Hume Coal response of 11 July 2018, page 23.

Re:

> *'The ability of the overburden to span across a panel is a function of both geometry, and to a lesser extent in terms of confidence levels, geology'*

Caution is advised. Geology has a major influence on the stiffness of the overburden and, therefore, on confidence levels in the mine design since it determines the thickness of strata units, t', (laminations) and their mechanical properties such as modulus, E, and Poisson's Ratio, ν. This is reflected in t', E and ν being the critical input parameters to LaModel. On the other hand, the same geometry (excavation width, W, and mining depth, H) can be associated with a wide range of overburden stiffnesses, depending on geology. These principles are reflected in Figure 1 and Figure 2 by the wide range in vertical surface displacement that can be associated with a given W/H value and by the subsidence behaviour reported for Berrima Colliery.

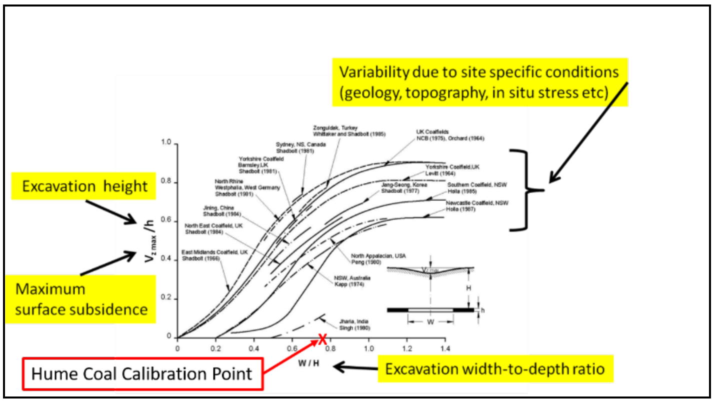

Figure 1: Illustration of the extreme nature of the numerical model calibration point by reference to international subsidence behaviour (adapted from Galvin**,** 2016)

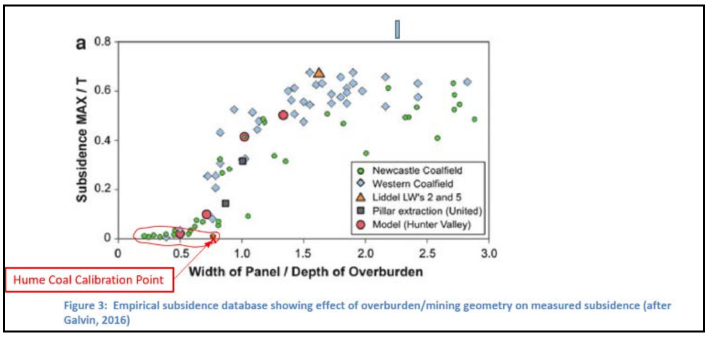

Figure 2: Illustration of extreme nature of the numerical model calibration point by reference to subsidence outcomes in NSW coalfields (adapted from Hume Coal response of 11 July 2018 which incorrectly attributes the base diagram to Galvin, 2016).

6.0 CORE ISSUE #3 – THE ROLE OF WEB PILLARS

The *Issue Synopsis* relates this topic to regional stability. As already noted, the main need from GAPL's perspective for evaluating web pillar behaviour relates to health and safety in the mine. The December 2017 report of GAPL dealt with the issue of regional stability as reflected in the *Overall Conclusions* of that report[3].

Many of the points raised in this section were discussed at the experts meeting and captured in the Record of Meeting (Attachment 1). GAPL has no further advice to offer but the following residual matters are noted for the record.

1. Re:

   As discussed earlier, it is inappropriate to calculate probabilities of failure for individual web pillars in the pillar/overburden system as has been done by Galvin and Associates for the following reasons:

   1. The assumption of full-tributary loading is incorrect; and

   2. ……….[4]

   The calculation of probabilities of failure does not depend on full tributary area load. Probability of failure has been determined by statistical analysis of the safety factors of both failed and unfailed cases, where safety factor was defined as the ratio of pillar strength to pillar working load. A probability of failure can be calculated for any loading situation – the load need not be tributary area load. As explained in GAPL's December 2017 report and presented in detail in **Galvin (2016)**, only tributary area loading cases were used to initially derive the probabilities of failure because they provided the highest degree of confidence that the pillar loading component of the safety factor was reasonably accurate. Once having derived the relationship between probability of failure and the ratio of pillar strength to pillar load, any load can be used in the analysis to produce a safety factor that can then equated to a probability of failure. The calculation of these loads is a primary objective of the numerical modelling as recommended by Professor Hebblewhite, Canbulat and GAPL. Numerical modelling is required because the mine layout does not satisfy the criteria required to apply tributary area load theory.

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[3] *In theory, a mining system that is based on exploiting the spanning capacity of strong overburden to shield narrow and very low width to height ratio pillars from load while still restricting surface subsidence and disturbance to the groundwater system is plausible.*

In practice, the safety of such a mining system and its success are highly dependent on geological conditions, the capability to maintain very tight control over mining dimensions, the reasonably accurate prediction of pillar loads and pillar strengths, and a high level of confidence in how pillars will behave if their peak load carrying capacity is exceeded.

The EIS does not address all of these issues in sufficient detail to enable a full and proper assessment of the safety of the proposed mine design for the Hume Coal Project. Suffice to state that the stability of narrow and very low width-to-height ratio pillars is very sensitive to deviations from planned mining dimensions and to geological conditions. If the pillar system proved to be unstable, surface subsidence is still likely to be at the lower end of the range and manageable.

[4] Hume Coal response of 11 July 2018, page 27.

2. Re:

Another key reasons why this analysis is inappropriate is that typical levels of rib spall and roof falls are already taken into account in the UNSW pillar database to some degree…[5]

It is correct that a level of rib spall and roof falls is likely to be associated with at least some of the case studies in the UNSW database. The number and extent is unknown. The integrity of some of the pillars in the UNSW database may also have been adversely affected to an unknown extent as a result of having been formed by blasting. These types of variations and unknowns are reflected in correlations between safety factor and probability of instability. For example, even if a pillar is designed to be 30% stronger than the load predicted to act on it, there is still a 5% chance that the pillar will fail if designed in accordance with the Salamon and Munro pillar strength formula, a 10% change of failure if designed using the UNSW linear pillar strength formula and a 4.5% chance if designed using the UNSW power strength formula.

What is known and easily demonstrated mathematically and in practice is that shallow roof falls and small amounts of rib spall have an increasing detrimental effect on the stability of coal pillars as their width-to-height ratio decreases. Knowing this, prudent risk management may decide to err on the side of caution and design to the changed mining dimensions, rather than assuming that the dimensional changes were adequately taken into account in the original pillar design database.

In the case of the Hume Coal project, there is an additional factor that needs careful consideration and that is the effect of off line drivage (that is, drivage orientated in the wrong direction). Again, this is a factor that is likely to be already incorporated to some extent in the correlation of safety factor with the probability of failure. Offline drivage is not uncommon in bord and pillar mining. It can be due to factors such as difficulty in breaking away a roadway (or drive) on a cross grade because the continuous miner wants to slide downgrade, especially if the floor is wet or greasy), deficient operator skill and survey error.

In its response of 11 July, Hume Coal provided details of field trails that demonstrated that one guidance system was capable of achieving an accuracy of 0.03 m deviation over the proposed 120 plunge.[6] This is encouraging but it does not address the potential for the direction of the plunge to be off line to start with.

In conventional bord and pillar operations, offline drivage errors usually become apparent and are corrected after forming each one or two rows of pillars. However, it was not uncommon in the days of Wongawilli pillar extraction, with which the Hume Coal layout has similarities as noted in the EIS, for ground control problems to be experienced in long run-outs (+90 m) due to them being driven off centre adjacent to the goaf.

In the case of the Hume Colliery layout, an uncorrected offline drivage of only 1^{o} would be sufficient to result in a 1 m change in pillar width after 60 m of driveage. As noted by Hume Coal, the reduction in the width of a web pillar on one side of a drive would

[5] Hume Coal response of 11 July 2018, page 27.
[6] Hume Coal response of 11 July 2018, page 28.

be compensated for to some extent by the associated increase in width of the pillar on the other side of the drive. The numerical modelling outcomes should assist in assessing the consequences of any offline drivage.

3. Re:

Mine Advice as well as peer reviewers from Hume Coal (Hebblewhite 2016) and DP&E (Galvin and Associates, 2017; and Canbulat, 2017) have all recognised the potential impact of geological structures on web pillar strength…..[7]

Hume Coal has proposed a range of response measures for managing this hazard. Until experience is gained with them, it is difficult to form a view as to how effective some of these controls may prove to be.

4. Re the empirical evidence from the neighbouring Berrima Colliery. Hume Coal has regard to graphical surface subsidence data sourced from the 2012 and 2013 Annual Environmental Monitoring Reports for Berrima Colliery to support its position that:

'……..the proposed areas of web pillars between barriers will be substantially subcritical, and that the overburden possesses considerable spanning potential at similar panel width-to-depth ratios to the highest proposed at Hume.'[8]

Dr Heasley's also had regard to this data in an endeavour to calibrate the numerical model. It is based on 120 wide pillar extraction panels extracted to a height of 2.3 m at a depth of 160 m to result in 85% extraction and less than 10 mm subsidence. Hume Coal states that:

'Importantly, the panels at Berrima contain no substantial remnant pillars…..'[9]

Based on the author's experience in subsidence engineering, this subsidence outcomes is an extreme case if the pillars were fully extracted. The attempt to calibrate the numerical model to this data set also suggests that this is the case. It produced a back-calculated lamination thickness of 155 m with a rock modulus of 22.3 GPa, which is extreme and outside the author's 35 year experience base with Salamon's laminated model. The overburden thickness ended up being significantly de-rated in the numerical model runs from the back-analysed properties, with the modelled overburden stiffness ranging down to about 1/20th of the back-analysed stiffness and with the highest modelled stiffness being about 1/3rd of the back-analysed stiffness.[10]

The extreme nature of the negligible subsidence is illustrated by reference to Figure 1 and Figure 2 (Figure 2 is incorrectly attributed to Galvin). As another point of reference, GAPL calculated predicted surface subsidence using the methodology and material values presented in the Hume Coal EIS. This approach predicts a surface subsidence of about 130 mm for the given dimensions.

[7] Hume Coal response of 11 July 2018, page 30.
[8] ibid
[9] ibid
[10] Hume Coal response of 11 July 2018, page 9.

The author visited pillar extraction workings at Berrima Colliery a number of times when the mine was operating, including as a member of the Chief Inspector's Pillar Extraction Committee. Based on these visits and the author's practical experience in conducting pillar extraction operations and having statutory oversight of them, it is considered unwise to apply the Berrima Colliery case study to the Hume Coal Project without, firstly, more robustly validating the data and, secondly, should the data prove to be reliable, carefully assessing if the associated mining circumstances apply to the Hume Coal project.

5. Re:

   'Any assertion that the Hume Coal Mine design is predicated on exploiting massive strata in the overburden is incorrect'[11]

If this is the case, Hume Coal may need to revise the *Mine Design Justification Report* presented in the EIS to avoid others forming the same conclusion as GAPL. For example:

'This section of the report has explained the various technical consideration relating to both coal pillars (FoS and w/h ratio) and layout geometry (W/H and the presence of thick massive strata units within the overburden) that have been applied to the design of mine layouts at Hume as will now be described in detail'[12]

6. Re:

'The assertion that the Hume Coal proposal "strives to prevent 'any' roof falls" (our emphasis) is a mischaracterisation of the EIS, and is not stated in the document.'

The term 'any' is superfluous and can be removed.

[11] Hume Coal response of 11 July 2018, page 32
[12] Mine Design Justification Report, Hume Project. Mine Advice Report: Hume 13/2. p11. Pdf page 658 of Appendix L of EIS

7.0 CORE ISSUE #4 – THE ROLE OF OPERATIONAL MANAGEMENT PLANS

Residual matters are:

1. The *Issue Synopsis* states that;

   'A large number of the issues raised in the Galvin and Associates review are issues that would typically be dealt with via the use of hazard management plans and other risk management systems at the mine site, rather than attempting to provide a solution for every potential operational eventuality at the development stage'[13]

   GAPL agrees. The difficulty in this case is that the mining method has not been applied in an underground mining environment before and it is yet to be established or confirmed how some issues can be dealt with. In the case of conventional mining systems, there is an existing experience base which gives confidence that, in most cases, deviations from planned outcomes can be addressed during mining operations through tools such as changes in mining sequences and operational management plans. Therefore, the actual mining method may not come in for close scrutiny during initial project assessment but rather the focus in on the impacts that the method gives rise to and their associated consequences. The DPE advised all parties at the expert's meeting on 28 March 2018 that it will be also be referring the project to the Resources Regulator for its assessment. This may clarify the situation and help prioritise safety related matters that need careful consideration in the current stage of the planning process.

2. The synopsis notes that:

   'Indeed, occupational health and safety laws require workforce participation in the development of such operational plans and their underlying risk assessments, so it is actually highly inappropriate to develop them prior to the operational workforce being employed.'[14]

   This also cannot be disputed. However, because the method has not been utilised underground before and the workforce will be unfamiliar and/or inexperienced in some aspects of it, there is a need for the risks to be first considered at the concept stage before possibly exposing the workforce to them.

   Hume Coal has advised that it has previously undertaken risk assessment workshops for both the mining concept and the use of bulkheads to contain water in mine panels.

3. Re:

   'Mines do not typically present detailed geological information on conceptual mine designs in the planning and assessment phase of a project'[15]

   GAPL concurs but notes that the Hume Coal mine layout is not typical of other mine designs and that its acceptance by the regulator and its safe and successful execution may be quite dependent on the presence, nature and density of geological structure and how this impacts on stability, especially in the workplace and locally, and on the safe disposal of water into old workings while the mine is still operational. In these types of

[13] Hume Coal response of 11 July 2018, page 35
[14] ibid
[15] Hume Coal response of 11 July 2018, page 36

circumstances, geological information may need to be considered during the planning and assessment phase of a project. The assessment of the EIS would be aided if it was supported by a geological plan.

4. Re:

'It is therefore disingenuous that the Hume Coal project represents a uniquely higher risk or unmanageable mining proposal'[16]

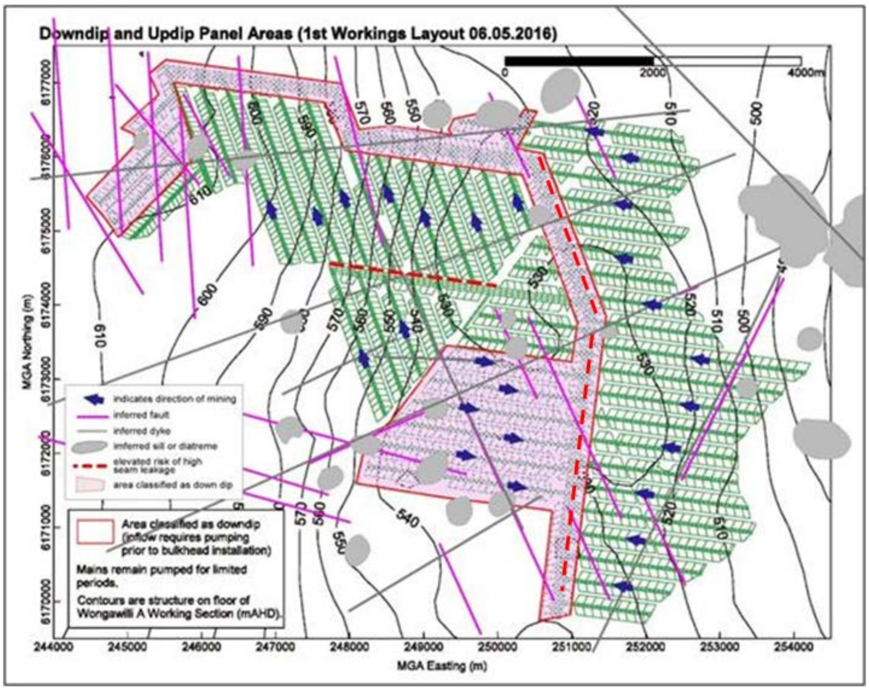
The GAPL report of December 2017 does not state or intend to imply that the Hume Coal project represents a uniquely higher risk or unmanageable mining proposal. It does identify a number of hazards that are not typical in underground mining and, therefore, need careful consideration at the conceptual stage to provide confidence to DPE that the hazards can be effectively managed and, importantly, that contingencies are available if the mining system does not perform as planned.

[16] Hume Coal response of 11 July 2018, page 39

8.0 CORE ISSUE #5 – IMPOUNDED WATER

1. There are two subtle but significant aspects of what is being proposed by Hume Coal that may not have come through clear enough in the first review by GAPL. They are that firstly, water is being deliberately put into the mine from the surface, rather than accumulating naturally in the mine, and secondly, it is planned to store the introduced water in all sections of the mine whereas typically water is impounded in only certain areas of a mine. These two characteristics can be expected to increase the risk profile associated with water at the mine. This is not to say that the risk cannot be effectively managed by the measures proposed in Hume Coal's response of 11 July.

2. Re: The following figure, which is Figure 13 in the December 2017 report of GAPL



GAPL agree that this figure and reference to it should be withdrawn in light of the confusion around its original form, the manner in which it has been annotated and clarification since provided by Hume Coal. The assessment of the EIS would be aided if it was supported by a mine plan showing the sequence of panel extraction and the sequence and timing of the filling of panels with coal reject and water.

9.0 CONCLUSIONS

Notwithstanding the lack of numerical modelling to give insight into the distribution of load between the various pillars in the Hume Coal mining layout, GAPL concluded in its December 2017 review that even if the web pillars proved to be unstable, surface subsidence was still likely to be at the lower end of the range and manageable. Although GAPL requires clarification on a number of aspects of the recent numerical modelling, it remains of the opinion that in the absence of adverse geological conditions, surface subsidence is unlikely to seriously impact on surface features. The extent of height of fracturing and its impacts on groundwater aquifers is difficult to quantify and definitive conclusions cannot be drawn by GAPL.

10.0 APPENDIX 1 – NON-CORE ISSUES

10.1. DESIGN APPROACH

1. Re:

‘However, the criticism of Galvin and Associates whereby they state that "it needs to be appreciated that the factors of safety derived from the two different design procedures (ARMPS-HWM and UNSW PDP) cannot be equated.[17]

This is simply a statement of fact intended to avoid persons who are not geotechnical specialist drawing incorrect comparisons and conclusions (as has happened on many occasions).

2. Re:

‘The only other criticism made of ARMPS-HWM made by Galvin and Associates relates to its genesis being in the United States – or it is assumed that this is a criticism given the context around which the statement was made in the report.

Again, this was not intended as a criticism. It is simply stating a fact.

3. Re:

‘The fact that UNSW eventually decided to adopt coal pillar strength equations founded in the work of Salamon rather than Bieniawski……..’

This is incorrect. UNSW produced two pillar strength equations and quantified the probability of success associated with each (Salamon et al**.,** 1996). The UNSW linear version of the strength formula was founded on the 1897 formulation that Bieniawski also founded his formula on, and the UNSW power version of the formula was founded on a 1929 formulation that formed the foundation of the Salamon and Munro's formula. Either can be used but the authors recommended the power strength version because a higher probability of success is associated with it (it is more reliable).

4. Re:

‘It is assessed on that the decision on the part of Galvin and Associates to disregard the proponents use of ARMPS-HWM in its EIS submission is unfounded, at least on the reasons provided by Galvin and Associates...........

The proponent fundamentally disagrees with Galvin and Associates on this material issues, as has been explained using the level of technical detail that Galvin and Associates should have provide in rejecting the use of ARMPS-HWM in the first instance.’[18]

GAPL did not reject the use of ARMPS-HWS. The scope of works provided to GAPL did not require it to review ARMPS-HWS. GAPL's review was very much guided by the weight given to ARMPS-HWS in the EIS, as reflected for example in the following extracts from the Mine Design Justification Report that comprises an element of the EIS:

[17] Hume Coal response of 11 July 2018, page 69
[18] Hume Coal response of 11 July 2018, page 71

'Applying the various design rules within the ARMPS-HWM process to the design of web pillars and intra-panel barriers resulted in preliminary mine layouts……

The basis and justification for the application of the ARMPS-HWM pillar design methodology to the two critical coal pillars (web and intra-panel barrier) within the proposed mining layout at the Hume Project are contained within ***Mine Advice (2014).***

To complete the mine layout to a standard that can be considered as part of a mining application in NSW whereby retaining long-term stability if the global remnant pillar system and overburden is a critical design requirement, the proposed mining layout(s) have been evaluated using the following:

(a) A coal pillar analysis in an underground mine setting rather than a surface HWM setting using the UNSW Pillar Design Procedure or UNSW PDP (Galvin et al 1998)

(b) .'[19]

and

'The design process was (a) an initial assessment using ARMPS-HWM [a USA methodology] which is specifically targeted at highwall mining (HWM) whereby similar low w/h ratio pillars are commonly formed up from highwall exposures followed by (b) a review of the ARMPS-HWS design outcomes using the UNSW PDP including limitations being placed on panel widths between barriers to ensure sub-critical overburden behaviour above low w/h pillars.'[20]

These extracts refer to ARMPS-HWS being used to develop *'preliminary mine layouts'* and to undertake *'an initial assessment'*. The report that is described as providing the basis and justification for the application of the ARMPS-HWM pillar design methodology is not included as part of the EIS. The EIS relies on a review of ARMPS-HWM design outcomes using the UNSW PDP, with the UNSW PDP methodology being utilised *'To complete the mine layout to a standard that can be considered as part of a mining application in NSW'*. Against this background, GAPL did not identify a need to review ARMPS-HWM in order to fulfil its scope of works.

10.2. NSW LEGISLATION

Hume Coal's response of 11 July 2018 states that:

(a) Galvin and Associates states that "minimum pillar widths" (or words to this effect) are "embedded", "advised" or "specified" in NSW legislation. Hume Coal understands that the current NSW legislations provides for two categorisations of pillars sizing – "conforming" and "non-conforming", with "non-conforming" pillars requiring a 7-day waiting period following a formal notification to the regulator. Hume Coal is not aware of any specified "minimum pillar width".

(b) Galvin and Associates states that Hume Coal will require an "exemption' or an "approval" from the regulator in order to form up pillars of dimensions less that the set "minimal pillar widths". Hume Coal is not aware of the legislative

[19] Appendix L, Mine Advice Report No: Hume13/2, pages12 and 13
[20] Appendix L, Mine Advice Report No: Hume13/2, page 31

mechanism for any formal "exemption" for forming up "non-conforming" pillars. DRE has verbally confirmed to Hume Coal that they do not issue approvals for HRA notifications, once the notification period has elapsed, which is consistent with our experience. It would be helpful if Galvin and Associates could specify the clause from which an exemption is required, and the process outlines in legislation for obtaining such an exemption.

(c) Galvin and Associates states that the reviewer is "unaware of any exemptions being granted to employ smaller pillars widths on a routine basis" (or words to that effect,…), however the mine design presented at Figure 6(a) on page 15 of the reviewer's report shows plans for an operating mine near Lithgow that contains entire panels where "non-conforming" remnant pillars are formed at 16.5m width….Hume Coal can provide other examples.

Hume Coal is correct in that since the Work Health and Safety (Mines) Regulation 2014 [NSW] was enacted, minimum pillar width is no longer prescribed and applications do not need to be made for an exemption from complying with the prescribed dimension (being a minimum width of 10m or 1/10th depth, which ever is the greater). Instead, legislation now defines a so-called *conforming pillar* as a pillar, the shortest horizontal dimension of which is no less than 1/10th depth or 10 m and states that the formation of a pillar other than a conforming pillar is identified as a high risk activity that cannot be conducted for seven days after the mine operator has given notice of the activity to the regulator. While, as stated by Hume Coal, the regulator does not issue approvals for high risk activity notifications, the regulator has the power to issue a prohibition notice for any activity that may occur or is occurring that involves a risk to the health or safety of a person. Hence, effectively, the regulator still has the power to prevent the formation of a pillar that has a minimum dimension of less than 1/10th depth or 10 m, whichever is greater, if the regulator considers that it presents a serious risk to health or safety of a person.

The figures in the GAPL report show a number of NSW mining layouts that involve pillars with a minimum width of less than 1/10th depth or 10 m. Hume Coal has also provided a number of examples. In all cases, however, these pillars are associated with pillar extraction operations and not bord and pillar operations and, therefore, were required to be approved under a different section of legislation that required approval to be sought to conduct pillar extraction and longwall mining. That mechanism is still effectively present in that these mining methods are now also classified as high risk activities in the Work Health and Safety (Mines) Regulation 2014 [NSW] and require the regulator to be given 3 months' notice of their intended application.

10.3. COMMENTS REGARDING ESTERHUIZEN 2010

Hume Coal comments have merit and the associated figure and commentary should be withdrawn from the December 2017 report of GAPL.

10.4. GAS

It is stated by Hume Coal that GAPL makes the point that *"the EIS does not provide information as to the likely gas composition and gas content"* of the atmosphere in the run-outs. The GAPL report does not state this but rather *"the EIS does not provide information as to the likely gas composition and gas content of the goaves and the manner in which mining operations are to be ventilated to safely control goaf gases"*. In replacing GAPL's term 'goaves' with the term 'run-outs', Hume Coal has added a footnote that its disagrees with the definition of "goaf" provided in the GAPL report.

Nothing particularly turns on the terminology. The fact is that the mining method is based on forming multiple blind or dead-end drives up to 120 m length that will be left in an unventilated state for a period of time.

Hume Coal also states that it believes the statement by GAPL to be untrue. Hume Coal appears to misunderstand GAPL's concern, which relates to the potential for noxious, irrespirable or flammable gases to accumulate in the drives while they are in an unventilated state, giving rise to the possibility that this atmosphere could be pushed out as a plug into the workplace in the event of pillar and/or roof instability. The EIS does contain information as to the gas composition and content of the coal seam and the concentration of seam gas when it is in a ventilation stream. But, it does not appear to discuss the potential atmosphere of unventilated drives. It is still possible for blackdamp (oxygen deficient atmosphere) to build up in unventilated drives in coal seams that have very low methane and carbon dioxide content.

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ATTACHMENTS

Attachment 1

DPE's Record of Meeting of 28 March 2018

NSW GOVERNMENT | Planning & Environment

Hume Coal Project – Expert Meeting 28 March 2018

Record of Meeting

Attendees:

Independent Chair	Emeritus Professor Ted Brown
Experts engaged by the Department	Emeritus Professor Jim Galvin Professor Ismet Canbulat
Experts engaged by Hume Coal	Dr Russell Frith Professor Bruce Hebblewhite
Department representatives	Mr Clay Preshaw – Director Resource and Energy Assessments Mr Paul Freeman – Team Leader Resource and Energy Assessments
Hume Coal representatives	Mr Greig Duncan – Project Director Mr Alex Pauza – Manager Mine Planning

Introduction – Independent Chair

- The meeting is being independently facilitated.
- It is an open discussion of technical matters.
- The participants were asked to be respectful and to keep to the point.

General comments about the proposal – Dr Russell Frith

- The project has evolved from being a longwall mine to an underground highwall mine.
- The 'pine feather' method is designed as a non-caving low-impact mining method.
- The design is assessable and the method has been successfully used in the United States.

Discussion – Independent Chair, Department Experts and Hume Coal Experts

Pillar stability

- The proposed web pillars and barrier pillars have been conservatively designed to increase overburden load distribution.

- Localised yielding of a web pillar would not necessarily lead to global instability.
- The experts generally agree that the stability of the system as a whole is the key factor, not the strength of individual pillars.

Groundwater modelling presentation – Mr Alex Pauza

- The groundwater model in the EIS is based on a 2D design and presents the worst-case scenario.
- The company has since undertaken a 3D modelling exercise to provide a higher level of confidence in the predictions.
- The 3D model has been calibrated to Berrima Colliery data and then de-rated.
- The 3D model will be included in the Response to Submissions (RTS) and generally is likely to show increased pillar stability and greater overburden load distribution.
- Based on Mr Pauza's presentation, the experts generally agree that the company's approach to 3D numerical modelling is appropriate and will assist the Department in its assessment process.

Subsidence

- The experts generally agree that subsidence is likely to be negligible-minor and is not the key assessment issue.
- Even if all web pillars are removed, the 3D model is likely to predict that the change in subsidence would be very minor.

Other safety issues

- Barrier pillars are wide, and any 'offline cutting' is unlikely to significantly affect stability.
- Unventilated workings may affect underground safety in the event that machinery fails and is required to be recovered.
- The experts generally agree that the proposed mining method is flexible and could be modified throughout operations, however further consideration of safety issues is required following the submission of the RTS.

Closing comments – Clay Preshaw

- The mine design and safety of the underground workings remain as important issues for the Department.
- The RTS will be provided to the Department's experts for further advice before the assessment is finalised.
- The Department will also provide the RTS to the Resource Regulator and seek feedback.
- A further meeting with the various experts and/or the Resource Regulator may be necessary before the Department finalises its assessment.

Attachment 2

Hume Coal's Record of Meeting of 28 March 2018 with Professor Galvin's Annotations

Hume Coal Project – Expert Meeting 28 March 2018

Record of Meeting

Attendees:

Independent Chair	Emeritus Professor Ted Brown
Experts engaged by the Department	Emeritus Professor Jim Galvin Professor Ismet Canbulat
Experts engaged by Hume Coal	Dr Russell Frith Professor Bruce Hebblewhite
Department representatives	Mr Clay Preshaw – Director Resource and Energy Assessments Mr Paul Freeman – Team Leader Resource and Energy Assessments
Hume Coal representatives	Mr Greig Duncan – Project Director Mr Alex Pauza – Manager Mine Planning

<u>Introduction – Independent Chair</u>

- The meeting is being independently facilitated.
- It is an open discussion of technical matters.
- The participants were asked to be respectful and to keep to the point.

<u>General comments about the proposal – Dr Russell Frith</u>

- The project has evolved from considering mining methods like longwall mining to low impact non-caving methods. The selected method has similarities in pillar layout and dimensions to highwall mining. **Agree**
- The 'pine feather' method is designed as a non-caving low-impact mining method, and the EIS pillar design methodology (ARMPS-HWM) was adopted from highwall mining due to the similarities in layout geometry. **Agree**
- The HWM design method is empirical, and the method has been successfully used in the United States, being based on case histories of over 3000 individual highwall mining plunges. A statistical analysis of failures to develop a probability of failure is unable to be undertaken because the failure rate is so low. **Agree that this is what was presented to the meeting (but not with the statement without the benefit of clarification. The minimum criteria that is generally adopted in Australia and**

South Africa for panels of pillars that are required to be stable in the medium to long term is a probability of failure of 14 in 10,000 (corresponding to a UNSW Power Probability of Stability of 1.6) where a panel can comprise many hundreds of individual pillars. 3000 individual pillars in highwall mining is likely to comprised between 400 to 600 panels of pillars. Hence, it would only take one panel to fail to exceed a probability of failure of 14 in 10,000. Time to failure is also a factor that needs to be considered. The statement attributed to Mark (2006) in Appendix L of the EIS is qualified viz 'He concluded that despite the fact that there were stable and unstable outcomes, the method *"does provide a reasonable first approximation of minimum suggested pillar widths"*).

- The method has been conservatively applied to Hume, with the drive length being limited to 120m, and the distance between barrier pillars limited to 60m. This provides for subcritical geometry between barriers and means that the interpanel barrier pillars and the chain pillars come into play in the design and provide additional stabilising influence, particularly at higher cover depth. **Agree**
- Emeritus Professor Brown remarked that Dr Frith's summary directly dealt with a number of his key points for discussion. **Agree**

<u>Discussion – Independent Chair, Department Experts and Hume Coal Experts</u>

Pillar stability

- The proposed web pillars and barrier pillars have been conservatively designed so that the pillars and overburden behave as a system. **Agree**
- Localised yielding of a web pillar would not necessarily lead to global instability. **Agree**
- The experts generally agree that the stability of the system as a whole is the key consideration as to whether the proposed layout designs are fit for purpose or not, not the strength and stability of individual pillars. **Agree in respect to regional (system) mine stability. However, the stability of individual elements of the system and the manner and timing in which the peak load carrying capacity of these may be exceeded, in particular the web pillars, can be critical to maintaining local stability (panel stability) and workplace stability, both of which are critical to ensuring the safety of the operation.**
- Emeritus Professor Galvin suggested that the assessment of stability could be re-framed around displacements rather than pillar stresses. This was agreed by Emeritus Professor Brown. **Agree**
- There was general agreement that assigning a probability of failure to a "system stability" factor of safety is inappropriate under the UNSW PDP and it was noted by Dr Frith that the two concepts were not intended to be linked in the EIS. **Agree**
- Furthermore, Mr Pauza suggested that since the 'system stability factor' is not key to the assessment, given the high stability factors on the intra panel and inter panel barrier pillars and chain pillars - even assuming the web pillars play no role, Hume Coal was willing to take this issue off the table by not relying on it as part of the assessment. **Agree**

Geotechnical numerical modelling presentation – Mr Alex Pauza

- The pillar design in the EIS is based on a 2D empirical design methodology and presents what is considered to be the worst-case web pillar loading scenario as a design input. **Agree**
- The company has since undertaken a 2D and 3D numerical modelling exercise to provide an independent and supplementary method of assessing pillar stability. **Agree**
- Dr Keith Heasley, from West Virginia University in the US has been commissioned to carry out this work using the LaModel software program. All the experts agreed that LaModel was an appropriate package to use for this analysis, in particular for the 3D work, and that Dr Heasley was well qualified and highly regarded for his work in this field. **Agree**

- The model has been calibrated to Berrima Colliery data and then de-rated in order to ensure that modelling runs are biased towards conservative assumptions in terms of overburden contribution to overall stability. **Agree**
- The results of the numerical modelling will be included in the Response to Submissions (RTS) and Hume Coal's final response to DP&E's expert reports, and will demonstrate that the pillar system has been designed to remain stable even under conditions of localised pillar yielding. **A statement by the Proponent – outcome still to be validated.**
- Based on Mr Pauza's presentation, the experts generally agree that the company's approach to the numerical modelling is appropriate and will assist the Department in its assessment process. **Agree**
- Professor. Canbulat asked for confirmation that the yielding version of the model had been used, rather than purely elastic, to provide for yielding of the web pillars. Hume Coal was of the understanding that this was the case, but agreed to confirm this with Dr Heasley. **Agree**
- Emeritus Professor Brown suggested that the numerical modelling by Professor Canbulat be set aside for the assessment and this was generally agreed by the experts. Professor Canbulat said that the aim of his modelling was to get a feel for the problem and was not intended to provide design outcomes. **To be confirmed**
- Emeritus Professor Galvin stated that the design was probably conservative in the deeper parts of the mine and that Hume Coal could consider widening the spans between intra-panel barriers. Mr Pauza noted that maintaining the geometry allows equipment to be standardised across the mine layout. **Agree**

Subsidence

- The experts generally agree that subsidence is likely to be negligible-minor and is not the key assessment issue. **Agree**
- Even if all web pillars are artificially removed from the model, the 3D model demonstrates that the change in subsidence would be very minor, and generally within the order of magnitude assessed in the EIS. **A statement by the Proponent – the 3D model outcomes had not been submitted for review at the time.**

Other safety issues

- Barrier pillars are wide, and any 'offline cutting' is unlikely to significantly affect their stability. **Agree in respect of barrier pillars (but not web pillars).**
- Professor Galvin remarked that he had not considered some potential safety matters in his report, such as unventilated plunges. **Disagree. The author (Professor Galvin) had not considered some safety issues, but had considered unventilated plunges, which he regards as goaves[21], Viz (page 44)** ***As mining retreats out of a mining (gateroad) panel, the web panels constitute goaves. Roof falls and pillar failures in the goaf can displace the goaf atmosphere into the active mine workings. Backfill and flooding will also displace goaf atmosphere. The EIS does not provide information as to the likely gas composition and gas content of the goaves and the manner in which mining operations are to be ventilated to safely control goaf gases.***
- Dr Frith noted that the number of plunges between intra-panel barriers was fixed by the design process, so that any offline drivage in one plunge would not change the overall

[21] ***Goaf - An area in which mining has been completed and left in a partially or totally collapsed state or in an inadequately supported state to assure safe entry. An abandoned area. Also referred to as 'gob'.*** **Galvin, J. M. (2016). Ground Engineering: Principles and Practices for Underground Coal Mining. 703 p. Switzerland: Springer. ISBN 978-3-319-25003-8**

reserve recovery and would increase the width of one pillar by the same amount that on the other side of the offline plunge was increased. **Agree.**

- The experts generally agree that the proposed mining method is flexible and could be modified throughout operations. **Agree. The method is flexible in some respects but not as flexible as alternative mining methods**

Closing comments – Clay Preshaw

- The mine design and safety of the underground workings remain as important issues for the Department. **Agree.**
- Mr Pauza asked if the Department could specify any specific safety concerns so that they could be addressed in the RTS, and none were able to be provided. **Professor Galvin does not consider this to be a fair reflection. Mr Preshaw made it clear that the proposal would need to be referred to the Resource Regulator within the Department for the purpose of reviewing risks to safety associated with the project.**
- The RTS and Hume Coal's response to DP&E's expert reports will be provided to the Department's experts for further advice before the assessment is finalised. **Agree.**
- The Department will also provide the RTS and Hume Coal's response to DP&E's expert reports to the Resource Regulator and seek feedback. Further consideration of safety issues may be required following the submission of Hume Coal's response to DP&E's expert reports and the RTS. **Agree.**
- A further meeting with the various experts and/or the Resource Regulator may be necessary before the Department finalises its assessment. **Agree.**

Actions

- **Hume Coal to provide the final Response to Experts Report, including the numerical modelling report and other matters discussed and agreed.** Agree.
- **The DP&E experts to review the responses and reports and provide supplementary reports to the DP&E.** Agree.