Appendix B

Additional information provided by the Applicant

Appendix B1 – Applicant Response to DPIE Water advice

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

21 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS
RESPONSE TO AGENCY COMMENTS – DPIE WATER.

Dear Mandana,

Thank you for providing the Agency comments.

Please find attached the Response from Hume Coal / EMM for the commentary provided by DPIE-Water.

Regards,

Rod Doyle
Project Manager

Hume Coal Pty Limited

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21 August 2020

Mandana Mazaheri
A/Team Leader, Planning and Assessment
Department of Planning Industry and Environment
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Re: Hume Coal response to DPIE-Water memo of July 2020

To Mandana,

This letter provides a detailed response to the comments and claims included in a letter from the Department of Planning, Industry and Environment (DPIE) – Water (the "DPIE – Water letter") addressed to DPIE Planning and Assessment, dated 22 July 2020, relating to the response by Hume Coal to the Independent Planning Commission (IPC) assessment report dated 27 May 2019 (the "IPC assessment report").

The DPIE – Water letter includes a main cover letter and an Attachment A. Direct quotes from the main cover letter are provided as boxed text within this response letter, followed by a summary of responses to the issues in the DPIE – Water letter Attachment A. The appendix to this letter addresses each of those Attachment A issues in further detail and context for your reference.

By way of background, the first six issues included in the DPIE – Water letter Attachment A originated as actions discussed and agreed upon in a meeting between DPIE – Water hydrogeologists, DPIE Planning and Assessment personnel, Hume Coal personnel, EMM and HydroSimulations/SLR Consulting hydrogeologists on 30 July 2019. The minutes were recorded by Hume Coal and distributed to all parties on 15 August 2019. The actions were addressed by Hume Coal in Annexure A "DPIE Water report" of the *Hume Coal and Berrima Rail Project Updated water assessment in response to recommendations R4, R5, R6, R7 and part of R8 within the Independent Planning Commission Assessment Report dated 27 May 2019* (the "updated water assessment") (EMM 2020a). The DPIE – Water letter is a response to the Annexure A "DPIE Water report".

The majority of the comments and claims in the DPIE – Water letter relate to DPIE – Water's assessment of the Hume Coal Project's groundwater modelling work. Essentially, DPIE – Water assert that the modelling and input data have outstanding issues and, as such, DPIE – Water do not support the appropriateness of the model predictions nor the feasibility of the make good approach. In contradiction to this assertion, the multiple independent peer reviews by world class modelling experts find the model and the assessment 'fit for purpose'. These independent peer reviews have been commissioned by both Hume Coal and DPIE. In each of these independent peer reviews, both the model and the assessment, have been found "fit for purpose" and "industry best practice" (eg Townley 2020, HydroGeoLogic 2017, 2018).

In regard to the groundwater modelling work, Hume Coal strongly suggest that the independent technical reviews, conducted by industry leading experts, be given more weight in the consideration of the project. The criticisms of DPIE – Water, in some cases, do not appear to be grounded on a clear technical basis and are more general in nature. Concerns raised in the EIS have been addressed and incorporated in subsequent peer reviews, the RTS and the final IPC response report. Increased weighting on the outcomes of the peer reviews by Townley (2020), HydroGeoLogic (2017, 2018) is strongly recommended. Reasons are explained below with respect to the specific remaining issues.

Main cover letter issues

> *Confirmation of the acceptability of the proposed make good arrangements to those landholders that have opted in to the monitoring and mitigation program has not been provided.*

The requirement for make good, as per the NSW Aquifer Interference Policy (AIP), is a commitment that Hume Coal have made. Definitive make good provisions are not outlined in detail within the AIP or other NSW legislation. In NSW, 'make good' means that Hume Coal is required to "ensure third parties have access to an equivalent supply of water through enhanced infrastructure or other means" (DPI Water 2013).

It is not appropriate, nor a legislated requirement, for specific details on make good arrangements for individual landholders to be agreed upon this far in advance of potential drawdowns being experienced. It is not fair or equitable for landholders to be locked into make good agreements many years (or decades) in advance of actual impacts occurring. Given some impacts are not predicted for over a decade, landholders need flexibility to change their mind about the specific detail as to what make good arrangements are most suited to their needs at the time. In addition, property ownership may change and new owners may prefer significantly different make good measures. At this stage, the legal requirement is that a firm "make good" commitment from Hume Coal is made, with flexible and workable specific options and details to be locked in over time, as and when needed. This is the fairest and most equitable and realistic approach for both the individual landholders and for Hume Coal.

It is noted that for the nearby Tahmoor Mine, the groundwater model conservatism has meant that many of the bores predicted to be impacted during mining have not actually been impacted. The below text is taken from the Tahmoor South Amended Project Report, dated August 3 2020 and clearly demonstrates the 'worst case' modelling of drawdown versus the reality of the actual impact for groundwater models:

> "Tahmoor Coal has previously enacted 'make-good' provisions for two landowners affected by the Tahmoor Mine. For context, the revised groundwater model predicts that the historical operation at Tahmoor North (32 longwalls extracted between the 1980s and 2019) and the few remaining Western Domain longwalls would have already affected, or would affect, 72 bores. This, when compared to the fact that only 2 bore uses have previously required make-good assistance, supports the idea that this assessment method is conservative for the reasons that many users might be affected beyond 2 m drawdown but not notice the effect compared to available drawdown and natural variation in water levels, or are not affected due to the reasons described above." (Tahmoor South Amended Project Report, dated August 3)"

Groundwater models are by nature very conservative and therefore provide worst case water level drawdown scenarios (as clearly demonstrated in the above Tahmoor Mine example). In reality, most models significantly over predict impacts to individual bores due to the inherent conservatism adopted by modellers throughout the modelling process. Having flexible make good provisions, and an active monitoring bore network to provide verification of the impacts and their timing, allow a more tailored and individually crafted make good programme to be rolled out to landholders.

> *Where there is the requirement from a make good provision to source water from a new location, from a deeper aquifer or at a higher extraction rate, the proponent may need to complete further impact assessment and obtain approvals if not addressed within this project. The need to acquire additional entitlement may also need to be considered.*

Make good is not about securing additional entitlement, it is about maintaining the same level of access to water for landholders in order to continue their current level of operations. The securing of an additional volume is not envisaged to be needed unless sourcing replacement water from a different water source is required. If different water sources are required, then it will be addressed as needed.

For existing users there are unknowns about the design and efficiency of existing bores. Bore details such as the screened interval, detailed geological logs, pump capacity, and bore efficiency are often not known or recorded in detail. It is likely that for many landholders a slightly deeper replacement bore, with a potentially more efficient design (ie wider diameter) will adequately meet make good requirements, particularly for stock and domestic supplies.

It is agreed that additional approvals (as different to licences) may be required to construct additional bores and/or dams for storage of water. Approvals for additional works will be sought as required. The purchase of additional licence volume is unlikely. It is noted that Hume Coal hold licence volume almost equivalent to the peak annual inflow volume, and that this peak will only occur in one year of the project. Therefore, in all other years, Hume Coal have spare (unused) entitlement available for trade to augment landholders, if this is required. It is noted that the peak drawdown within landholder bores, is delayed and offset from the peak inflow to the mine workings. Therefore, licence availability (should it be required) will be available from Hume Coal's existing licences to account for water take from third parties, if required.

Further impact assessment of the take from landholder bores is not deemed required, as additional volumes are not being taken. The Hume Coal Project groundwater model already takes into account current levels of extraction from individual landholders during mining. Therefore, impacts from individual landholder use is already considered in the model. Should the existing landholder bore licence volume be taken from a deeper groundwater system (ie rather than the Hawkesbury Sandstone), the impacts within the Hawkesbury Sandstone would be minimal (and potentially unmeasurable).

The possibility that importing water from other sources (either through piping or trucking in tanker loads) would be complicated and likely to have adverse effects on the local area. Whilst this appears to have been replaced as an option by financial incentives in the form of compensation, it does not appear to have been formally excluded.

Hume Coal will consider each make good agreement on a case by case basis and plan to work with the individual landholders to agree on the best outcome for each situation. No reasonable make good options are explicitly excluded. Ideally, replacement bores would be the clear preference in the hierarchy of potential works for make good, as it is replacing like with like. However, consideration of logistics, local impacts, and the landholder preference will be the driver for the optimal solution in each case.

Hume Coal acknowledge that importing water from other sources (either through piping or trucking in) is likely to be a complicated solution for providing make good and at this stage is not being considered as an optimal solution for most or even all cases. However, Hume Coal are not excluding it as an option, in case it is a landholder's preferred solution and small volumes are involved. If it is preferred, the benefits and drawbacks would be considered and assessed objectively at the appropriate time. For example, it may be suitable for a landholder with a very small water demand that is only impacted marginally for a few years, with the additional volume able to be easily met by several water truck top-ups annually. It is these low volume, low frequency cases that trucking water may be suitable for the individual landholder and Hume Coal.

The proponent has undertaken separate analysis of affected water bores and potentially groundwater dependent heritage gardens that may be affected. It is not clear to the department that properties that have both will have their bore water supply appropriately reinstated under make good arrangements.

The Hume Coal Project has provisions for make good arrangements to be made available for all registered bores that are predicted to experience greater than 2 m of drawdown as a result of the mine operation. Bores on properties with heritage gardens are already included in this assessment, so bores on these properties are already automatically included in the make good arrangements. However, it is possible that some properties have bores that are not registered with the NSW Government, in which case Hume Coal may not be aware of these and they would not be included in the impact assessment. It is also possible that some bores identified in the NSW Government register no longer exist, or are no longer used but they have still been included in the current list of bores where access to water supply will be made good. Because of this, Hume Coal will be adaptable and flexible in its approach to make good.

Hume Coal will ensure that all legitimate groundwater users can access the make good arrangements. In addition, Hume Coal will ensure (via active monitoring and model verification over time) that make good measures are applied to offset the actual drawdown impacts as they occur. Hume Coal will adjust the make good timeframe and schedule to accommodate drawdown and impacts as they occur (ie it may be slightly earlier or later than predicted). In reference to other nearby mines, such as Tahmoor Mine, it is acknowledged that predicted impacts were greater than the actual impacts measured once mining commenced (ie 72 predicted, but only two required make good). Therefore, using data and the results from Tahmoor Mine, Hume Coal is confident that the make good provisions outlined will absolutely address the make good requirements for the Hume Coal Project. It is also noted that the approach being suggested by Hume Coal is effectively the same as Tahmoor Mine, and that the Hume Coal make good assessment and strategy has gone into considerably more detail, as per requests from the NSW Government during the ongoing consultation process.

> *We are also concerned that those properties with heritage gardens which have not been historically irrigated may not receive equitable treatment.*

The requirements for make good only applies to water supply works (bores), high value groundwater dependent ecosystems (GDEs) and culturally significant sites. Potential impacts of watertable drawdown on heritage gardens has been assessed by Hume Coal. The Hume Coal Project is not predicted to result in any groundwater related impacts on heritage gardens.

Heritage gardens that are not currently or previously irrigated by groundwater and are not predicted to be impacted by reductions in the watertable are not subject to make good as there are no mining related impacts. The make good provisions are there to protect existing users. Should heritage gardens, who currently do not use groundwater, wish to start using groundwater, they can construct a bore themselves to access water whenever they wish, subject to any required licences and approvals.

The Hume Coal Project will not desaturate the Hawkesbury Sandstone (ie there will always remain groundwater available for extraction), vegetation access to groundwater in the Wianamatta Shale will not be affected, and there will also be water available in deeper formations. All listed heritage gardens accessing shallow groundwater and part of the vegetation in the landscape conservation areas are situated above the Wianamatta Group shale. As this is a perched groundwater system with limited hydraulic connection to the underlying Hawkesbury Sandstone (where groundwater drawdown is predicted to occur), no impacts are predicted in these areas.

> *…limitations in the model which mean that the current presented impact predictions should be considered the minimum likely impact. In other words, any changes to the model are unlikely to decrease the predicted impact. DPIE Water also notes that apart [from] changing parameters in the model, the model is as advanced as it can get at this stage and unlikely to be able to provide further support to decision making.*

It is not clear what the technical basis of the above statement is or why the impacts should be considered the minimum likely impact. This statement is not in agreement with any of the multiple independent technical reviews by leading groundwater modelling experts (Townley 2020; HydroAlgorithmics 2016; Kalf and Associates 2016; and HydroGeoLogic 2017, 2018).

The groundwater model has undergone greater than 10 reviews and include:

- on behalf of Hume Coal: Dr Noel Merrick, Dr Frans Kalf, Neil Manewell, Liz Webb and Dr Lloyd Townley;
- on behalf of regulators: Hugh Middlemis (HydroGeoLogic; twice), representatives of IESC, DoI – Water hydrogeologists and WaterNSW hydrogeologists; and
- on behalf of the community: Dr Steven Pells, Doug Anderson, Chris Jewell and John Lee.

The following reviewers found that the groundwater model is fit for purpose and appropriate for assessing the impacts of the Hume Coal Project:

- Dr Noel Merrick, acting as independent reviewer of the Coffey (2016a) work and prior to taking ownership of the groundwater model;
- Dr Frans Kalf, independent reviewer of the EIS and RTS groundwater model;
- Neil Manewell who conducted an audit of the EIS groundwater model;
- HydroGeoLogic, acting as an expert reviewer for the then Department of Planning and Environment (DPE) and conducted reviews of the EIS and RTS groundwater model versions; and
- Dr Townley (2020) who conducted an expert review of the groundwater modelling work conducted as part of the EIS and RTS.

The independent expert reviewer commissioned by the NSW Government during the response to submissions phase, HydroGeoLogic, notes that:

> "the Hume Coal model (in terms of the combination of the 2016 EIS and its adjunct the 2018 revised modelling) is consistent with best practice in design and execution. It is fit for mining project impact prediction purposes, the results presented are reasonable in terms of inflows and drawdown predictions and related uncertainties, providing suitable information for decision-making and licensing." (HydroGeoLogic 2018).

In addition, HydroGeoLogic (2018) also states that the:

> "Hume Coal groundwater modelling uncertainty analysis and sensitivity analysis has been conducted consistent with best practice (Barnett et al 2012; Middlemis and Peeters 2018), and presented the results in terms of the probabilities associated with mine inflows, drawdowns, bores affected and stream baseflows, in a best practice manner that provides information to support decision-making on licensing and like matters." (HydroGeoLogic 2018)

In specific contradiction to DPIE – Water's claim that the "impact predictions should be considered the minimum likely impact", Townley (2020) states that:

> "it seems likely that the distributions of hydraulic conductivities generated by HydroSimulations (2018) are conservative, in the sense of over-estimating mine inflows and over-estimating the likelihood of drawdown caused by mining." (Townley 2020)

The legitimacy of DPIE - Water's objection to the accuracy and suitability of the model is strongly questioned. It is unclear why DPIE - Water consider this model inadequate to provide further support to decision making when multiple groundwater modelling experts independently agree that this model is "best practice", in terms of design, execution, and uncertainty and sensitivity analysis. Hume Coal are concerned that the professional judgement of well-known industry leaders in groundwater modelling and uncertainty analysis continues to be challenged without any clear succinct technical grounds.

Hume Coal have no choice but to suggest that the groundwater model for the Hume Coal Project is being reviewed in an inequitable manner by DPIE Water compared to other models for other mines and the NSW Government's own requirements for models. Hume Coal have undertaken more expert reviews than most other projects of its kind. All reviews are coming back as *'fit for purpose'*. The most recent review states that the groundwater model is, in fact, "*fit for purpose, for the purpose of predicting groundwater inflows to the proposed mine and drawdown of the water table within and near the project area*" (Townley 2020). DPIE – Water state that '*the model is as advanced as it can get at this stage'*, yet they are not satisfied with it, and have not provided clear succinct technical basis for their ongoing concerns. With over ten years of groundwater level data in the model, some of the best modelling minds in the world having worked on and or reviewed it, and application of world first and cutting-edge uncertainty analysis, Hume Coal strongly suggest that it should be approved as '*fit for purpose'* by the IPC and not hold the project up any further.

DPIE - Water attachment

The specific comments raised in the DPIE - Water letter attachment are addressed in Table 1 and then in greater detail and with additional context in Appendices A.1 through A.7.

Table 1 Issue summary and response

Action item	Summary	Hume Coal response	Appendix
1. Cross Sections	Hume Coal provided five additional cross sections as requested from DPIE – Water. However, DPIE – Water now claim that the level of detail provided is insufficient.	Hume Coal contend that the exact request has been delivered and additional information (ie in addition to the original DPIE – Water request) has also been provided. The DPIE - Water comment regarding even 'more detail could have been included' is an ambiguous and unconstructive comment. Hume Coal has provided more detail in areas that are of hydrogeological interest based on DPIE – Water questions. Of course, more detail can always be provided, but there is a 'fit for purpose' level of detail in regard to this that Hume Coal feels has already been overdelivered on and categorically met already. In addition, the role of HydroGeoLogic as the NSW Government's expert reviewer included review of the groundwater model layers, and found that the model is fit for purpose.	A.1
2. Hydraulic Data	Hume Coal provided hydraulic conductivity with depth data reanalysed and represented. However, DPIE – Water are not satisfied that the provided information is useful for their assessment.	Hume Coal provided a series of maps and multiple series of charts to demonstrate the relationship between hydraulic conductivity and depth using regional aquifer test data to satisfy this action and to assist the DPIE – Water assessment. Hume Coal contend that further provision of this same information, reworked into another series of maps or charts, would add no further value on top of the existing information and expert reviews that have already been conducted.	A.2
3. Comparison with Berrima Coal Mine	Hume Coal provided an enhanced discussion of the similarities and differences between the existing Berrima Colliery and the proposed Hume Coal Project to the satisfaction of DPIE – Water. However, DPIE – Water still do not accept that the use of Berrima Colliery data as a suitable calibration dataset.	The use of Berrima Colliery data to inform calibration was endorsed strongly by both the NSW Government expert reviewer (HydroGeoLogic 2017, 2018), and the additional peer review undertaken by Dr Lloyd Townley (Townley 2020). The continued dismissing of the opinions of these industry leaders by DPIE – Water concerns Hume Coal and raises questions regarding the equitable treatment of the groundwater assessment for the Hume Coal project.	A.3

Table 1 Issue summary and response

Action item	Summary	Hume Coal response	Appendix
4. Calibration statistics	DPIE – Water wanted more information on model calibration statistics and specifically wanted to know: if the model predicts 70% of the monitoring bores hydrograph history match is in excess of 2 metres, then what are the impacts of the 2 metre drawdown on landowner bores. DPIE – Water assert that this question remains unanswered. DPIE – Water refer to DPIE -Water requested re-runs of the model with higher hydraulic conductivity values for the Hawkesbury Sandstone. DPIE – Water also state: • Detailed hydraulic property information about all the layers above the mine voids been provided as per prior DPIE recommendations. • The calibration to multiple data sets, in particular the data for the Berrima Coal Mine, remains a concern for DPIE - Water that has not been alleviated by the current reporting.	The modelling work has been conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al 2012), including Guiding Principle 7.4 which states that there is "more uncertainty when reporting confidence intervals around an absolute model output, and less uncertainty when a prediction can be formulated as a subtraction of two model results". That is, the relative change in groundwater levels is more important than the absolute level. Therefore, if the modelled groundwater levels at a landholder bore differs from the measured level by 2 m, but the modelled change in groundwater level is consistent with the measured change, then the model can be used to predict potential changes in groundwater levels (ie drawdown) at those bores. The reference to "2 m" should apply only to drawdown, as prescribed in the AIP; there is no mention of its relevance to absolute groundwater level in either the AIP or the Groundwater Modelling Guidelines (Barnett et al 2012). DPIE – Water's request for re-runs of the model with higher hydraulic conductivity values for the Hawkesbury Sandstone were not captured in the minutes that were shared by Hume Coal on 15 August 2019. It was discussed in the meeting (dated 30 July 2019) that these higher values did not represent reality at a regional scale, and therefore re-running the model using these values would not be representative of reality. DPIE – Water did not provide a response to the minutes to identify any perceived omissions or corrections needed regarding this point. The RTS and the IPC response report (EMM 2020a) presented all measured hydraulic conductivity, including data for stratigraphy above the mine voids. The modelling work has been reviewed and audited many times by technical experts and deemed fit for purpose. The expert reviews identified that the use of four separate datasets as calibration datasets strengthens the model's robustness and the calibration approach is consistent with the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and "best practice". Given the above, validity of DPIE – Water's inquiry into the calibration results appears unwarranted and potentially more of an academic interest request.	A.4

Table 1 Issue summary and response

Action item	Summary	Hume Coal response	Appendix
5. Uncertainty Analysis	DPIE - Water requested that Hume Coal describe the range of parameters explored and map them. Hume Coal provided additional maps showing 95th percentile distributions of hydraulic conductivity used in the uncertainty analysis to the satisfaction of DPIE – Water. But DPIE – Water now request to also be provided with 5th percentile values too, along with more clear descriptions on depth and thicknesses of model layers, and additional sensitivity analysis for higher conductivities.	The modelling work has been reviewed and audited many times by technical experts and deemed fit for purpose. Considerable IESC-compliant uncertainty analysis has been completed over a very wide range of values, as disclosed previously. Use of the 67th percentile results is conservative for assessing impacts and not considered 'minimum'. Presentation of the 95th percentile distribution of hydraulic conductivity values used in the uncertainty analysis (in the DPIE Water Report (EMM 2020b)) illustrates the very upper range in hydraulic conductivity values used in the predictive uncertainty analysis, which DPIE – Water advised they were interested in. The selection of the 95th percentile hydraulic conductivity values means that there were 27 model runs (of 550) in the uncertainty analysis that used higher values than those presented. The 5th percentile distribution would represent the very low end in hydraulic conductivity values used in the uncertainty analysis. The approach to uncertainty analysis has been well documented throughout the EIS, RTS and recent IPC response report. This has included information on the model layer thickness and hydraulic conductivity. Hugh Middlemis of HydroGeoLogic was one of the authors of the Independent Expert Scientific Committee (IESC) publication *'Uncertainty analysis—Guidance for groundwater modelling within a risk management framework'*, and, he also undertook the independent review of the Hume Coal project model for the NSW Government. Mr Middlemis of HydroGeoLogic stated that "the Hume Coal model (in terms of the combination of the 2016 EIS and its adjunct the 2018 revised modelling) is consistent with best practice in design and execution. It is fit for mining project impact prediction purposes, the results presented are reasonable in terms of inflows and drawdown predictions and related uncertainties, providing suitable information for decision-making and licensing." (HydroGeoLogic 2018). Dr Lloyd Townley was then also commissioned to undertake an independent review of the model, including the uncertainty, and also deemed it "fit for purpose" (Townley 2020). Hume Coal are concerned that the professional judgement of clear industry leaders in groundwater modelling and uncertainty analysis continue to be overlooked without any clear technical grounds by DPIE -Water.	A.5
6. Packer Test data	Hume Coal have provided raw data from the packer tests to the satisfaction of DPIE – Water.	This is now closed out. No further actions required.	

Table 1 Issue summary and response

Action item	Summary	Hume Coal response	Appendix
7. Impact on Groundwater Dependent Ecosystems	This is a new issue raised by DPIE – Water in the DPIE – Water letter. DPIE – Water assert that evidence in support of the conceptual hydrogeological understanding is not obviously provided. DPIE – Water are concerned that make good arrangements will not cover groundwater dependent heritage gardens, that may require irrigation if the watertable is drawndown.	This item was raised in the IPC assessment report (R16) and has been addressed. The ecohydrological conceptualisation is based on information presented in the EIS, RTS and IPC response reports. This includes groundwater level data supporting the understanding. All listed heritage gardens accessing shallow groundwater and part of the vegetation in the landscape conservation areas are situated above the Wianamatta Group shale. As this is a perched groundwater system with limited hydraulic connection to the underlying Hawkesbury Sandstone (where groundwater drawdown is predicted to occur), no impacts are predicted in these areas.	A.7
General comments	DPIE – Water raised some additional concerns regarding the groundwater modelling and input data and suggest that the IPC consider: • the suitability of higher Kx and Kv values for the Hawkesbury Sandstone; • appropriateness of model runs with high K values; • addressing previous DPIE – Water recommendations made during EIS and RTS; and • getting further technical advice on modelling from external reviewers.	The modelling work has been reviewed and audited many times by leading technical experts and deemed fit for purpose, including by DPIE's own technical expert, HydroGeoLogic (2017 and 2018). The ongoing call for additional simulations with higher hydraulic conductivities is unwarranted as that option has been explored thoroughly in the IESC-compliant uncertainty analysis. The specific purpose of the DPIE-Water report prepared in April 2020 was to address all DPIE-Water concerns for the project, as per the minutes provided from the meeting held on 30 July 2019. Hume Coal disagree that there are any outstanding recommendations to be addressed from the EIS or RTS. The legitimacy of DPIE-Water's objection to the accuracy and suitability of the model is strongly questioned. It is unclear why DPIE-Water consider this model inadequate to provide further support to decision making when multiple leading groundwater modelling experts independently agree that this model is "best practice", in terms of design, execution, and uncertainty and sensitivity analysis.	A.8

Yours sincerely,

Liz Webb
Director EMM

lwebb@emmconsulting.com.au

A.1 Appendix 1 Cross-sections

> *Hume Coal to provide additional north–south and east¬west sections to assist DPIE Water with making their assessment on impacts.*

Hume Coal have provided adequate examples of cross-sections and geological information to assist the DPIE – Water assessment and contend that provision of additional detail on cross-sections would add no further value on top of the expert reviews that have already been conducted.

The conceptual geological understanding, incorporating Hume Coal's geological model, and the groundwater model construct has been discussed in detail in the EIS, RTS and IPC response report (including Appendix B to the report). Cross-sections demonstrating the geological model and the groundwater model have also been included.

Following the July 2019 meeting, Hume Coal attempted to coordinate with DPIE – Water to confirm the location of the additional requested cross-section locations. In light of unsuccessful attempts to collaborate with the relevant parties, Hume Coal selected multiple (five) representative locations that traverse the project area, two in a north-south orientation and three in an east-west orientation, to satisfy the original request. The cross-sections provide comparison between the geological model and the layers within the numerical groundwater model. Representations of the geology and topography in the groundwater model as has been done for the Hume Coal Project is common practice, where layers are often approximated.

Since the purpose of the groundwater model is to predict wide-scale impacts and not site-specific issues, the resulting predictive modelling of the groundwater system is considered fit for purpose. The groundwater model has been reviewed numerous times by various industry experts that have all concluded that the groundwater model is a valid tool for the prediction of the effects of the proposed mine on the groundwater system (Townley (2020); HydroAlgorithmics (2016); Kalf and Associates (2016); and Hydrogeologic (2017, 2018)).

The DPIE – Water letter comments that:

> *more (and more detailed) parts of sections could have been included in the document to more clearly demonstrate the relationship between the geological units and the groundwater model layers. Such supplementary information would prove considerably more useful in assessing the model construct.*

Hume Coal agrees that, "more (and more detailed) parts of sections could have been included". More detail can always be included, but Hume Coal deem that the sections already provided are sufficient to consider the project and that the information provided is more than adequate. Hume Coal have demonstrated clear openness and willingness to provide the appropriate level of detail to assist the DPIE – Water assessment for cross sections. However, in this instance, the request for "more" information seems to be boundless.

Hume Coal disagree that the request for "more (and more detailed) parts of sections" is warranted, given that numerous industry experts have already reviewed the groundwater model and determined that it is "fit for purpose", "best practice", and the geological "conceptualisation is sound" (eg HydroGeoLogic 2018). The experts concluded that the groundwater model is a valid tool for the prediction of the effects of the proposed mine on the groundwater system (Townley 2020; HydroAlgorithmics 2016; Kalf and Associates 2016; and Hydrogeologic 2017, 2018). The amount of review and scrutiny that the Hume Coal groundwater model, including the model construct, has already been subject to seems excessive and is not experienced by other projects (mines and otherwise) in NSW.

It is noted that one of the expert reviewers that deemed the groundwater conceptualisation 'sound' was appointed by the NSW Government (HydroGeoLogic 2017, 2018). The IPC in their assessment recommended an additional peer review be undertaken. The commissioning of this review was not adopted by the NSW Government, therefore Hume Coal elected to commission this additional independent peer review as per the IPC recommendations. Hume Coal is perplexed as to why DPIE – Water's assessment continues to remain at odds with the independent expert reviews, particularly when one of the reviewers was appointed by the DPIE (then DPE) itself.

A.2 Appendix 2 - Hydraulic data

Hume Coal is to re-evaluate original data from the EIS and Response to Submission (RTS) graphs showing hydraulic conductivity with depth (Coffey's EIS graphs and refined HydroSimulations graphs in the RTS). The data is to be reproduced and charted spatially on a map or series of maps.

Hume Coal provided a series of maps and multiple series of charts to demonstrate the relationship between hydraulic conductivity and depth using regional aquifer test data to satisfy this action and to assist the DPIE – Water assessment (Chapter 3 of EMM 2020b). Hume Coal contend that further provision of this information, reworked into yet another series of maps or charts, would add no further value on top of the expert reviews that have already been conducted.

Hume Coal understands that DPIE – Water are seeking to verify whether the hydraulic conductivity values assigned within the model are appropriate with respect to measured field hydraulic test data and known geology.

For context, the EIS model developed by Coffey (2016a) had single values of horizontal hydraulic conductivity and vertical hydraulic conductivity for each model layer; ie these properties were assumed to be uniform or homogeneous over the whole model domain in each layer. These values were based on field data. For the modified impact assessment presented in the RTS (Hydrosimulations 2018), a depth function was used to statistically derive varied and appropriate hydraulic conductivity values at points across each model layer from a field data basis. Sophisticated uncertainty analysis using "relatively modern techniques" (Townley 2020) was then performed to understand the uncertainty in impact predictions based on a large number of spatial distributions of hydraulic conductivities. This approach has been described as industry "best practice" (Townley 2020).

It should be reiterated that the purpose of the Hume Coal groundwater model is not to create an exact scaled replica of the real world; this is in fact impossible. The purpose of the Hume Coal model is for the prediction of the effects of the proposed mine on the groundwater system; ie for predicting groundwater inflows to the proposed mine and drawdown of the water table within and near the project area. As both Townley (2020) and HydroGeoLogic (2018) clearly state, the Hume Coal model is fit for this purpose.

Not only is the model fit for the purpose of predicting the effects of the proposed mine on the groundwater system, it is conservative in the predictions. The actual impacts are likely to be less than what has been predicted by the model and presented in the impact assessment (EMM 2018). Townley (2020) states that "it seems likely that the distributions of hydraulic conductivities generated by HydroSimulations (2018) are conservative, in the sense of over-estimating mine inflows and over-estimating the likelihood of drawdown caused by mining." The inherent conservatism and industry "best practice" approach adopted in this groundwater modelling work should, in theory, offer reassurance to the decision makers that the outer bounds of the likely impacts of the proposed operation are known and understood.

Further investigation into the applied hydraulic conductivity values as proposed by DPIE – Water would not provide further support to decision making and would appear to be more of an academic pursuit. Hume Coal would therefore commit to further investigations on hydraulic conductivity values in collaboration with DPIE Water post approval and as a condition of project consent.

A.3 Appendix 3 - Comparison with Berrima Colliery

Hume Coal to provide an enhanced discussion of the similarities and differences between the existing Berrima Colliery and the proposed Hume Coal Project.

Hume Coal provided a comprehensive comparison between the Hume Coal Project and the Berrima Colliery in EMM (2020b). However, DPIE – Water remain concerned over the use of Berrima Colliery data for model calibration targets and question the validity of the impact predictions as a result. This assertion is in contradiction to the independent expert reviews conducted by HydroGeoLogic (2017, 2018) and Townley (2020), who both recognise the use of the Berrima Colliery data and three other separate datasets as calibration datasets actually **strengthens the model's robustness**, as explained below.

Townley (2020) notes, with respect to the baseline data obtained from the Berrima Coal Mine, that "having any data from a nearby mine within the domain of a model is rare and extremely valuable", and "while the existence of an historic (previously operating) mine like the Berrima Colliery inside the model domain is not unique, it is relatively unusual. The fact that Coffey (2016a,b) attempted to use data from and near the Berrima Colliery should provide confidence in their efforts."

Calibration of the original EIS model (Coffey, 2016a, Section 4) was undertaken manually and took advantage of four large and independent data sets:

- hydraulic heads;
- hydraulic conductivities;
- shallow groundwater discharge (baseflow to streams); and
- deep groundwater discharge (inflows to the Berrima mine).

Townley (2020) observes:

> "Coffey (2016a, Executive Summary) described the model calibration as being based on **"the optimal set of data for calibration of a numerical groundwater flow model"**. Hydrogeologic (2017, Section 4) describes Coffey's (2016a) approach to model calibration as **"best practice history match calibration methods"**. In the opinion of [Townley (2020)], it is rare to have data sets of these four kinds, so the comments made by Coffey (2016a) and Hydrogeologic (2017) are justified."

Further, Townley (2020) notes "in the case of the Hume Coal Project, the existence of the Berrima Coal Mine and the availability of some data that have been used in calibration is a significant advantage."

Hydrogeologic (2017) agrees that the calibration approach, using Berrima Colliery data, "is a good example of best practice method that minimised non-uniqueness issues…".

Townley (2020) also states that:

> "the calibration methodology is not only consistent with the [Australian Groundwater Modelling Guidelines (Barnett et al 2012)], but in the experience of [Townley (2020)], this is one of the first times that four separate types of data have been used in a model of a proposed mining project, in an attempt to balance the different sources of information. The methodology is supported by the guidelines, which explain in Recommendation 5.4 that over-emphasis on fitting a model to observations of piezometric heads using an arbitrary value of SRMS is not appropriate." (Townley 2020)

Given the discussion above, the legitimacy of DPIE - Water's objection over the use of the Berrima Colliery data as a calibration target is questioned. The independent reviewers (Hugh Middlemis of HydroGeoLogic and Lloyd Townley of GW-SW) have substantial experience reviewing groundwater models and are well versed in the application of the Australian Groundwater Modelling Guidelines (Barnett et al 2012). In fact, Dr

Townley was an author of the current guidelines, and Mr Middlemis was an author of the precursor version, the Murray Darling Basin Commission Groundwater Flow Modelling Guideline published in 2000. Both are well respected, leading experts within the Australian groundwater modelling community. The continued dismissing of the opinions of these industry leaders by DPIE – Water concerns Hume Coal and raises questions regarding the equitable treatment of the groundwater assessment for the Hume Coal project.

A.4 Appendix 4 - Calibration statistics

> *Hume Coal was asked to provide more information on model calibration statistics. DPIE Water wanted to know if the model predicts 70% of the monitoring bores hydrograph history match is in excess of 2 metres, then what are the impacts of the 2 metre drawdown on landowner bores.*

The modelling work has been conducted in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al 2012), including Guiding Principle 7.4 which states that there is "more uncertainty when reporting confidence intervals around an absolute model output, and less uncertainty when a prediction can be formulated as a subtraction of two model results". That is, the relative change in groundwater levels is more important than the absolute level. Therefore, if the modelled groundwater levels at a landholder bore differs to the measured level by 2 m, but the modelled change in groundwater level is consistent with the measured change, then the model can be used to predict potential changes in groundwater levels (ie drawdown) at those bores.

> *DPIE Water finds that the data is the same as has been used before, and that the requested re-runs of the model with higher hydraulic conductivity values for the Hawkesbury Sandstone has not been done. Nor has detailed hydraulic property information, about all the layers above the mine voids been provided as per prior DPIE recommendations. This is a major shortcoming of the modelling and reporting and does not allow DPIE Water to have confidence in the model predictions. The calibration to multiple data sets, in particular the data for the Berrima Coal Mine, remains a concern for DPIE Water that has not been alleviated by the current reporting.*

DPIE – Water's "request" for re-runs of the model with higher hydraulic conductivity values for the Hawkesbury Sandstone were not captured in the minutes that were shared by Hume Coal, as it was discussed in the meeting these higher values did not represent reality at a regional scale. DPIE – Water did not provide a response to the minutes to identify any perceived omissions or corrections needed.

The RTS and the IPC response report (EMM 2020) presented all measured hydraulic conductivity, including data for stratigraphy above the mine voids.

DPIE – Water state that use of multiple datasets as part of the model calibration, in particular data from the Berrima Colliery, remains a concern and affects their ability to have confidence in the model predictions. These assertions unjustly undermine the validity of the calibration method and approach and are in direct contradiction to the independent expert reviews conducted by HydroGeoLogic (2017, 2018) and Townley (2020), who both recognise the use of the Berrima Colliery data and three other separate datasets as calibration datasets actually strengthens the model's robustness, as explained in Appendix A.3, and that the adopted calibration approach is a demonstration of "best practice".

The modelling work has been reviewed and audited many times by technical experts and deemed fit for purpose. The independent expert reviews (HydroGeoLogic 2017, 2018; Townley 2020) identified that the use of four separate datasets as calibration datasets strengthens the model's robustness; the calibration approach is consistent with the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and is "best practice". Given the above, validity of DPIE – Water's inquiry into the calibration results appears unwarranted and potentially more of an academic interest request.

A.5 Appendix 5 – Uncertainty analysis

DPIE Water requested that Hume describe the range of parameters explored and map them

Hume Coal provided a series of maps demonstrating the 95th percentile (upper 5%) of hydraulic conductivity values sampled in the uncertainty analysis for the Hawkesbury Sandstone, as well as plots of the range of hydraulic conductivity values explored in the uncertainty analysis compared with field data (EMM 2020b). DPIE – Water agreed this information was helpful. However, DPIE – Water are not satisfied with this information and request to also be provided with 5th percentile values too, along with more clear descriptions on depth and thicknesses of model layers, and additional sensitivity analysis for higher conductivities. DPIE – Water assert that "considerable" more justification is needed for the adoption of values of horizontal and vertical conductivity for each layer in zones 1 and 2 which are most likely to be affected by mining". DPIE – Water also state that their previous recommendation of running sensitivity analysis for higher conductivities has also not been addressed. These assertions are in contrast to the independent expert reviews conducted by HydroGeoLogic (2017, 2018) and Townley (2020), who both recognise the values of hydraulic conductivities and the range of values applied are appropriate, as explained below. Hume Coal see limited, if any, value running additional sensitivities on the model with hydraulic conductivities that are well beyond what is reality for this regional groundwater system.

Regarding the appropriateness of the range of input parameters used, Townley (2020) notes that the uncertainty analysis has been undertaken with a large number of spatial distributions of hydraulic conductivities and concludes that the range of parameters is sufficient and should not be larger. Townley (2020) further notes that "sensitivity analysis does not become better or more useful simply because the range of input parameters is large. The key issue is that the range of input parameters should be realistic". Variability within generated spatial fields of hydraulic conductivities and storage coefficients should be consistent with variability observed in the real world. Townley (2020) notes that the range of the distributions of horizontal hydraulic conductivity (Kh) generated by HydroSimulations (2018) is probably large enough and may be too large; and the range of Kh/Kv may be too small, as it is not uncommon for Kh/Kv to be 1,000 or 10,000 in some materials in the Sydney Basin. However, if Kh/Kv were larger the predicted impacts on the watertable would tend to be smaller (Townley 2020).

The purpose of the Hume Coal model is for the prediction of the effects of the proposed mine on the groundwater system; ie for predicting groundwater inflows to the proposed mine and drawdown of the water table within and near the project area. The various reviews of the Hume Coal groundwater model conducted by industry experts have determined that the groundwater model is fit for purpose and appropriate for use to assess mining impacts on the groundwater resource. This includes the uncertainty analysis completed as part of the RTS (EMM 2018).

Not only is the model fit for the purpose of predicting the effects of the proposed mine on the groundwater system, it is conservative in the predictions. The actual impacts are likely to be less than what has been predicted by the model. Townley (2020) states that "it seems likely that the distributions of hydraulic conductivities generated by HydroSimulations (2018) are conservative, in the sense of over-estimating mine inflows and over-estimating the likelihood of drawdown caused by mining." The inherent conservatism and industry "best practice" approach adopted in this groundwater modelling work should, in theory, offer reassurance to the decision makers that the outer bounds of the likely impacts of the proposed operation are known and understood.

Further demonstration of the applied hydraulic conductivity values during the uncertainty analysis as proposed by DPIE – Water is unlikely to be able to provide further support to decision making and would appear to be more of an academic interest pursuit.

A.6 Appendix 6 – Provision of packer test data

Hume Coal to provide raw data from the packer tests conducted for the project.

Hume Coal note that DPIE – Water are satisfied with the provision of information to meet this action. As such, no further actions or comments are required.

A.7 Appendix 7 - Impact on groundwater dependent ecosystems

This is a new issue not previously raised by DPIE - Water. Potential impacts of watertable drawdown on heritage gardens was raised in the IPC assessment report (R16) and has been assessed and addressed by Hume Coal in the IPC response report (EMM 2020a).

Recommendation 16 (R16) of the IPC assessment report stated:

> "Further information should be provided to allow the assessment of the potential impact of water table drawdown on heritage items (including gardens, plantings and landscape settings) within or in the vicinity of the Project area. The information should include confirmation of the existing level of the water table and the anticipated drawdown at both the 67th percentile and the 90th percentile."

A.7.1 Assessment methods and findings

DPIE-Water suggest that separate analysis has been undertaken to assess potential effects of the project on bores and potentially groundwater dependent heritage gardens. The input data for the assessment of potential impacts on vegetation, including heritage gardens, and existing registered bores, is derived from the same model: with gardens referencing the predicted drawdown from the groundwater model, and bores referencing the predicted drawdown within the layer of the model that the bores is deemed to be screened within. The potential impacts of watertable drawdown on heritage gardens has been assessed in Appendix G of the IPC response report ("Groundwater dependence assessment for cultural heritage landscapes and gardens"). The assessment was conducted by a team comprising an ecologist, an archaeologist, a landscape planner/registered landscape architect, arboricultural specialist, a hydrogeologist and a spatial analyst, using the inputs from the Updated Statement of Heritage Impact (Appendix F to the IPC response report) and Updated Water Assessment (EMM 2020c). This interdisciplinary approach provides a robust impact assessment that addresses the IPC recommendation.

The assessment of potential impacts on GDE (terrestrial ecosystems) used the outputs of the uncertainty analysis at 50th, 67th and 90th percentile.

All listed heritage gardens accessing shallow groundwater and part of the vegetation in the landscape conservation areas are situated above the Wianamatta Group shale. As this is a perched groundwater system with limited hydraulic connection to the underlying Hawkesbury Sandstone (where groundwater drawdown is predicted to occur), no impacts are predicted in these areas.

The remaining non-native, exotic grassland and private gardens located within the landscape conservation study areas that are predicted to experience watertable drawdown and have been identified as being at risk of water stress during periods of prolonged drought cover a small area (0.11% of the cultural landscape study area), are not classified as high priority GDEs and are not covered under any statutory requirement to manage or mitigate the potential and unlikely effects.

A.7.2 Evidence supporting conceptual understanding

The ecohydrological conceptualisation is based on information presented in the EIS, RTS and IPC response reports (including the Updated Water Assessment; Appendix B to the IPC response report). This includes groundwater level data supporting the understanding that there is limited natural vertical connectivity between the Wianamatta Group shale and the underlying Hawkesbury Sandstone aquifer (refer Section 2.4 of the Updated Water Assessment (EMM 2020c)). At groundwater monitoring sites such as at the HU0035A and B, groundwater in the shale is perched above the regional watertable and there are areas of unsaturated Hawkesbury Sandstone underlying the saturated shale (refer to Figure 2.8 of the Updated Water Assessment). At HU0035, the difference in hydraulic head between the Wianamatta Group shale and the underlying Hawkesbury Sandstone is around 15 m. In addition, the conceptual understanding is illustrated in numerous conceptual diagrams (refer Figure 2.7 of the Updated Water Assessment; Plate 4.1 and 4.2 of the Groundwater dependence assessment for cultural heritage landscapes and gardens (EMM 2020d)).

A.7.3 Make good arrangements

DPIE – Water state in their letter:

> "Of particular concern are the make good arrangements for those properties that include heritage gardens that have not previously required irrigation for maintenance. It is not apparent that those properties once affected will have a bore water volume for purposes other than garden watering (identified under existing make good arrangements) and an amount for the watering of impacted heritage gardens (not apparently identified under existing make good arrangements)."

The Hume Coal Project has provisions for make good arrangements to be made available for all registered bores that are predicted to experience greater than 2 m of drawdown as a result of the mine operation. Bores on properties with heritage gardens are already included in this assessment, so bores on these properties are already automatically included in the make good arrangements. However, it is possible that some properties have bores that are not registered with the NSW Government, in which case Hume Coal may not be aware of these and they would not be included in the impact assessment. It is also possible that some bores identified in the NSW Government register no longer exist, or are no longer used but they have still been included in the current list of bores where access to water supply will be made good. Because of this, Hume Coal will be adaptable and flexible in its approach to make good with all affected registered bore owners.

Hume Coal will ensure that all legitimate groundwater users can access the make good arrangements. In addition, Hume Coal will ensure (via active monitoring) that make good measures will be applied to offset the actual drawdown impacts as they occur, and will adjust the make good timeframe and schedule to accommodate drawdown and impacts as they occur (ie it may be slightly earlier or later than predicted). In reference to other nearby mines, such as Tahmoor, it is acknowledged that predicted impacts were greater than the actual impacts measured once mining commenced. Therefore, using data and learning from this nearby mine, Hume Coal is confident that the make good provisions outlined will absolutely address the make good requirements for the Hume Coal Project.

The requirements for make good only applies to water supply works (bores), high value GDEs and culturally significant sites. Potential impacts of watertable drawdown on heritage gardens is not a requirement of the Aquifer Interference Policy, but has been assessed by Hume Coal following recommendations from the IPC. The Hume Coal Project is not predicted to result in any groundwater related impacts on heritage gardens (see above).

Heritage gardens that are not currently or previously irrigated by groundwater abstracted from a bore, and are not predicted to be impacted by reductions in the watertable are not subject to make good, as there are no mining related impacts. The make good provisions are there to protect existing users. Should property owners with heritage gardens, who currently do not use groundwater, wish to start using groundwater, they can construct a bore themselves to access water whenever they wish, subject to any required licences and approvals. The Hume Coal Project will not desaturate the Hawkesbury Sandstone (ie there will always remain groundwater available for extraction), vegetation access to groundwater in the Wianamatta Shale will not be affected, and there will also be water available in deeper formations.

A.8 Appendix 8 – General Comments

A.8.1 DPIE – Water's "ongoing concern" with the groundwater model

Hume Coal challenges the overarching comments from DPIE - Water to DPIE regarding the appropriateness of the Hume Coal groundwater model. The 'ongoing concern' from DPIE-Water is not supported by clear technical evidence, and is not the view formed by world industry leading groundwater experts.

The NSW Government's independent groundwater peer reviewer, Hugh Middlemis of HydroGeoLogic, is an experienced, accomplished and reputable hydrogeologist and groundwater modeller, as well as an author of IESC uncertainty guidelines (Middlemis and Peeters 2018), provided input to the Australian Groundwater Modelling Guidelines (Barnett et al 2012), and was the lead author for the predecessor Murray Darling Basin Groundwater Flow Modelling Guideline (Middlemis et al 2000). The review by HydroGeoLogic (2017 and 2018) found the Hume Coal groundwater model to be suitable for mining impact assessment purposes (Class 2 confidence level) and confirmed that the model is '**fit for purpose**'.

The uncertainty analysis undertaken of the Hume Coal groundwater model is extremely detailed and of a world class standard, having been undertaken by Dr Noel Merrick, a world class groundwater modeller. The mathematics and concepts in uncertainty analysis are fundamental to the results and their interpretation. This is a critical reason why the IPC and the NSW Government can rely on the findings of the experience and expertise of the independent peer reviewer appointed by DPE (now DPIE).

Hume Coal engaged Dr Townley of GW-SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the RTS groundwater model. The experience and qualifications of the reviewer are summarised in Attachment 1 of his review. The full review is contained in Annexure C of Appendix B to the IPC response report (Townley 2020).

With a view to resolving ongoing differences of opinion between DPIE-Water and Hume Coal on the groundwater modelling, Townley (2020) was engaged to conduct an independent and systematic review focusing on items raised by the IPC and DPIE – Water in the past. Dr Townley's review finds that the modelling undertaken for the Hume Coal Project is **fit for purpose**, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the Project area (Townley 2020).

Consultation between Hume Coal and the NSW Government on the groundwater data for the project, the conceptual model and the numerical groundwater model has occurred over the past ten years. However, the findings of the peer reviews completed by leading groundwater modelling experts appears to be continually overlooked, or not relied upon, by DPIE-Water.

A.8.2 Additional model runs with revised hydraulic conductivity

DPIE – Water are requesting that the groundwater model be updated to include using:

1. higher hydraulic conductivity (Kx and Ky) across all model layers, including as part of sensitivity analysis; and

2. hydraulic conductivity higher than 10^{-2} m/d.

The modelling work has already assessed hydraulic conductivities over a large range. This has been reported in the EIS, RTS and IPC response report (including Appendix B to that report).

DPIE – Water is not correct in regarding specific capacity analysis (the source of values higher than 10^{-2} m/d) as "most reliable".

Model simulations using higher hydraulic conductivity values (horizontal, in the x and y direction) in the Hawkesbury Sandstone will not result in greater drawdown (when treated in isolation of storage parameters).

In fact, the change will have the opposite effect, less drawdown and area of influence. As such, the modelling work conducted for the project can be considered conservative with regard to drawdown, and not “minimum predicted impact” as suggested by DPIE-Water.

A.8.3 Addressing prior DPIE-Water recommendations

DPIE – Water are suggesting that Hume Coal have not addressed prior recommendations made by DPIE-Water in the review of the EIS and RTS. Hume Coal do not agree with this suggestion and have absolutely considered and addressed prior recommendations by DPIE-Water, and have specifically sought to do this by engaging world class peer reviewers to consider DPIE-Water comments and recommendations specifically.

The specific purpose of the “DPIE Water Report” (EMM 2020b) prepared as part of the IPC response report is to address all submissions made by DPIE-Water in the review of the EIS and RTS, and items raised and minuted in the meeting held between DPIE-Water hydrogeologists, DPIE Planning and Assessment personnel, Hume Coal personnel, EMM and HydroSimulations/SLR Consulting hydrogeologists on 30 July 2019. In addition, consultation between Hume Coal and the NSW Government on the groundwater model has occurred over the past ten years.

A.8.4 Additional model review

The Hume Coal groundwater model has undergone numerous reviews by many leading experts in groundwater modelling in Australia, including a review by the then DPE’s expert HydroGeoLogic.

As outlined by EMM in the RTS (2018) and Dr Townley (2020), the groundwater model has undergone greater than 10 reviews and include:

- on behalf of Hume Coal: Dr Noel Merrick, Dr Frans Kalf, Neil Manewell, Liz Webb and Dr Lloyd Townley;
- on behalf of regulators: Hugh Middlemis (HydroGeoLogic; twice), representatives of IESC, DoI – Water hydrogeologists and Water NSW hydrogeologists; and
- on behalf of the community: Dr Steven Pells, Doug Anderson, Chris Jewell and John Lee.

The following reviewers found that the groundwater model is fit for purpose and appropriate for assessing the impacts of the Hume Coal Project:

- Dr Noel Merrick, acting as independent reviewer of the Coffey (2016a) work and prior to taking ownership of the groundwater model;
- Dr Frans Kalf, independent reviewer of the EIS and RTS groundwater model;
- Neil Manewell who conducted an audit of the EIS groundwater model;
- HydroGeoLogic, acting as an expert reviewer for the then DPE and conducted reviews of the EIS and RTS groundwater model versions; and
- Dr Townley (2020) who conducted an independent expert review of the groundwater modelling work conducted as part of the EIS and RTS.

Hume Coal engaged Dr Townley of GW-SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the RTS groundwater model (Townley 2020).

DPIE advised Hume Coal, following the release of the IPC report, that they would not be willing to jointly engage an independent expert, so Hume Coal proceeded to engage Dr Townley for that role in order to respond to the IPC.

Dr Townley's review found that the modelling undertaken for the project is fit for purpose, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the project area (Townley 2020).

Hume Coal contend DPIE – Water's suggestion that further independent review is warranted on top of the substantial reviews this groundwater model has already been subject to.

A.8.5 Model adequacy

i Model class

Townley (2020) concluded that modelling undertaken for the Hume Coal Project is fit for purpose, for the purpose of predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the Project area. This conclusion is consistent with the previous expert reviews by HydroAlgorithmics Pty Ltd (2016), Kalf and Associates Pty Ltd (2016) and HydroGeoLogic (2017, 2018) on behalf of DPE that concluded the original EIS model and subsequently the Modified EIS Model (RTS model) were fit for purpose.

Townley (2020) notes that Hume Coal has modified the design of its mine during the process of environmental impact assessment, in order to ensure that potential environmental impacts are significantly lower than they would be with mining methods used in many other projects.

With respect to the discussion of the confidence level classification for the model, following extensive review of the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and their intent, Townley (2020) concludes that the model is a **Class 2 model**, and has **some elements of a Class 3 model**. Earlier reviews by HydroGeoLogic (2017) and HydroSimulations (2018) considered all aspects of the model and argued that the model is Class 2.

Townley (2020) agrees that the model is Class 2 with Class 3 elements and also places special emphasis on two key indicators related to:

- the length of time for which predictions are made relative to the time period of calibration, and
- the magnitude of future stresses relative to historical stresses during the calibration period.

These two key indicators often lead to models of greenfields mining projects being considered Class 1, but this conclusion is not reasonable for the Hume Coal Project. Because transient data are available during historical mining at the Berrima Colliery, the modelling undertaken for the Hume Coal Project should be judged to be Class 2.

ii Model calibration

Dr Townley (2020) continues in his review stating:

- that the modelling approach is appropriate and consistent with the Australian Groundwater Modelling Guidelines;
- the calibration methodology is consistent with the Australian Groundwater Modelling Guidelines. The calibration is impressive because this is one of the first times that four separate types of data have been used for calibration in a model for a proposed mining project. This is a challenging but robust way to calibrate and has been done in an attempt to balance the different sources of information;
- the calibration methodology is supported by the Australian Groundwater Modelling Guidelines (Barnett et al 2012), which explains in Recommendation 5.4 that over-emphasis on fitting a model to observations of piezometric heads using an arbitrary value of SRMS is not appropriate. Therefore, the

attempt to fit the model to four separate data sets is aligned to the recommendations of the Australian Groundwater Modelling Guidelines; and

- regional scale groundwater models can never predict watertable elevation or piezometric heads with an accuracy of less than 1 m. No reference to this requirement was provided, and it is unreasonable to suggest that this level of accuracy is ever possible.

A.9 Reference to information previously provided

To assist DPIE and IPC in their assessment, Table 2 provides lists key information previously provided in technical reports from the EIS, RTS and IPC response report phases of the project.

Table 2 Reference to relevant information in previous reports

Type of information	Report	Section in report
Conceptual geological understanding	EIS Water Assessment (EMM 2017)	Chapter 6.1 and 6.2
	Groundwater Assessment Volume 1: Data Analysis (Coffey 2016b)	Chapter 4
	Updated Water Assessment (EMM 2020c)	Chapter 2.2
Cross-sections	EIS Water Assessment (EMM 2017)	Chapter 6
	Groundwater Assessment Volume 1: Data Analysis (Coffey 2016b)	Chapter 6
	DPIE Water Report (EMM 2020b)	Chapter 2
Conceptual hydrogeological model	EIS Water Assessment (EMM 2017)	Chapter 6.3-6.10 and 7
	Groundwater Assessment Volume 1: Data Analysis (Coffey 2016b)	Chapter 5 Subsurface hydraulic properties Chapter 6 Groundwater levels Chapter 7 Groundwater inflows to Berrima mine void Chapter 8 Groundwater character Chapter 10 Hydrogeological conceptual model
	Revised Water Impact Assessment for the RTS (EMM 2018)	Chapter 6.3-6.10 and 7
	Updated Water Assessment (EMM 2020c)	Chapter 2 • 2.3 Hydrogeological setting • 2.4 Conceptual hydrogeological understanding
Groundwater model class	EIS Water Assessment (EMM 2017)	Chapter 3.6
	Revised Water Impact Assessment for the RTS (EMM 2018)	Chapter 8
	Updated Water Assessment (EMM 2020c)	Chapter 3
	Revised Groundwater Modelling for Response to Submissions (HydroSimulations 2018)	Chapter 3.2
Model calibration	EIS Water Assessment (EMM 2017)	Chapter 8
	Revised Water Impact Assessment for the RTS (EMM 2018)	Chapter 8
	Revised Groundwater Modelling for Response to Submissions (HydroSimulations 2018)	Chapter 3 and 5
Model layers and representation of geology	Revised Water Impact Assessment for the RTS (EMM 2018)	Chapter 8
	Revised Groundwater Modelling for Response to Submissions (HydroSimulations 2018)	Chapter 3 and 4
	Updated Water Assessment (EMM 2020c)	Chapter 3.5

Table 2 Reference to relevant information in previous reports

Type of information	Report	Section in report
Model sensitivity	Revised Water Impact Assessment Report (EMM 2018)	Chapter 8.6
	Revised Groundwater Modelling for Response to Submissions (HydroSimulations 2018)	Chapter 7
Model predictive uncertainty	Revised Groundwater Modelling for Response to Submissions (HydroSimulations 2018)	Chapter 7
	Revised Water Impact Assessment Report (EMM 2018)	Chapter 8.6
	Revised Groundwater Modelling for Response to Submissions (HydroSimulations 2018)	Chapter 7
	DPIE Water Report (EMM 2020b)	Chapter 6
Make good strategy	Revised Water Impact Assessment Report (EMM 2018)	Chapter 11 and Appendix M (Make good strategy report)
	Updated Water Assessment (EMM 2020c)	Chapter 4

A.10 References

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Appendix B2 – Applicant Response to Water NSW advice

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

21 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS
RESPONSE TO AGENCY COMMENTS – WATER NSW.

Dear Mandana,

Thank you for providing the Agency comments.

Please find attached the response by Hume Coal and EMM regarding the commentary provide by Water NSW.

Regards,

Rod Doyle
Project Manager

Hume Coal Pty Limited

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21 August 2020

Mandana Mazaheri
A/Team Leader, Planning and Assessment
Department of Planning Industry and Environment
12 Darcy Street
Parramatta NSW 2124

Re: Hume Coal response to WaterNSW advice to Department of Planning Industry and Environment

To Mandana,

This letter provides a detailed response to the comments included in a letter from WaterNSW addressed to Department of Planning, Industry and Environment (DPIE) Planning and Assessment, dated 17 June 2020 (WaterNSW 2020). The letter outlines comments and feedback on the response by Hume Coal to the Independent Planning Commission (IPC) assessment report dated 27 May 2019 (the "IPC response report").

The focus of WaterNSW's comments relate to the Updated Water Assessment (Appendix B) prepared by EMM Consulting (dated April 2020). The following sections provide a summary of Hume Coal responses to the WaterNSW comments. Direct quotes from the WaterNSW letter are shown in boxed text throughout the letter.

1 Hume Coal response

General comments from WaterNSW

> *It is noted that the residual concerns of WaterNSW outlined in our previous response to the Response to Submissions (RTS) report were not specifically addressed in this latest response, however some of WaterNSW's concerns were similar to those concerns raised by the IPC.*

Hume Coal responded to recommendations made in the *Hume Coal and Berrima Rail Project Independent Planning Commission Assessment Report in relation to the Minister for Planning's request dated 27 May 2019* (the "IPC assessment report"). Two recommendations were made in the IPC assessment report in relation to surface water, these were:

- R7 - The Applicant is to confirm whether the provisional water treatment plant does form part of the Project – and if so, provide suitable information to permit an appropriate assessment of its impacts.
- R8 - Should underground emplacement and water impounded have to cease for any reason, the Applicant is to confirm how long under normal mining operations it would take for the reject emplacement stockpile and primary water dam to reach capacity.

As outlined in Section 6 and 8.4.2 of Volume 1 of the RTS report (EMM 2018a) and multiple sections of the RTS revised water assessment (EMM 2018b), excess water will be managed by storing it in the primary water dam (PWD) and pumping to the void/underground behind sealed bulkheads. A water treatment plant (WTP) was included in the RTS assessment as a provisional item only. However, as the project water balance work has assessed that the PWD has adequate capacity to store excess water under all (107) climate scenarios, the WTP will not be required. Therefore, this item (R7) has not been assessed further.

The RTS Goldsim water balance has been used to respond in part to R8, assessing how long under normal mining operations it would take for the PWD to reach capacity. A summary response is provided in Section 6.5.1 of the Hume Coal IPC response report (EMM 2020a). A detailed response is provided in Section 5 of the Updated Water Assessment (EMM 2020b).

The IPC findings relating to surface water and Hume Coal's responses were presented in the IPC response report (EMM 2020a) and are also presented in Table 1 below.

Table 1 Hume Coal response to IPC findings – Surface water

Reference number	IPC's finding	Hume Coal response
183	The Commission has carefully considered the additional information in the Applicant's Submission and its responses to the Commission's questions regarding surface water. The Commission has also noted the response of the Resources Regulator which has indicated that successful storage of water occurs at a number of NSW mines. This information suggests that the concerns expressed by the Department's PAR and those raised at the public hearing on the possible impact of the Project on surface water could be resolved satisfactorily if the mine design, safety of proposed operations and underground emplacement are demonstrated to be able to be implemented as proposed in the Project.	Section 4 of the Hume Coal Response to the IPC assessment report provides information regarding mine method and safety (EMM 2020a).
184	The Commission finds that that the Department may not have adequately assessed the potential impacts of the project on surface water because, whilst the Commission agrees that mine water should not be disposed to surface watercourses, it does not agree with the Department's suggestion that safety risks may necessarily result in the transfer of mine water to the surface with subsequent discharge into watercourses.	Noted. Excess water will not be discharged to watercourses. The work completed as part of the RTS shows that the PWD has sufficient capacity to store excess water under all 107 assessed climate scenarios.
185	At this stage of its assessment the Commission finds that it is not satisfied with the information provided up to this point regarding surface water impacts because of disagreement over the acceptability of the mine design and the consequent ability to store water underground.	Section 4 of the Hume Coal Response to the IPC assessment report (EMM 2020a) provides information regarding mine method and safety. As outlined in previous submissions to the NSW government, the proposed mine design is based on long established mine principles. Many mines also store water underground. Notably, water will be stored downdip of the sealed bulkheads in the majority of the mine workings, with the exception of one panel towards the end of mine life where the seam dip flattens out. There is therefore no information to support claims that the mine design, combined with the storage of water underground, will result in serious safety risks, therefore the claims are rejected. The risk of inrush and inundation in relation to the Project, has been addressed in Section 8.2 of Russell Howarth & Associates (2020).

Hume Coal has addressed the recommendations raised in the IPC assessment report and contest WaterNSW's concern that residual issues remain. Responses to WaterNSW's concerns are listed below.

WaterNSW key concern

Hume Coal (the applicant) has not adequately demonstrated that the Hume Coal Mine project (SSD-7172) will have a Neutral or Beneficial Effect (NorBE) on water quality.

This item has been addressed in the RTS report (EMM 2018a,b) and was not raised by the IPC in their assessment (findings or recommendations).

It is noted that the NorBE Tool (SCA 2015) is not applicable to the Hume Coal Project given it is a State Significant Development (SSD) and, as such, is not a Designated Development.

Clause 10(2) of the SEPP (Sydney Drinking Water Catchment) 2011 provides that the NorBE Tool must be used "if the proposed development is one to which the NorBE Tool applies". Section 4.5 of SCA (2015) states that the development types to which the NorBE Tool apply are listed in Appendix 1 - Table A1. Table A1 includes 'designated development' but does not include SSD.

Although an underground coal mine can be a 'designated development' per Schedule 3, Clause 11 of the EP&A Regulation, Section 4.10(2) of the EP&A Act specifically excludes SSD from being a designated development, "despite any such declaration". As such, an underground coal mine that is an SSD is not a Designated Development. Therefore, the Hume Coal project does not fall into any of the classes of development listed in table A1 of SCA (2015), and as such, the NorBE Tool does not apply to the Hume Coal Project.

The conclusion that the NorBE Tool does not and ***should not*** apply to SSDs was accepted by the Land and Environment Court in *4nature Incorporated v Centennial Springvale Pty Ltd* [2016] NSWLEC 121 (at paragraph 143) and not overturned by the New South Wales Court of Appeal in *4nature Incorporated v Centennial Springvale Pty Ltd* [2017] NSWCA 191 (at paragraph 60).

Despite this, Hume Coal have assessed the potential project impacts of the project against the NorBE criteria. As stated in Section 3.5.14 of the RTS revised water assessment (EMM 2018b), achieving NorBE has been a fundamental goal for Hume Coal, and it has received detailed consideration in the mine design and water infrastructure and management. A primary objective has been to limit the potential for water releases from the project area. The assessment and comparison to NorBE criteria is documented in Section 10.2 of the RTS revised water assessment (EMM 2018b) and the results indicate that pollutant concentrations modelled during operations scenario are equal to or lower than the pre-mining scenario between the 50^{th} and 98^{th} percentiles, and **are therefore compliant with NorBE criteria (on water quality)**.

Water balance modelling demonstrates that the proposed storage capacity of the PWD is sufficient to contain and manage all surplus mine water and internally generated rainfall runoff, in conjunction with pumping surplus water to the void behind sealed bulkheads. Therefore, treatment and release of water from the PWD is not required.

WaterNSW's concern relates to the uncertainty associated with the unconventional mining method and proposal for re-injecting mine water and coal rejects into the mine voids and sealing those voids with bulkheads. This is a highly specialised technical area and there appears to be residual disagreement between the relevant experts about the likely effectiveness of the proposed re-injection and storage of mine water underground. Given this context of uncertainty, WaterNSW considers a risk-based approach should be adopted.

This concern has been addressed in the RTS report and IPC response report, including additional peer review. Hume Coal contest that there is any residual uncertainty related to the mining method and appropriateness and ability to store rejects and water in the mine voids.

As outlined in previous submissions to the NSW Government, the proposed mine design is based on long established mine principles. Many mines also store water underground. Notably, water will be stored downdip of the sealed bulkheads in the majority of the mine workings, with the exception of one panel towards the end of mine life where the seam dip flattens out. There is therefore no information to support claims that the proposed mine design, combined with the storage of excess mine water underground, will be ineffective, therefore the claims are rejected.

To assist with responding to the IPC assessment report, Hume Coal engaged Russell Howarth and Associates Pty Limited as an independent expert with over 40 years of practical mining experience in innovative coal mining technology. Russell Howarth and Associates reviewed the feasibility and safety of the proposed mining technique, including the project's consequent ability to store excess mine water underground, with a view to resolving ongoing differences of opinion.

The risk of inrush and inundation in relation to the project, has been addressed in Section 8.2 of *Hume Coal Project Independent Planning Commission Recommendations 1 and 2: Independent review of residual issues of disagreement between the Applicant and the Department of Planning associated with the Hume Coal Project* (Russell Howarth & Associates 2020), Appendix A to the IPC response report (EMM 2020a). Russell Howarth's review states:

> "the mine layout maximizes recovery of the resource and results in a long-term stable pillar system that keeps mining induced surface subsidence impacts to an imperceptible level, minimises hydrogeological impacts on subsurface strata above the Wongawilli Seam, and **provides an ability to store mining wastes and excess water underground"** (Russell Howarth & Associates 2020)."

The independent reviewer did not identify hazards associated with underground excess water storage at the Hume Coal Project.

Hume Coal's water management approach (managing and storing water above ground in the PWD and pumping it underground into the mine voids to allow continued and safe water storage at surface) is consistent with water management approaches for other approved mining projects. Most recently, the Vickery Mine Extension project was approved by DPIE on 12 August 2020. The water management for this project involves the pumping of mine water to mine water dams, and in the event that these dams reach 95% capacity, excess water would be pumped to an old open cut pit. This has been modelled to occur under many of the 98 climate scenarios modelled for the Vickery Mine Extension. While the location for storing excess water at Vickery Mine Extension differs to Hume Coal's approach, Hume Coal's approach to water management is to transfer water underground as soon as panels are available underground, rather than storing water above ground until the dam(s) reach 95% capacity. Hume Coal's approach to excess water management is arguably more sustainable, as the excess water is allowed to return to its original source (ie groundwater) much sooner, rather than being stored above ground and lost to evaporation.

> *As the applicant has now confirmed that the project does not include a water treatment plant, WaterNSW is therefore concerned that this could result in untreated mine water discharges into Oldbury Creek, which forms part of the Warragamba Dam catchment. Any discharges of untreated mine water into Oldbury Creek would have a detrimental effect on surface water quality in Sydney's drinking water catchment and would not achieve a NorBE on water quality.*
>
> *Unless the uncertainty and disagreement about the likely effectiveness of re-injection of mine water can be resolved, WaterNSW considers that contingency measures for the management of any discharges of untreated mine water from the primary water dam should be specified and designed upfront, in order to ensure the NorBE test on water quality is satisfied.*

As reported in the RTS (EMM 2018a,b), the water balance model (in all 107 climate sequences modelled) indicates that the PWD has adequate capacity to store excess supply and that treatment and release will not be required.

Hume Coal are committed to operating as a zero discharge mine and will not discharge untreated water to the environment. In addition, despite NorBE not being applicable to SSD projects, Hume Coal have committed to complying with NorBE criteria on water quality and have demonstrated through the assessment that this is feasible, implementable and achievable.

As stated above, Hume Coal contest that there is any residual uncertainty related to the mining method and appropriateness and ability to store rejects and water in the mine voids. As such, additional assessment is not required.

Groundwater and surface water quality

> *WaterNSW's residual issues about water quality from its response to the RTS report still exist, including potential impacts on groundwater quality, and potential pollution of surface water due to reductions in dilution of baseflow to Medway Rivulet and Wingecarribee River. These issues have not been adequately addressed the applicant's latest response as it continues to rely to the information provided in the RTS Report.*

The potential for changes to groundwater and surface water quality as a result of the Hume Coal Project has been assessed in Section 10.2 and 11.2 of the RTS revised water impact assessment (EMM 2018b). The IPC assessment report did not require this to be reassessed.

The assessments conducted as part of the EIS, RTS and IPC response report are industry leading, including conducting detailed numerical groundwater flow modelling (and industry leading predictive uncertainty analysis), hydrogeochemical modelling, surface water balance modelling, surface water flow assessment and modelling (with additional sensitivity analysis) and surface water quality modelling. In addition, the groundwater assessments have undergone independent technical review and have been confirmed **fit for purpose**: HydroGeoLogic (2017 and 2018), Kalf and Associates (2016), GW-SW Pty Ltd (Townley 2020) and others. The surface water model also underwent external auditing by Dr Justin Bell.

Assessment of the project considered the NSW Aquifer Interference Policy (AIP), the Commonwealth Department of Environment *Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (DoE 2013) and the *Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals* (IESC 2015). In addition, the principles of NorBE on water quality have been adopted for the project impact assessment.

There is no predicted change in the beneficial use category of the groundwater source beyond 40 m from the mining zone (in accordance with AIP). As per the *Significant impact guidelines* (DoE 2013), groundwater quality changes are considered **insignificant** (EMM 2018b).

The effects of baseflow reduction and, separately, coal dust deposition on streamflow water quality are predicted to have a neutral effect with respect to the existing beneficial use category. As per the *Significant impact guidelines* (DoE 2013), surface water quality changes are considered **insignificant** (EMM 2018b).

Given the insignificant predicted water quality impacts, the independent peer reviews, and the fact the IPC assessment report required no re-assessment of water quality impacts, Hume Coal contend that there are any outstanding issues relating to water quality impacts that warrant additional attention or assessment.

Loss of yield

> *WaterNSW reiterates that it considers that any reduction in yield to watercourses within the area potentially affected by mining must be negligible and notes that the applicant has not provided any new information relying on the yield calculations presented in the RTS report.*

Potential reduction in yield to watercourses (due to baseflow losses and reduction in surface water catchment areas) has been assessed in the EIS and Section 10.1 of the RTS revised water impact assessment (EMM 2018b). The IPC assessment report did not require this to be reassessed.

The assessments conducted as part of the EIS, RTS and IPC response report are to an industry standard level and apply hydrological methods and models applied widely across NSW and Australia, including conducting detailed surface water balance modelling, surface water flow assessment and modelling (with additional sensitivity analysis) and surface water quality modelling. In addition, the groundwater assessment has undergone multiple independent technical reviews and has been confirmed fit for purpose: HydroGeoLogic (2017 and 2018), Kalf and Associates (2016), GW-SW Pty Ltd (Townley 2020) and others. The surface water model also underwent external auditing by Dr Justin Bell.

Changes to surface water flows due to the project are predicted to be negligible overall. As per the *Significant impact guidelines* (DoE 2013), flow and yield changes for users and the environment are considered **insignificant** (EMM 2018b).

Given the insignificant predicted impacts on surface water flows (including baseflow), the independent peer reviews, and the fact the IPC assessment report required no re-assessment of these impacts, it is Hume Coal's position that there are no outstanding issues relating to streamflow that warrant additional attention or assessment.

2 Summary

Hume Coal have adequately assessed the potential for quantity and quality changes to surface water and groundwater as a result of the project. Hume Coal contest the assertion by WaterNSW that issues raised in the EIS process have not been adequately addressed. The information within this letter provides reference to sections within the RTS and IPC response report where these items have been described and addressed.

The specific purpose of the IPC response report (EMM 2020a) was to address findings and recommendations raised by the IPC. In preparing the IPC assessment report, the IPC considered all information provided to it, including advice from NSW Government departments. Accordingly, the issues described in WaterNSW's letter (2020) were not raised by the IPC.

As per the *Significant impact guidelines* (DoE 2013), the results of the water assessments completed for the Hume Coal Project predict:

- flow and yield changes for users and the environment will be **insignificant**;
- surface water quality changes will be **insignificant**;
- reductions to baseflow will be **insignificant**;
- water quality changes due to coal dust deposition will be **insignificant**; and
- water quality changes for private landholder bores will be **insignificant**.

Given the above, Hume Coal contend that no further assessment is required for surface water quality and quantity changes. Hume Coal stand by the methods and findings of the assessments conducted for the project in the EIS, RTS and IPC responses phases.

Yours sincerely

Kate Holder
Associate Hydrogeologist
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3 References

Commonwealth of Australia Department of the Environment (DoE) 2013*, Significant impact guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources*, Australian Government.

EMM Consulting Pty Ltd 2018a, Hume Coal Project and Berrima Rail Project - Response to Submissions Report Main Report. Volume 1. Prepared for Hume Coal Pty Ltd. June 2018. Reference J12055.

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2020b, *Hume Coal and Berrima Rail Project – Updated water assessment in response to recommendations R4, R5, R6 and part of R8 within the Independent Planning Commission Assessment report dated 27 May 2019*. Prepared for Hume Coal Pty Ltd, March 2020. Reference J12055.

Hydrogeologic 2017, *Hume Coal Project EIS Independent Expert Review Groundwater Modelling*, prepared for NSW Department of Planning and Environment.

2018, *Hume Coal Project EIS, Independent Expert Review, Groundwater Modelling*, 16 October.

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Kalf and Associates 2016, KA Peer Review of Coffey Groundwater Modelling Assessment of the Hume Coal Project. Prepared for Hume Coal Pty Ltd.

Russell Howarth and Associates Pty Ltd 2020, *Hume Coal Project Independent Planning Commission Recommendations 1 and 2: Independent review of residual issues of disagreement between the Applicant and the Department of Planning associated with the Hume Coal Project*. Prepared for Hume Coal Pty Ltd, January 2020. Reference HUMECOAL RH 01.

Sydney Catchment Authority (SCA) 2015, Neutral or Beneficial Effect on Water Quality Assessment Guideline, NSW Government.

Townley L 2020, Review of Groundwater Modelling Undertaken for the Hume Coal Project. Prepared for EMM Consulting Pty Ltd. GW-SW Pty Ltd. 16 March 2020.

WaterNSW 2020, *SSD-7171 and SS-7172: Hume Coal Mine and Berrima Rail Projects Hume Coal's Response to the Independent Planning Commission*. Letter provided to Department of Planning Industry and Environment, 17 June 2020.

Appendix B3 – Applicant Response to NSW Environment Protection Authority advice

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21 August 2020

Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA NSW 2124

Re: Hume Coal Project - Addendum to Updated Noise Assessment

Dear Ms Mandana,

1 Introduction

EMM Consulting Pty Limited (EMM) has been requested by Hume Coal Pty Limited (Hume Coal) to prepare a response to the *Hume Coal Project – Comments on Hume Coal's Response to IPC Noise Recommendations* letter (NSW Environmental Protection Authority (EPA) 10 June 2020) (EPA letter) to the NSW Department of Planning, Industry and Environment (DPIE).

The EPA letter is a response to the *Updated Noise Assessment in response to recommendations R10 and R11 within the Independent Planning Commission Assessment Report* (EMM May 2020) (Updated Noise Assessment).

The EPA letter confirms that in-principle they agree with the assessment method and outcomes presented in the Updated Noise Assessment. Notwithstanding, throughout the Environmental Impact Statement (EIS), Response to Submission (RTS) and Independent Planning Commission (IPC) assessment process, there were changes in property ownership and NSW EPA and DPIE noise policy, which had implications on assessment outcomes, for which the EPA has requested clarification.

The purpose of this letter is to clarify the items raised by the EPA, which are mainly in relation to property ownership and voluntary mitigation and acquisition entitlements.

2 Review of mapping

The EPA recommended "that the location of marginally and significantly affected properties be clarified in an updated map prior to consideration of any Approval" (p.1 letter).

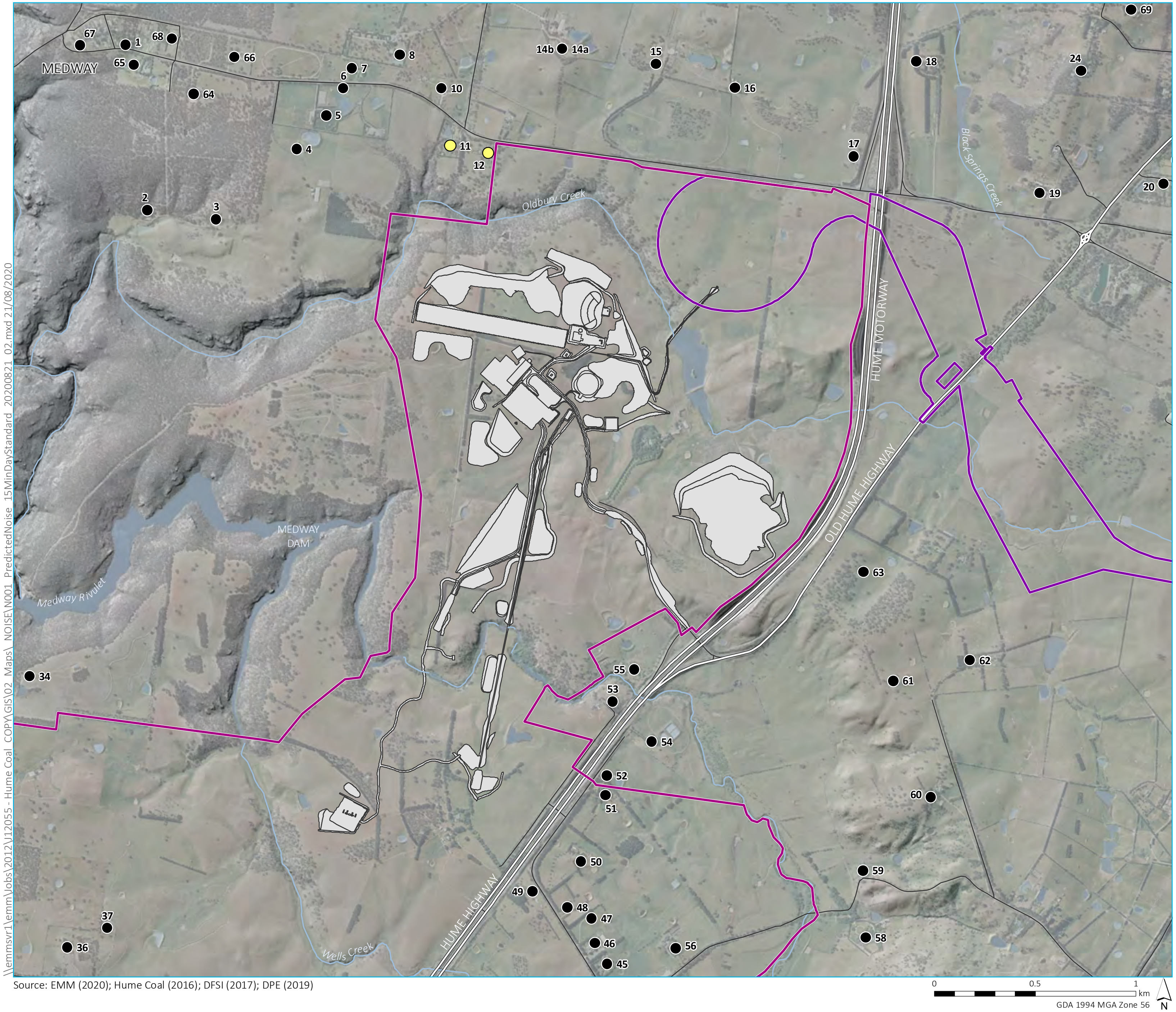
The EPA recommended "that the location of marginally and significantly noise affected properties be clarified in the report and that a revised map be drawn showing the final locations and updated status of noise impacts and VLAMP mitigation" (p.1 attachment to letter).

Chapter 14 of the *Hume Coal Project and Berrima Rail Project – Response to Submissions – Main Report* (EMM, June 2018) contained the following figures mapping the classification of noise affected residential properties:

- Figure 14.2 - Predicted $L_{Aeq, 15min}$ noise levels for operations, day, calm weather;

- Figure 14.3 - Predicted $L_{Aeq, 15min}$ noise levels for operations, night, calm weather; and
- Figure 14.4 - Predicted $L_{Aeq, 15min}$ noise levels for operations, night, adverse weather.

There have been some changes to these maps which are explained in the Updated Noise Assessment (EMM 2020). EMM has updated these maps which are presented in Figure 2.1 to 2.3 as requested by the EPA.



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KEY

- Hume Coal Project area
- Berrima Rail Project area
- Major road
- Minor road
- Named watercourse
- Waterbody
- Surface infrastructure area direct disturbance footprint

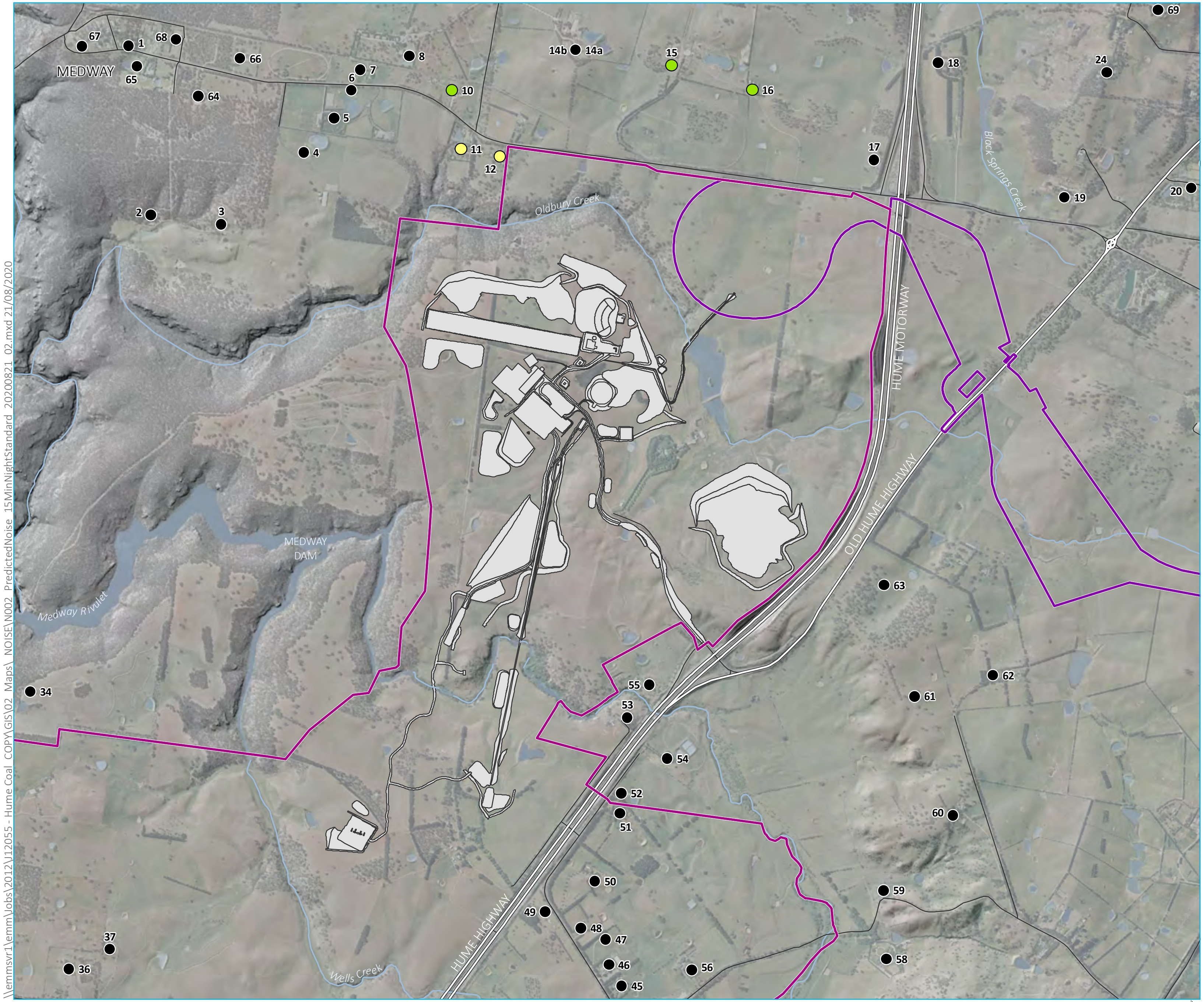
Characterisation of residual noise level

- Complies
- Marginal

Predicted $L_{Aeq,15min}$ noise levels for operations, day, standard weather

Hume Coal and Berrima Rail Project
Addendum to Updated Noise Assessment
Figure 2.1

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)



KEY

- Hume Coal Project area
- Berrima Rail Project area
- Major road
- Minor road
- Named watercourse
- Waterbody
- Surface infrastructure area direct disturbance footprint

Characterisation of residual noise level

- Complies
- Negligible
- Marginal

Predicted $L_{Aeq,15min}$ noise levels for operations, night, standard weather

Hume Coal and Berrima Rail Project
Addendum to Updated Noise Assessment
Figure 2.2

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 0.5 1 km
GDA 1994 MGA Zone 56
N

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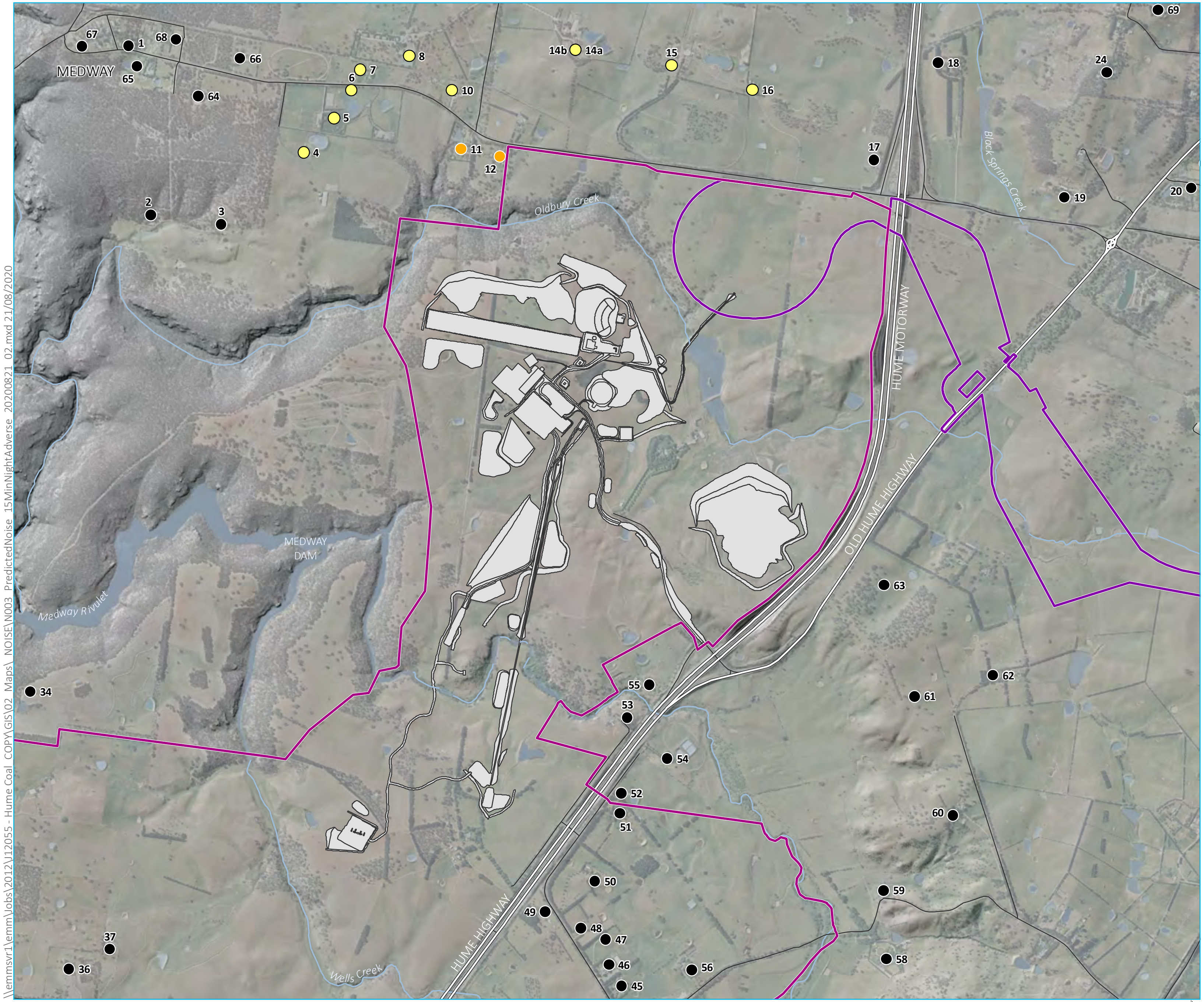

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Major road
- Minor road
- Named watercourse
- Waterbody
- Surface infrastructure area direct disturbance footprint

Characterisation of residual noise level

- Complies
- Marginal
- Significant

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 0.5 1 km

GDA 1994 MGA Zone 56

N

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Predicted $L_{Aeq,15min}$ noise levels for operations, night, adverse weather

Hume Coal and Berrima Rail Project
Addendum to Updated Noise Assessment
Figure 2.3

3 Clarification of noise impacts at locations 10, 11, 12 and 13

> The EPA states "the updated noise assessment also states that under the updated VLAMP, assessment locations (11 and 12) are predicted to experience significant residual noise levels and are therefore entitled to voluntary acquisition. However, no description or diagram has been provided showing the location of the affected properties" (p.1 attachment to letter).
>
> The EPA state "The EPA's review of the original EIS contains a map of affected receivers (attached below from EIS, Volume 7, Appendix I, Noise and Vibration Assessment Report). The map shows that receiver number 12 and 13 may be significantly affected by noise and are entitled to voluntary acquisition. There is no receiver location 11. However, Figure 14.4 of the Response to Submissions shows receivers locations 10 and 11 but no receiver 13.

Table 3.1 provides an overview of potentially noise affected properties identified throughout the approval process to date.

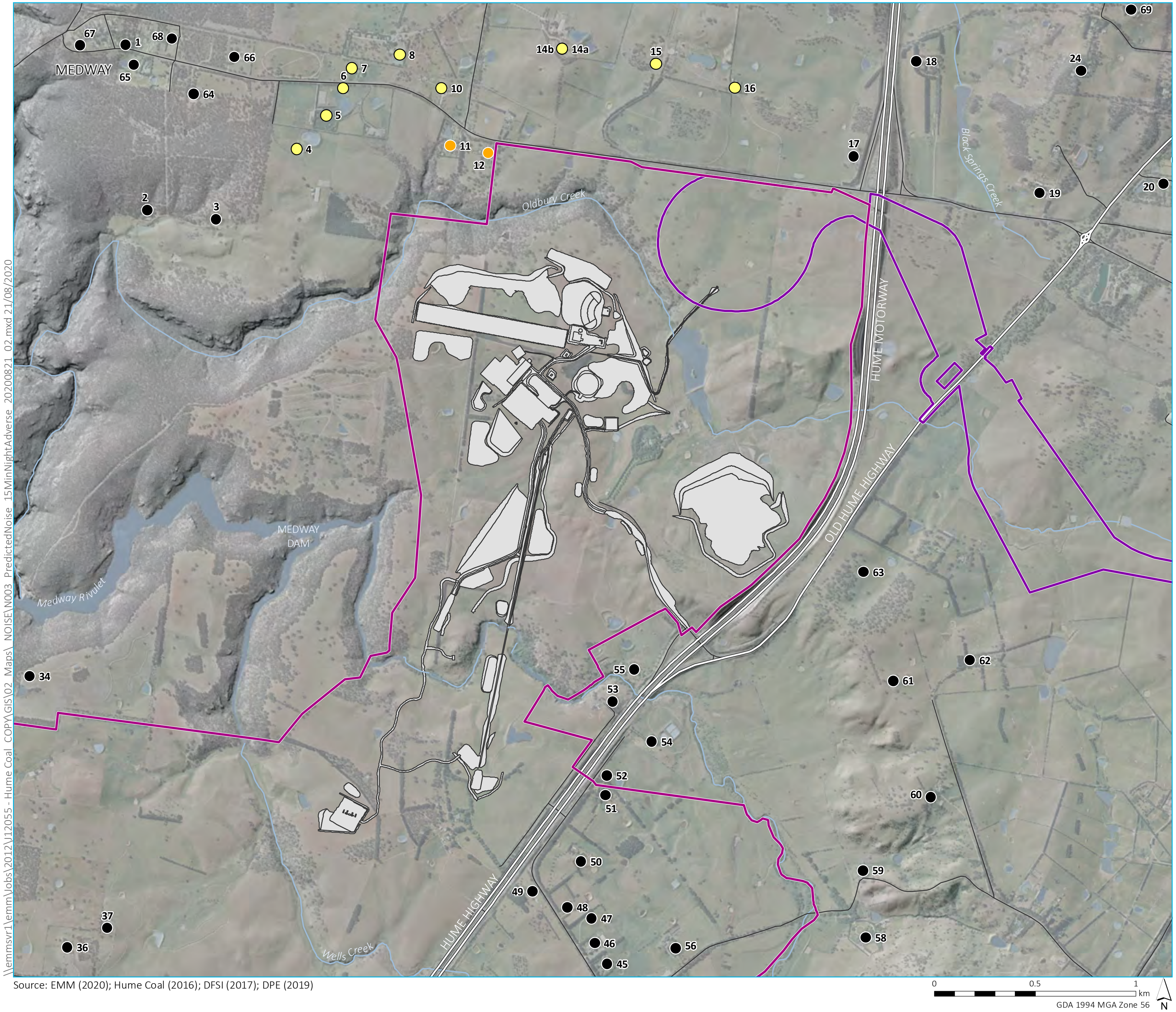
Table 3.1 Noise affected properties identified through the assessment process

Location	EIS INP (2000) & VLAMP (2014)	RTS INP (2000) & VLAMP (2014)	IPC NPfI (2017) & VLAMP (2018)
	Overall characterisation of impacts (VLAMP)		
Locations 4, 5, 6, 8, 10, 14, 15, 16	Moderate	Moderate	Marginal
Location 7	Negligible	Negligible	Marginal
Location 11	Pending acquisition	Significant	Significant
Location 12	Significant	Significant	Significant
Location 13	Significant	Acquired	Acquired

Location 10 has been mapped in the EIS and RTS. The application of the NPfI (2017) and VLAMP (2018) has reduced the overall VLAMP characterisation of this location from 'moderate' to 'marginal', as is the case for Locations 4, 5, 6, 8, 14, 15 and 16. Location 10 is not predicted to exceed the day project noise trigger level (PNTL), as shown to comply on Figure 2.1. However, during the night period the predicted noise levels exceed the PNTL for both the 'standard' and 'adverse' (noise-enhancing) conditions, respectively categorising Location 10 as 'negligible' for standard night conditions (Figure 2.2) and 'marginal' for adverse night conditions (Figure 2.3). As mentioned above and in Table 3.1 the overall characterisation of Location 10 under the VLAMP (2018) is 'marginal' (Figure 3.1).

Location 11 was excluded from noise assessment during the EIS, as Hume Coal was in the process of purchasing this property. When the purchase did not eventuate, Location 11 was assessed during the RTS phase, with its location mapped in Chapter 14, Figures 14.1 to 14.4 of the *Hume Coal Project and Berrima Rail Project – Response to Submissions – Main Report* (EMM, June 2018).

Section 14.1.1 (v) of the RTS Main Report explained "Further to this, at the time of preparation of the Hume Coal EIS one property along Medway Road was in the process of being purchased by Hume Coal and was therefore not included as an assessment location. However, an agreement was unable to be reached and therefore predicted noise levels are presented below and shown in revised Figures 14.2 to 14.4, which puts this property (location 11) into acquisition entitlement as per the VLAMP" (p.324). The predicted noise levels were also summarised in the RTS Main Report, Chapter 14, p.324.



Overall characterisation of noise impacts (VLAMP 2018)

Hume Coal and Berrima Rail Project
Addendum to Updated Noise Assessment
Figure 3.1

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

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Under the application of the NPfI (2017) and VLAMP (2018) the overall VLAMP characterisation of Location 11 is ‘significant’. Location 11 is predicted to exceed both day and night PNTLs; and is categorised as ‘marginal’ for day conditions (Figure 2.1), ‘marginal’ for standard night conditions (Figure 2.2) and ‘significant’ for adverse night conditions (Figure 2.3). As mentioned above and in Table 3.1 the overall characterisation of Location 11 under the VLAMP (2018) is ‘significant’ (Figure 3.1).

Location 12 was mapped in the EIS and RTS. Under the application of the NPfI (2017) and VLAMP (2018) the overall VLAMP characterisation of Location 12 remains ‘significant’. Location 12 is predicted to exceed both day and night PNTLs; and is categorised as ‘marginal’ for day conditions (Figure 2.1), ‘marginal’ for standard night conditions (Figure 2.2) and ‘significant’ for adverse night conditions (Figure 2.3). As mentioned above and in Table 3.1 the overall characterisation of Location 12 under the VLAMP (2018) is ‘significant’ (Figure 3.1).

Location 13 was mapped and included in the noise assessment during the EIS, with its overall VLAMP characterisation categorised as ‘significant’. Location 13 was acquired by Hume Coal prior to the submission of the RTS, as stated “location 13, which was found to be subject to an acquisition entitlement due to noise level predictions in the EIS, has since been acquired by Hume Coal and therefore removed from the noise assessment results. The net effect of these two changes is nil in terms of the total number of remaining private properties entitled to acquisition, which remains at two (now being locations 11 and 12)”. (RTS Main Report, Chapter 14, p.324). Location 13 has therefore been removed from the mapping.

4 Closure

We trust the proceeding meets your current requirements. Should you need anything further, please feel free to contact the undersigned.

Yours sincerely

Daniel Weston
Associate, Acoustics Team Manager

dweston@emmconsulting.com.au

Review: NI 21/8/20

Appendix B4 – Applicant Response to Resources Regulator advice

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

21 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS
RESPONSE TO AGENCY COMMENTS – SUBSIDENCE – PRINCIPAL SUBSIDENCE ENGINEER.

Dear Mandana,

Thank you for providing the Agency comments.

Please find attached the response from Hume Coal regarding the Gang Li (Principal Subsidence Engineer) email report dated 3rd June 2020.

Regards,

Rod Doyle

Project Manager
Hume Coal Pty Limited

Subsidence Notes

Introduction

Hume Coal has reviewed the email note dated the 3rd June 2020 from Dr. Gang Li (Principal Subsidence Engineer – the Resource Regulator) regarding subsidence matters. This note details Hume Coal's responses to the Principal Subsidence Engineers comments and provides commitments to minimising subsidence impacts.

Firstly, Hume Coal is totally confident in the work undertaken by Dr Russell Frith in the design of the mine plan for the Hume Coal Project. This confidence is further enhanced by the initial 3D modelling work undertaken by Dr. Keith Heasley that clearly demonstrates that the mine design is, fit for purpose. In addition, Dr Heasley secondary follow up work demonstrates that even when all web pillars in a set are removed the subsidence is still negligible. Further, the work of Mr Russell Howarth an independent mining expert with in excess of 40 years of complex mining experience and implementation of novel systems also supports the proposed mine plan following his extensive review. Howarths' work is perhaps best summed up by Dr David Blackmore (Director Resource Assessments – Mining, Exploration & Geoscience) who states:-

> *"The proposed mining technique was found to be technically feasible. The mine layout maximises recovery of the resource and results in a long-term stable pillar system that keeps mining-induced surface subsidence impacts to an imperceptible level, minimizes hydrogeological impacts on subsurface strata above the Wongawilli Seam, and provides an ability to store mining wastes and excess water underground"*

The mine designer, Dr Russell Frith (Mine Advice) is a recognised expert in his field. He has provided Hume Coal with some significant reports relating to subsidence and three of them should be reviewed as part of this response. They are critical to the understanding of potential subsidence impacts. (have been provided in published reports in the EIS and the RTS and the response to the IPC report. (2015 cited by Dylan)

Mine Advice (2016a) **Mine design Justification Report, Hume Project.** Commercial consulting report to Hume Coal Report HUME 13/2.

Mine Advice (2016b) **Environmental Impact Statement, Subsidence Assessment**. Commercial consulting report to EMM Consulting, Report EMM 01/2.

Mine Advice (2017) **Formal Responses to the Issues Raised by NSW Roads and Maritime Services (RMS) Relating to the Hume Project EIS** April 2017 Report Hume 19/1.

Dr Frith states that "the most critical design aspect of this entire mining system is the restriction of the span between intra-panel barriers within which the web pillars are located. The original basis of the layout design was deliberately crafted to control the overburden whilst maintaining significant coal underground to support the overburden. The remnant mine workings were deliberately designed to *remain long-term stable from day one and have undergone the most comprehensive review process one could possibly imagine."*

1) Depth of Cover

In general, Hume Coal accepts the comments made by the Principal Subsidence Engineer regarding Depth of Cover. The one exception being the reference to 'speed' of deformation in shallow depths of cover. This expression 'speed' tends to be emotive and suggests that some deformation could be rapidly developed similar to for example sink holes which may appear in the space of minutes or seconds. This would not be the case with the proposed mining method and its protective pillar systems and the overlying, well layered, competent nature of the Hawkesbury Sandstone Formation. It is worth noting that the minimum mining depth of cover over the western workings is some 80m (240 feet) of overburden.

2) Critical Infrastructure

A) ***Hume Motorway:*** Hume Coal has designed a major barrier into its mine plan to protect the Hume Motorway from any subsidence impacts whatsoever. The barrier is fundamentally an indestructible pillar, it will never fail and as such there will be nil subsidence impacts on the trafficable surfaces above it. Figure 1 below shows the location of the proposed mine workings. Figure 2 shows the size of the proposed barrier below the Hume Motorway.

The coal barrier width will be a minimum of 150m wide along the length of its interaction with the Hume Coal Mine Plan. In addition, any plunge will be a minimum offset of 50m away from the trafficable road surfaces of the Hume Motorway proper. (For clarity, secondary streets such as Kardinia Lane are not part of the barrier design.)

There are areas where some underground roadways (tunnels) will be required to be driven through the barrier. The design of these roadways and pillars will be such that they will ensure stability of the barrier and result in negligible subsidence at the surface in the zone of the Hume Motorway. Hume Coal will work with the Resource Regulator and the Principal Subsidence Engineer to ensure that mining will not impact upon this Critical Infrastructure.

Table 1 below highlights the various Factors of Safety of the 150m wide barrier pillar at varying depths of cover. The UNSW pillar stability calculations have been undertaken to prove that a 150m 'square pillar' (or barrier) is essentially indestructible with FOS averaging about 100. This means that the pillar strength for the barrier/pillars is very significant.

Where tunnels are required to pass through the barrier (in a few locations) the minimum pillar width will ensure a significant strength and factor of safety. Thus, the Hume Motorway will not experience subsidence impacts.

TABLE 1 PILLAR STABILITY CALCULATIONS (using generalised UNSW Rectangular Pillar Design Procedure)															
IUME COAL - HUME MOTORWAY BARRIER PILLAR															
PILLARS		DEPTH	WIDTH (w1)	LENGTH (w2)	PILLAR ANGLE	BORD1 (b1)	BORD2 (b2)	MINING HEIGHT	SEAM THICK	w/h RATIO	LOAD	STRENGTH (Power)	UNSW FOS	UNSW FOS	PROB. OF FAILURE
From	To	(m)	(m)	(m)	(^{0})	(m)	(m)	(m)	(m)		(MPa)	(MPa)	Dev't		
Barrier		100	150.0	150.0	90	5.2	5.2	3.50	7.00	42.9	2.33	504.36	216.49	166.5	Negligible
Barrier		120	150.0	150.0	90	5.2	5.2	3.50	7.00	42.9	2.80	504.36	180.41	138.8	Negligible
Barrier		140	150.0	150.0	90	5.2	5.2	3.50	7.00	42.9	3.26	504.36	154.64	119.0	Negligible
Barrier		160	150.0	150.0	90	5.2	5.2	3.50	7.00	42.9	3.73	504.36	135.31	104.1	Negligible
Barrier		180	150.0	150.0	90	5.2	5.2	3.50	7.00	42.9	4.19	504.36	120.27	92.5	Negligible
Pllars		100	150.0	35.0	90	5.2	5.2	3.50	7.00	10.0	2.05	33.12	16.12	12.4	Negligible
Pillars		120	150.0	35.0	90	5.2	5.2	3.50	7.00	10.0	2.47	33.12	13.43	10.3	Negligible
Pillars		140	150.0	35.0	90	5.2	5.2	3.50	7.00	10.0	2.88	33.12	11.51	8.9	Negligible

Notes: 1. Pillar widths (w1 and w2) are actual pillar side dimensions, regardless of shape, whereas bord widths (b1 and b2) are actual perpendicular widths

2. 90 degree pillar angle represents a rectangular/square pillar

3. Probability figures must be determined from the relevant 1999 Table, relating to the pillar formulae used here.

N.B An acceptable pillar FOS relates to the probability of failure. Anything larger than a FOS of 3 in 1,000 or >1.59 was deemed an acceptable risk of failure.

For the Hume Motorway Barrier with a minimum width of 150m (solids) has a FOS of about 100.

For the tunnels which cross the Hume Motorway the pillars here have FOS values of about 10.

Thus the barrier and the pillars under the Hume Motorway can effectively be described as indestructable.

Factors Of Safety	Failure Probability	Power Law
1 in	1	0.87
1 in	5	1.00
1 in	10	1.24
1 in	100	1.48
3 in	**1,000**	**1.59**
1 in	1,000	1.69
1 in	10,000	1.88
1 in	100,000	2.06

B) ***Illawarra Highway:*** The proposed mine has been designed to stand off the Illawarra Highway. Explicitly, the mine will not mine beneath the highway. As part of this response Hume Coal will commit to not mining plunges within the 26.5 degree Angle of Draw (i.e. half the depth of cover distance) of the centerline of the Illawarra Highway road surface.

To clarify the point regarding plunges (or so-called secondary extraction) they will not be mined closer to the Illawarra Highway than the half the depth of cover distance. However, normal development roadways may extend up to within the normal 20m mining barrier of a MLA. These pillars will be designed not to cause subsidence to occur on the trafficable surface of the Illawarra Highway itself. Figure 3 highlights these mining set-offs from the highway.

For example, where the Depth of Cover (DOC) is 160m, Hume Coal will stand off from the centerline of the Illawarra Highway with its plunges by 80m etc.

C) ***Gas Pipelines and Fiber Optic lines***

Hume Coal will have undertaken considerable subsidence monitoring by the time mining will take place in the environment of the Gas Pipelines and the Fiber Optics lines. Figure 2.7 from the EIS (also below) outlines the proposed timing of the mining footprints. It is expected that approximately 10 years of mining will have passed before undertaking any mining beneath the gas pipelines and fiber optics.

Monitoring of surface behaviour (subsidence) over earlier mined areas will allow the actual measured levels of subsidence to be confirmed. This can then be compared against the requirements for the gas pipelines and the fiber optic cables. With actual subsidence monitoring data to-hand, there will be far more confidence in the design and the operation of the mining system. This historic behaviour will assist in assessing the mine layout design in proximity to this critical infrastructure.

Figure 4 outlines the location of the gas pipelines and associated infrastructure.

This work will also be complemented by a better knowledge of geological structures present in the mine via mining experience and underground geological mapping along with further exploration work as required.

Hume Coal will work with the Resource Regulator and the Principal Subsidence Engineer to ensure appropriate mining, based around the empirical evidence from years of subsidence monitoring to ensure that mining will not impact adversely upon serviceability criteria of this Critical Infrastructure.

3) Theoretical Subsidence

Hume Coal's proposed mine plan intends to set out from its Pit Bottom in the central north of the MLA area (as shown in the EIS Figure 2.7) and extend to the west. The initial mining will take place beneath Hume Coal's own property. Panels will also extend out under private properties (5) in the west, before extending under the Belanglo State Forest.

It is in association with its proposed mine plan that Hume Coal will undertake early subsidence monitoring to prove the suitability of the mining system. It is anticipated that subsidence monitoring will take place both on the ground on its own property and where access is obtained from private landholders, as well as being complemented from the air (drones and Lidar).

In addition, extensive pillar stability monitoring will be undertaken to assist with proving up the long-term viability of the overall mine design. Hume Coal will undertake to obtain specific expert advice regarding the design and implementation of this work.

This monitoring will prove up the suitability of the current design. Or it could potentially lead to modification of the design based on the monitoring results. Together with the underground pillar behavior work the suitability of the mine design will be confirmed. The monitoring of subsidence impacts by surface surveying will also ensure that the finished product meets the design criteria. As well as the stated aims of protecting critical surface infrastructure.

The issue of minimising subsidence while critical, is only a part of the overall mine design. The other critical aspect of the mine design is that it has been developed to reduce roof failure and fracturing. The design is to maintain the Hawkesbury Sandstone intact so that there is reduced water ingress into the mine and thereby protect the Hawkesbury Sandstone aquifer. To that extent approximately 34% of the coal is to be removed from the mine, the other 66% of coal will act to maintain rigid pillars and barriers in place to ensure the stability of the overlying Hawkesbury Sandstone Formation.

Overall the mine design was developed by the eminent practical geotechnical expert Dr Russell Frith from Mine Advice. His work was confirmed by 3D modelling undertaken by Dr Keith Heasley (USA) who developed the LaModel software. His work proved that Dr Frith's original design was safe and fit for purpose, fit for the Project. This 3D modelling work provided significant confirmation in the design.

4) Suggestion

Hume Coal intends to commence mining in the central northern part of its MLA and then head out to the west. While the Hume Motorway is in this initial mining environment it will be protected by the barrier described above. Surface subsidence monitoring together with the underground pillar monitoring will allow a Plan Do Check Act (PDCA) cycle to ensure that the mine progresses as planned and without incident. If required tweaking to the mine plan design will be implemented if it is required to minimize impacts.

5) Additional comments from the IPC Report – 27 May 2019

IPC Response Paragraph 69 – The Department acknowledges that the Applicant has selected a mining method in an attempt to limit subsidence-related impacts …..

IPC Response Paragraph 75 – "Notwithstanding some minor residual uncertainties about pillar stability and associated subsidence, the Department considers that it is unlikely that subsidence would cause any significant impacts to surface features."

IPC Response Paragraph 85 – All experts, both for the Applicant and the Department, agree that the mining method chosen will lead to minimal subsidence.

IPC Response Paragraph 209 – At the joint expert meeting, the experts agreed in-principle that subsidence is likely to be negligible to minor and is not the key assessment issue.

IPC Response Paragraph 212 – The Commission understands that the proposed mining method will result in minimal subsidence impacts on surface features with peak worst-case subsidence in the order of 23.5 mm. The Commission notes that the experts engaged by both the Applicant and Department agree on subsidence related issues.

Conclusion

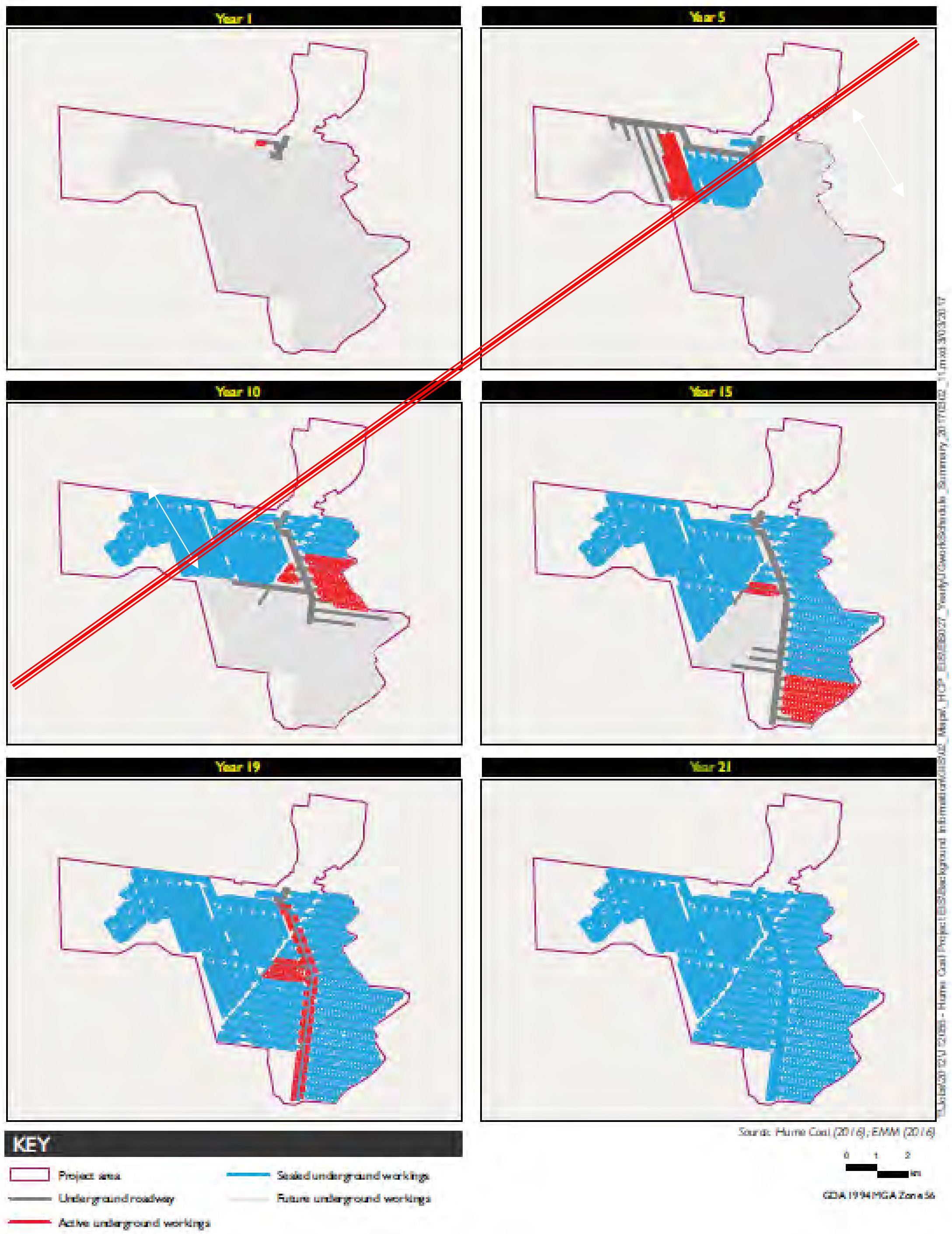
The proposed mine plan has been designed to minimize hydrogeological impacts on the overlying Hawkesbury Sandstone which in turn inevitably leads to low levels of surface subsidence. As the mining system provides for significant flexibility in leaving effective barriers or surface protection pillars in place without significantly effecting the mining process.

As well as protecting overlying aquifers and local groundwater bores, the proposed mining allows Hume Coal to ensure that critical infrastructure is protected from unacceptable subsidence impacts as well as maintaining the general surface subsidence footprint at negligible levels. :-

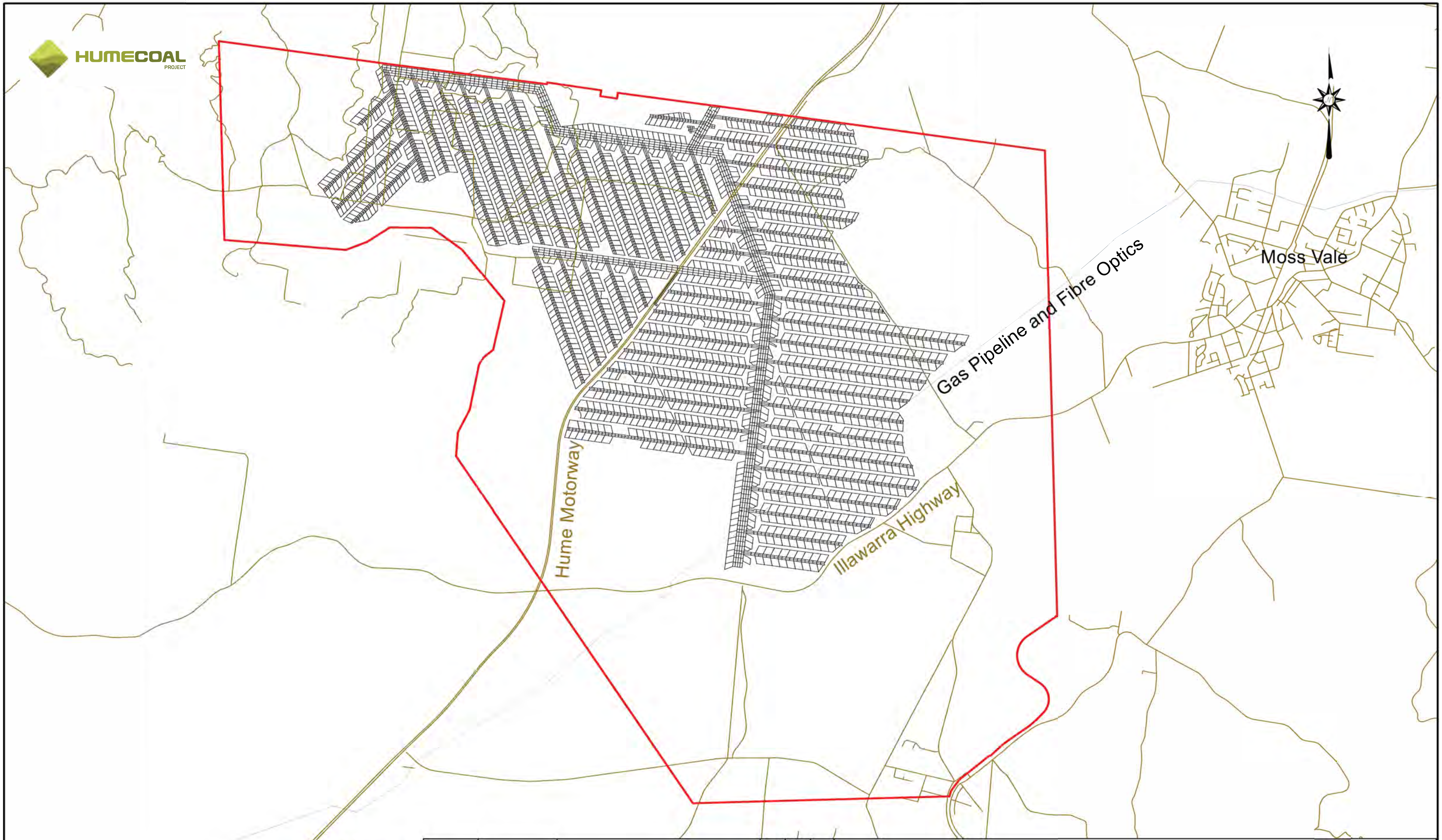
- Protect the overlying aquifer and local groundwater bores.
- Hume Coal will ensure that critical surface infrastructure is protected by subsidence impacts.

Rod Doyle BSc (UOW), MAppSc - Geomechanics (UNSW), AusIMM

Project Manager
Hume Coal Project



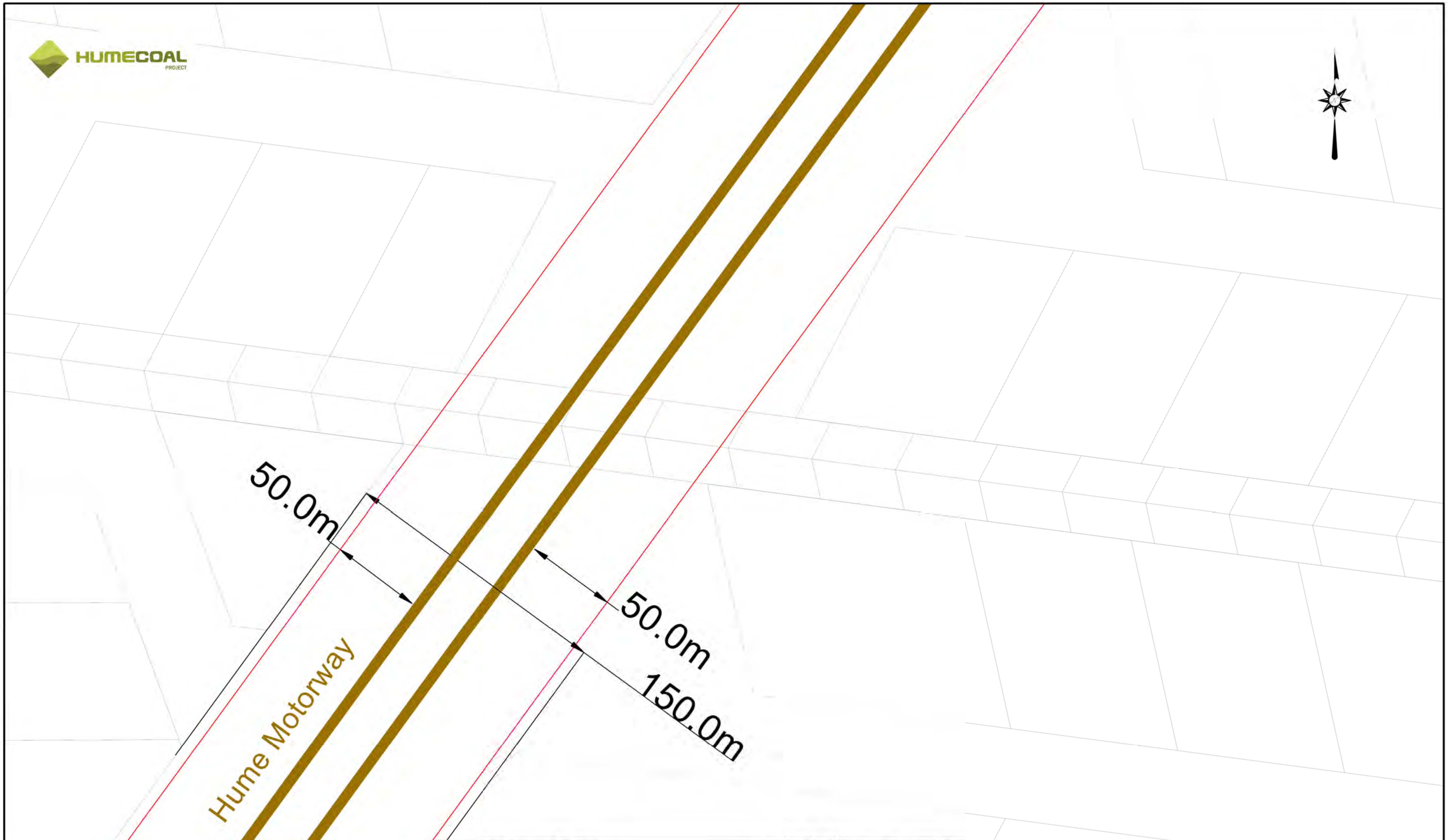
Indicative underground mine progression
Hume Coal Project
Environmental Impact Statement
Figure 2.7



Rev:	Rev. Date:	Description	Drwn	Chkd	Apvd
2	18/08/20	Added titles and north arow	FVP	RD	
1	11/08/20	Version 1	FVP	RD	

Project Title:	Hume Coal Project	Project No:
Drawing Title:	Barrier Pillar at the Hume Motorway	
Originator:		Figure/Drawing No.:-
Date Drawn:	18/08/2020	HUME5178 - 20
Scale:	NTS	

HUMECOAL PROJECT

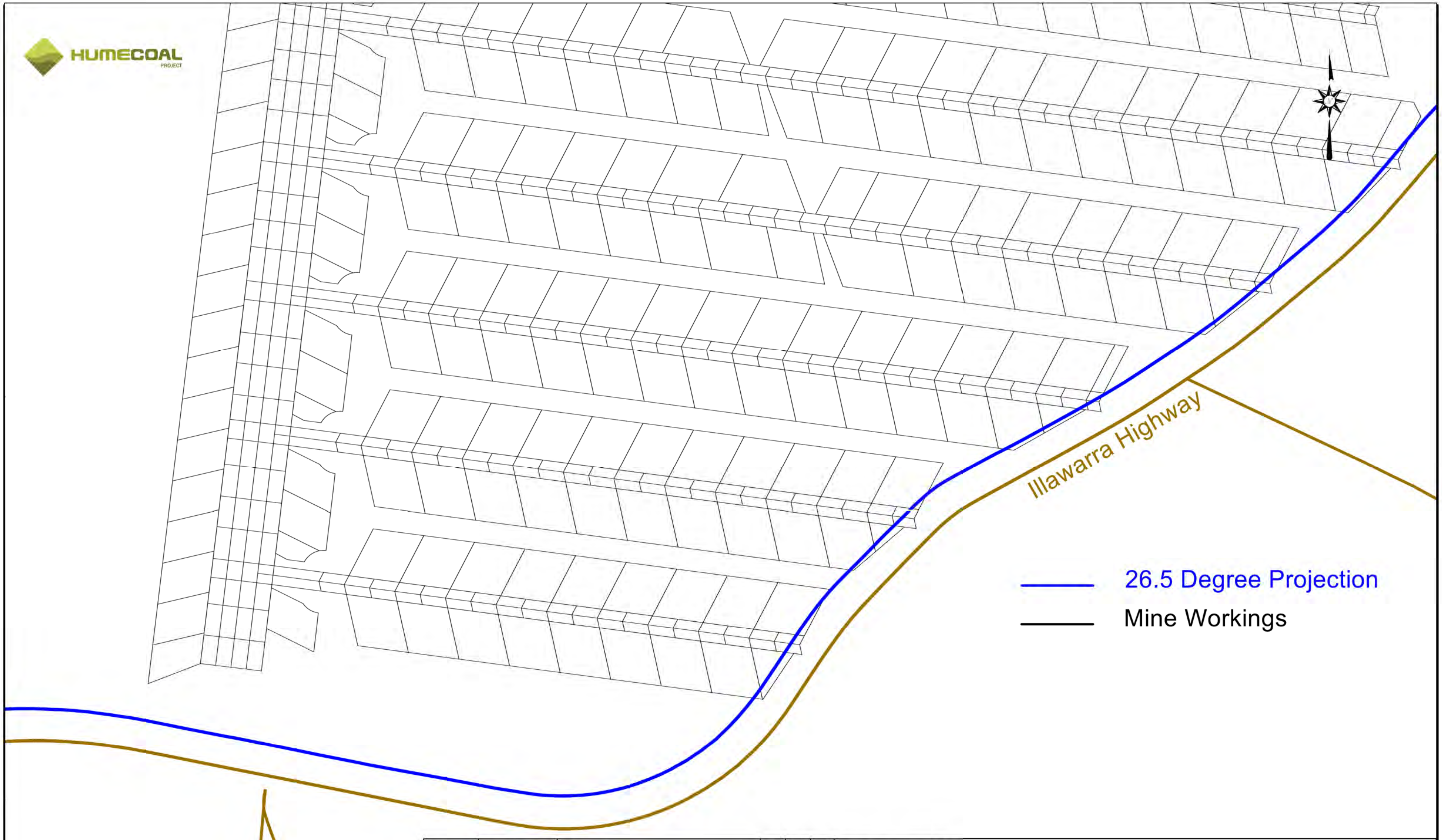


palaris

Rev:	Rev. Date:	Description	Drwn	Chkd	Apvd
2	18/08/20	Added titles and north arow	FVP	RD	
1	11/08/20	Version 1	FVP	RD	

Project Title:	Hume Coal Project
Project No:	
Drawing Title:	Barrier Pillar at the Hume Motorway
Originator:	
Date Drawn:	18/08/2020
Scale:	NTS
Figure/Drawing No.:-	HUME5178 - 21

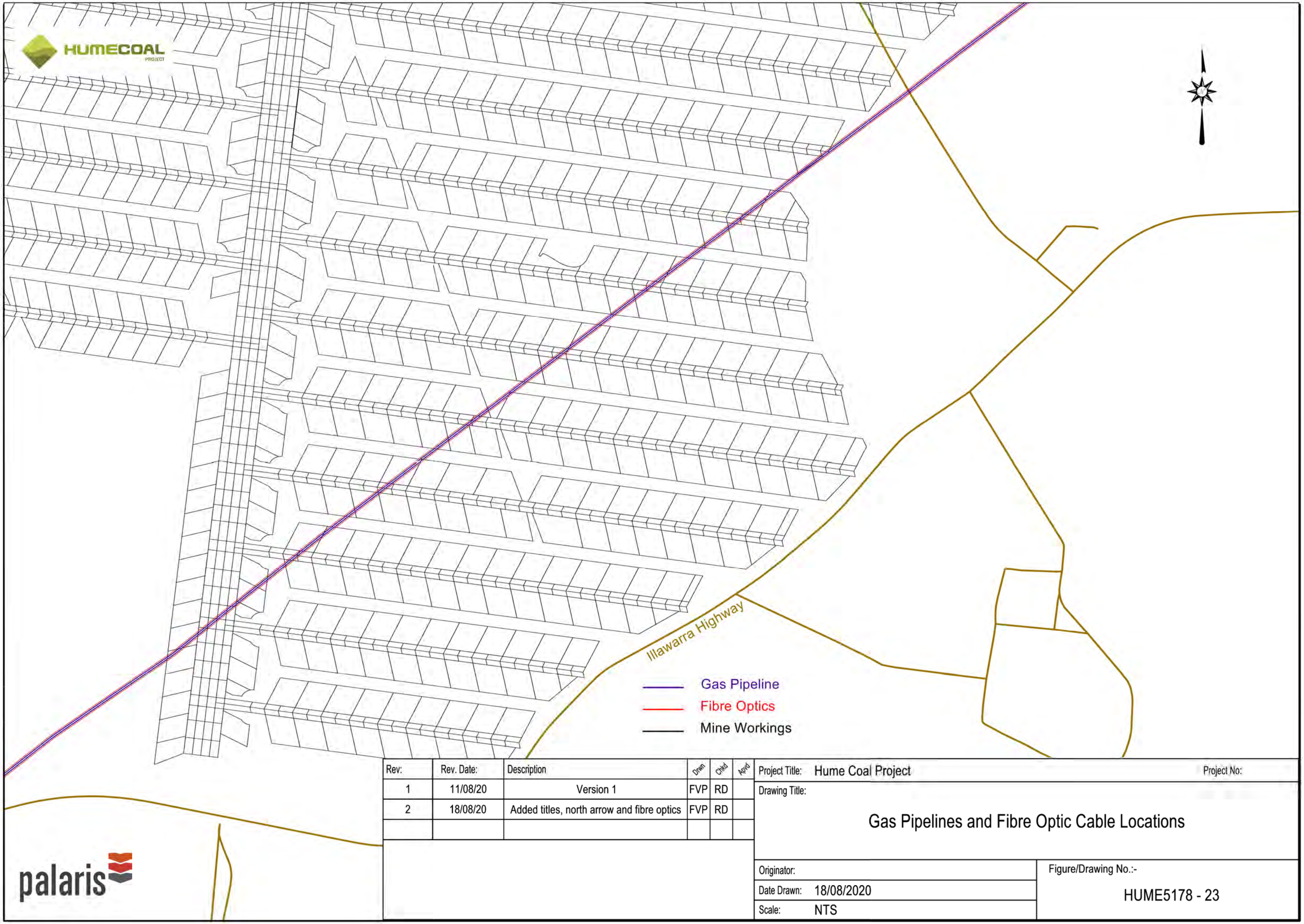
HUMECOAL PROJECT



Rev:	Rev. Date:	Description	Drwn	Chkd	Apvd
1	11/08/20	Version 1	FVP	RD	
2	18/08/20	Added titles and north arrow	FVP	RD	

Project Title: Hume Coal Project	Project No:
Drawing Title: Plunge Stand-off on Illawarra Highway based on Tan 26.5 Angle of Draw	
Originator:	Figure/Drawing No.:- HUME5178 - 22
Date Drawn: 18/08/2020	
Scale: NTS	

palaris



Rev:	Rev. Date:	Description	Drwn	Chkd	Apvd
1	11/08/20	Version 1	FVP	RD	
2	18/08/20	Added titles, north arrow and fibre optics	FVP	RD	

Project Title:	Hume Coal Project
Project No:	
Drawing Title:	Gas Pipelines and Fibre Optic Cable Locations
Originator:	
Date Drawn:	18/08/2020
Scale:	NTS
Figure/Drawing No.:-	HUME5178 - 23

Appendix B5 – Applicant Response to Regional NSW – Mining, Exploration and Geoscience advice

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

17 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS RESPONSE TO AGENCY COMMENTS – MINING, EXPLORATION & GEOSCIENCE.

Dear Mandana,

Thank you for providing the Agency comments. From Hume Coal's perspective it is refreshing to see that the Coal Resources defined by the various exploration programmes, over generations, are consistently recognised by the various Government professionals within their respective exploration departments. This strongly reflects the adequacy of Hume Coal's Geological Model. Despite this recognition, in the references cited and elsewhere, some still deny the very existence of a Geological Model!

The Mining, Exploration & Geoscience groups (MEG) decision to quote Mr. Russell Howarth, is in our opinion a confirmation of his extraordinary practical expertise and service to the Australian Coal Industry in general. We are grateful to see this recognition by this Government Department. The cited quote details his findings regarding the numerous benefits of the Projects; their technical feasibility, the maximizing of resource recovery, developing long-term stable pillars, imperceptible subsidence, minimising hydrogeological impacts and including the storage of water and rejects underground.

MEG recognises that the mine design hasn't changed since the EIS was submitted and as such most aspects remain unchanged. The Hume Coal Projects have been specifically designed to minimize environmental impacts and to achieve this the mine proposal seeks to mine approximately 50Mt over the life of the Projects.

With their expertise in assessing coal resources MEG deems that there will be a satisfactory financial return to the State of NSW, should the Project be approved.

Regards,

Rod Doyle
Project Manager

Hume Coal Pty Limited

Hume Coal Pty Limited
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Appendix B5 – Applicant Response to Heritage NSW advice

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

21 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS
RESPONSE TO AGENCY COMMENTS – HERITAGE NSW.

Dear Mandana,

Thank you for providing the Agency comments.

Please find attached the Response from Hume Coal / EMM for the commentary provided by Heritage NSW.

Regards,

Rod Doyle
Project Manager

Hume Coal Pty Limited

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21 August 2020

Mandana Mazaheri
A/Team Leader, Energy, Resources & Compliance Division
Planning and Assessment Group, Department of Planning, Industry and Environment
4 Parramatta Square, 12 Darcy St
PARRAMATTA NSW 2150

Re: Heritage NSW Review of Hume Coal response to IPC

Dear Ms Mazaheri,

We provide this letter report to respond to Heritage NSW's submission to the NSW Department of Planning, Industry and Environment (DPIE) titled *Hume Coal Project (SSD 7172) and related Berrima Rail Project (SSD 7171): HNSW Review of Hume Coal Response to IPC Review Report* (DOC20/2378500) and dated 19 June 2020.

The letter from Heritage NSW (the submission) contains a number of representations as to the content, adequacy and competence of documentation within the IPC Response Report prepared by EMM and Hume Coal, dated 8 April 2020.

This letter report (the response) corrects several statements, misinterpretations and misconceptions made by Heritage NSW within the submission and responds directly to key points in their correspondence worthy of rebuttal. Accordingly, not all of the submission is repeated herein, just those key points where EMM and Hume Coal have identified a need to set the record straight.

The response has been framed in four themes; Mereworth House and Gardens, Cultural Landscape, Archaeology, and Conditions of Consent and is presented in the same order as the submission.

1 Mereworth House and Gardens

1.1 Mereworth House and Garden – Significance

(Submission reference: Page 2, Paragraph 1)

Statement:

> *Heritage NSW previously requested a comparative analysis of Paul Sorensen's body of work and assessment of the Mereworth garden within his oeuvre, to enable a conclusion as to the significance of this garden. The USHI contains Catherine Brouwer's report, which concludes that the Mereworth garden includes the typical Sorensen garden design features however that the garden is not uncommon in a state context, and that it is unlikely to be amongst his highest calibre rural homestead garden designs. The report therefore concludes that the Mereworth garden is a place of local significance. Heritage NSW does not agree with this assessment, instead an assessment by Heritage NSW has indicates that the site may be of state significance.*

Response:

Heritage NSW refers to an assessment on the Mereworth House and Garden that it has in its possession. At no time has Heritage NSW *until now* identified its existence. The email sent by Veerle Norbury (Heritage NSW, 7 August 2020, 9.06 am) states that NSW Heritage assessed Mereworth House and Garden *may* be of state significance based on research of the Richard Ratcliffe book and several other documents. All of the documents referred to in this email were reviewed and referenced by Catherine Brouwer in the course of her research, in addition to other references on Sorensen's work. The references referred to in this email were assessed for all and any contribution to the establishment of Mereworth House and Garden as a place of significance to the state, and the conclusions of this research detailed in her report (Brouwer, 2020a).

The contribution of the place to the state of NSW is not established by the references noted in the email sent by Veerle Norbury. They provide factual information, history and descriptions and a list of authors and excerpts from their publications. Assessment specifically addressing the state heritage listing criteria, or which can be directly supporting one or more of those criteria has not been completed. The association of Sorensen with the notable figure Cecil Hoskins through gardens he designed for him (and Australian Iron and Steel) applies to *Invergowrie, Southern Portland Cement grounds* (now Boral Cement) and the Illawarra places *Greenhill* and *Hillside*, and in particular *Mt Kiera Scout Camp.* With this association they appear to potentially have a significance to the state. The Sorensen association with Hoskins is not present at *Mereworth*. Accordingly, *Mereworth* does not have the associations significant to the state.

The Stuart Read 2008 paper referenced in the email sent by Veerle Norbury provides a good inventory, with history and brief descriptions of Sorensen's work in the Southern Highlands and Illawarra regions. However, it does not assess the nature and quality of the significance of these places to the state of NSW (places on the State Heritage Register (SHR) are noted in the Stuart Read 2008 paper eg *Glennifer Brae*). The Stuart Read 2008 paper has no detailed critique or analysis of the design characteristics and designed qualities of the places, nor assessments of whether the aesthetic qualities of the places not on heritage registers indicate the places potentially meet the criteria of heritage significance. Though the Stuart Read 2008 paper mentions associations, it does not assess whether these would confer heritage significance. There is no statement of significance for each place not on a register, or not on the SHR, which would be a basis for assessment of heritage significance – state or local. Stuart Read concludes Sorensen is "arguably NSW's finest landscape garden designer of the 20th century leaving a legacy of some 100 gardens". The basis or analysis for this statement is not presented in the paper, assuming that the number of extant gardens is not the measure of calibre and state significance.

When Ratcliffe, in his book, "Australia's Master Gardener" referred to *Mereworth* as "among the great cultural landscapes of Australia" it was of the part of the property encompassing the long driveway approach as a landscape. It must be noted and taken into consideration that that driveway approach no longer exists as it was removed with the new realignment of the Hume Motorway. Ratcliffe wrote: "Through this change all the artistry of the original approach concept has been lost and the arrival experience degraded." The arrival experience is now along a route from a different direction (Brouwer, 2020a). Ratcliffe's opinion of the lost *Mereworth* cultural landscape was the only one found amongst all the references which has really assessed part of the *Mereworth* property on aesthetics and design.

The authors in the reference book "Interwar Gardens", published 2003 and specifically written as a reference text on garden designers and gardens, did not recognise Sorensen's work as significant, though the interwar period was one of his important periods of his oeuvre. He was ignored by these experts except for a mention of *Everglades* (on the SHR). Two NSW authors in the book, Stuart Read and Colleen Morris, fully neglect Sorensen in that book. If those authors have changed their opinion that would have to be, presumably, based on new evidence and new assessments which must explain how the Sorensen gardens, or even just *Mereworth* above others, meet the SHR criteria. Such assessment has not been published or presented.

The *Mereworth* garden now has lost the original (Sorensen) driveway and has views of parts of the Hume Motorway's raised landform and traffic. The inner garden around the house was designed by Sorensen with limited and focused views out to the property. These few outlooks, primarily only available in winter when the trees along the inside of the ha has walls are deciduous, have been detailed in the Hume Coal Project reports (EMM, 2020a incorporating Brouwer, 2020a, 2020b and EMM, 2020d). These reports found that the garden setting of the house and swimming pool would not have any substantive or noticeable views of the proposed infrastructure. The view of the proposed Hume Coal Project infrastructure would be very limited and only available by walking to one relatively narrow part of the outer edges of the garden, or from the cattle and works yards beyond. The yards are not part of the house visitor usual garden experience.

If the assessment referred to by Heritage NSW has identified that the garden has significance, then withholding this assessment has prevented critique and evaluation from being undertaken as part of Hume Coal's heritage investigations. Importantly, Heritage NSW states that its assessment identifies the '*site may be of state significance*'. In the context of the findings of the *Sorensen gardens comparative analysis and the garden at Mereworth* (Brouwer 2020a) ie that the site is of local significance, Heritage NSW's assessment should be clearer; either Mereworth House and Garden *is* or *is not* of state significance.

At Hume's request, DPIE requested further information from Heritage NSW on the matter of the assessment cited in their response. E-mail correspondence to DPIE from Heritage NSW (Veerle Norbury) dated 7 August 2020 reiterates Heritage NSW's statement that Mereworth House and Garden (WLEP I352) '*may be of state significance'.* Rather than providing a copy of the formal assessment against set heritage assessment criteria, demonstrating conclusively that Mereworth House and Garden has amongst other matters contributed to the development of NSW, the correspondence provided a listing of source documentation and what it believes are pertinent points that it claims supports their assertion.

Heritage NSW cites, specifically, the works of four authors – Richard Ratcliffe, Richard Aitken, Collen Morris and Stuart Read.

Regarding the points presented by Heritage NSW in relation to the body of Sorensen's work, Stuart Read identified in a 2008 paper (*Paul Sorensen in the Southern Highlands and the Illawarra)*:

> *'His lack of plans and written records means he has been neglected in comparison to 'published' or publicised contemporaries such as Walling or Burley Griffin …';* and
>
> *'Since 1990 no survey has been done of which gardens survive or their condition [...] Their poor representation in heritage studies or statutory heritage listings reflects a low awareness and level of inclusion of gardens and designed landscapes in heritage studies and listings …*

Given the request by Heritage NSW in 2017/2018 for a comparative analysis of Sorensen's gardens to be undertaken (resulting in the commissioning of Brouwer's (2020b) study by Hume Coal) it is apparent that despite the observation in 2008 that the work of Sorensen is poorly documented:

- Heritage NSW failed to undertake a study of Sorensen's work in the intervening period;
- despite the lack of comparative analysis Heritage NSW has a belief that Mereworth House and Garden 'may be of state significance'; and
- Heritage NSW was relying on Brouwer's comparative study to 'fill the gaps' in its own knowledge and confirm their preconceived opinion that the Mereworth House and Gardens may be of State significance.

It is confirmed, however, that all of the publications cited by Heritage NSW <u>have been considered</u> in the formulation of the assessment of significance by Catherine Brower. Therefore, on the basis of the investigations undertaken by Brouwer at the request of Heritage NSW, and the assessment of the body of material cited, the conclusion by Brouwer that Mereworth House and Gardens is of local significance, stands. Statements otherwise by Heritage NSW are a matter of differing expert opinion and appear to be limited to a confirmation biased desktop review.

1.2 Mereworth House and Garden Impacts - Curtilage

(Submission reference: Page 2, Paragraph 2)

Statement:

> ***The USHI Groundwater Dependence Assessment includes an assessment of shallow groundwater access making a distinction between firstly Mereworth's house and garden and secondly the gardens and trees located within the heritage listed item described as 'outside Mereworth heritage curtilage'. Consultation with Wingecarribee Council has clarified that no curtilage studies have been undertaken for the locally listed Mereworth House and Garden, and that the entire allotment was listed.*** *It was also clarified that the significance of the views and vistas, including the use of the ha-ha walls to ensure retention of uninterrupted views, could be considered in a curtilage assessment; therefore, the surrounding landscape could be considered part of the heritage item's curtilage. Figure 5.1 of the groundwater assessment clarifies that potential drawdown impacts on gardens and trees do exist in some of these other areas on the property.*

Response to emboldened text in above statement:

Whilst the entire Mereworth property cadastral allotment (Lot 2 in DP 1138694) is listed on the *Wingecarribee Local Environmental Plan* (WLEP) 2010, heritage values are not present across the entire allotment. Generally, there is no link between the legal descriptor of land in NSW and its heritage value; with the former required as a descriptor of its location on a heritage register.

A detailed physical heritage curtilage assessment of Mereworth and the garden has in fact been carried out by a qualified and experienced archaeologist, Pamela Kottaras of EMM, and was presented in the EIS, Figure 6.1 – Mereworth heritage curtilage and associated driveway (EMM 2017; Appendix T – Statement of Heritage Impact, pp. 98)). The setting and visual impacts were considered in separate reports and summarised in the Updated Statement of Heritage (USHI) (EMM 2020a).

Plate 1 Hume Coal Project EIS, Figure 6.1, Appendix T of EIS – showing detailed heritage curtilage on Mereworth property

The WLEP contains provisions dealing with heritage conservation. Heritage items are described in Schedule 5 of the WLEP. Heritage Conservation Areas, of which the Mereworth property is one, are shown on the heritage map, as well as being described in Schedule 5.

The definition of "heritage item" and Schedule 5 make no reference to the heritage map attached to the WLEP. The map therefore has no bearing upon what constitutes a "heritage item".

The dictionary to the WLEP define that a *"heritage item means a building, workplace, relic, tree, object or archaeological site the location and nature of which is described in Schedule 5".*

Under clause 5.10 of the WLEP, and specifically in relation to Mereworth House and Gardens, development consent is only required where:

a) demolition of the item is proposed (clause 5.10(2)(a));

b) there are physical changes to the heritage item (clause 5.10(2)(b));

c) there is the proposed erection of a building on the land identified in the Schedule (clause 5.10(2)(e)); and

d) there is a proposed subdivision on the land identified in Schedule 5 (clause 5.10(f)).

Legal advice received from Sparke Helmore Lawyers, 18 August 2020, (Attachment 1) states:

- the planning controls in clause 5.10 of the WLEP apply to the lots identified in the schedule (triggering a requirement for development consent in certain circumstances), the "heritage item" is the physical part of the land on which the "heritage item" (Mereworth house and garden, which may include the driveway) is located, and not to the curtilage or the whole cadastral lot;

- Heritage NSW is incorrect in its reliance on 'Wingecarribee Shire Council advice' that the whole of the cadastral lots that compromise the Mereworth property are heritage listed; and

- works outside of the house and gardens do not require development consent for works on a Heritage item.

1.3 Mereworth House and Garden Impacts – Significance of Views and Vistas

(Submission reference: Page 2, Paragraph 2)

Statement:

> *The USHI Groundwater Dependence Assessment includes an assessment of shallow groundwater access making a distinction between firstly Mereworth's house and garden and secondly the gardens and trees located within the heritage listed item described as 'outside Mereworth heritage curtilage'. Consultation with Wingecarribee Council has clarified that no curtilage studies have been undertaken for the locally listed Mereworth House and Garden, and that the entire allotment was listed.* ***It was also clarified that the significance of the views and vistas, including the use of the ha-ha walls to ensure retention of uninterrupted views, could be considered in a curtilage assessment; therefore, the surrounding landscape could be considered part of the heritage item's curtilage.*** *Figure 5.1 of the groundwater assessment clarifies that potential drawdown impacts on gardens and trees do exist in some of these other areas on the property.*

Response to emboldened text in above statement:

Material on the Office and Environment and Heritage website (https://www.heritage.nsw.gov.au/search-for-heritage/search-for-nsw-heritage/ accessed Friday 21/8/20) identifies the following heritage attributes for the property:

> *"Situated on a rise in gently undulating open pasture country south of Berrima. Visually dominates the immediate area and is recognisable for some distance through the bold conifers and golden elm driveway that feature significantly in the layout. The house is reached via a long driveway planted with golden elms foward of a dark green cypress "hedge". The house and garden are enclosed on 3 sides but open to the west offering views across to distant hills. The style and layout of the garden reflects the period of its construction and it has a number of significant landscape elements including a curved swimming pool and formal rose garden and raised pedestal fountain from which a cherry walk leads to the house. Plantings around the immediate house are bold with a row of purple acer palmatums hugging the wall near the pool. An enclosed courtyard off the driveway leads to the house."*

Heritage NSW has questioned the accuracy of Brouwer's (2020a) comparative assessment. Brouwer (2020a) identified that '*the views to and from Mereworth garden as designed by Sorensen are not all remaining due to loss of much of the driveway. The garden design is a relatively small and simple design with fewer 'garden rooms', and minor relationship to the landscape setting and minor incorporation of potential views (relative to Sorensen's other homestead gardens)'.*

At Mereworth, Sorensen essentially designed a closed garden with internal views enclosed on three sides by tall trees and hedges (evergreen windbreak and view screen), with the exception of one outward view to the north-east from the edge of the Mereworth garden ha-ha (refer section 5.5.2, Brouwer 2020a) affording landscape views to the east and north-east, outward views are generally not possible from the garden. See also **Section 1.1 – Mereworth House and Garden -Significance, Response paragraph 6** of this response**.**

Outward views of the surrounding landscape have been contrived by Sorensen from a viewing point equidistant between the outer garden windbreak of *Ulmus glabra* 'pendula' and from a convolution (or protrusion) of the ha-ha to the landscape to the north-east. Whereas the remainder of the garden is enclosed and well screened by vegetation (tall trees and hedges), the *Ulmus glabra* 'pendula' are openly spaced (in contrast to the tightly spaced wind breaks) and even from entry to the garden from the house, afford filtered glimpses (albeit below the canopy) of the agricultural landscape beyond the garden. During winter when the deciduous *Ulmus glabra* 'pendula' along the inside of the haha have shed their leaves more uninterrupted views are available. From the narrow outer edges of the garden the focal point is the high point in the high country to the north of the Wingecarribee River (north of Berrima and the Hume Motorway). This is approximately in the vicinity of Old Mandemar Road/Compton Park Road. The view is represented by Plate 5.64 Mereworth Viewpoint 3 (EMM 2020b).

Photomontages (Plates) 5.83-5.86 (EMM 2020b) represent the views for existing (Plate 5.83), post construction (Plate 5.84), year 5 (Plate 5.85) and year 15 (Plate 5.86). These show that this primary outward view from the ha-ha is preserved. As Project infrastructure could be present in the viewing field, tree planting has been carefully located, with planting occurring within the trees planted by Sorensen to guide the viewers eye to the landscape beyond. This proposed planting therefore borrows from and is consistent with Sorensen's own frame planting. In addition, appropriate species and planting locations will be coordinated by a landscape architect to ensure that the Sorensen philosophy is maintained. This view and vista, therefore, will not be impinged and the primary outward Sorensen view will not be diminished. The interpretation and analysis provided here is discernible when viewed from within the garden. It is questioned whether the Heritage NSW interpretation can be concluded from desktop reviews and aerial photo interpretation alone. It is further noted that the material on Heritage NSWs own website (see above) which states that '*The house and garden are enclosed on 3 sides but open to the west offering views across to distant hills'* is factually incorrect. Views to the west of Mereworth House and Garden would take in views of the SIA. Brouwer (2020a) definitively identifies that Sorensen's constructed landscape views are to the north-east. Accordingly, Hume Coal reiterates the invitation for Heritage NSW to visit Mereworth house and garden to assist with their assessment of the project.

In summary:

- the borrowed views contrived by Sorensen as part of the design, including the legibility devices (the planted trees) are not substantially affected and remain intact;
- the planning controls outlined by the WLEP applying to the "heritage item" relate to the physical part of the land on which the "heritage item" in this case Mereworth house and garden, which is located and not to the curtilage or the whole cadastral lot; and
- Heritage NSW is incorrect in its reliance on 'Wingecarribee Shire Council advice' that the whole of the cadastral lots that compromise the Mereworth property and the potential views to the landscape beyond are heritage listed.

1.4 Mereworth House and Garden Impacts – Groundwater draw down effects on existing vegetation

(Submission reference: Page 2, Paragraph 2)

Statement:

> *The USHI Groundwater Dependence Assessment includes an assessment of shallow groundwater access making a distinction between firstly Mereworth's house and garden and secondly the gardens and trees located within the heritage listed item described as 'outside Mereworth heritage curtilage'. Consultation with Wingecarribee Council has clarified that no curtilage studies have been undertaken for the locally listed Mereworth House and Garden, and that the entire allotment was listed. It was also clarified that the significance of the views and vistas, including the use of the ha ha to ensure retention of uninterrupted views, could be considered in a curtilage assessment; therefore, the surrounding landscape could be considered part of the heritage item's curtilage.* ***Figure 5.1 of the groundwater assessment clarifies that potential drawdown impacts on gardens and trees do exist in some of these other areas on the property.***

Response to emboldened text in above statement:

Figure 5.1 of the groundwater assessment (Hume Coal and Berrima Rail Project – Groundwater dependence for cultural heritage landscapes and gardens prepared in response to recommendations R16 and E19 in the Independent Planning

Commission assessment report dated 27 May 2019) clarifies that potential drawdown impacts, only during periods of prolonged drought, to pine trees do exist in some of these other areas of the property.

This report identifies that drawdown effects are limited to 0.1 ha of planted pine windbreaks, and that these are only potential impacts in periods of prolonged drought. These windbreaks, although within the Mereworth allotment, are not part of the Sorensen garden and therefore do not form an intrinsic component of the heritage values of Mereworth (EMM 2020c - Refer to Section 5.1.2 and Figure 5.1 of Annexure A to USHI).

Vegetation potentially affected includes the *Pinus sp* windbreaks located over 700 m to the west and south-west of Mereworth house and gardens. Although there are potential impacts to planted exotic species on Mereworth property as depicted on Figure 5.1, statutory protections to planted non-native vegetation are not afforded outside of the heritage curtilage (refer to **Section 1.2 Mereworth House and Garden Impacts - Curtilage**).

Overleaf is a reproduction of Figure 5.1, Groundwater dependence assessment for cultural heritage landscapes and gardens from the Hume Coal and Berrima Rail Project, IPC Response Report. It shows potential drawdown impacts on gardens and trees outside the Mereworth heritage curtilage – 50th, 67th and 90th percentiles.

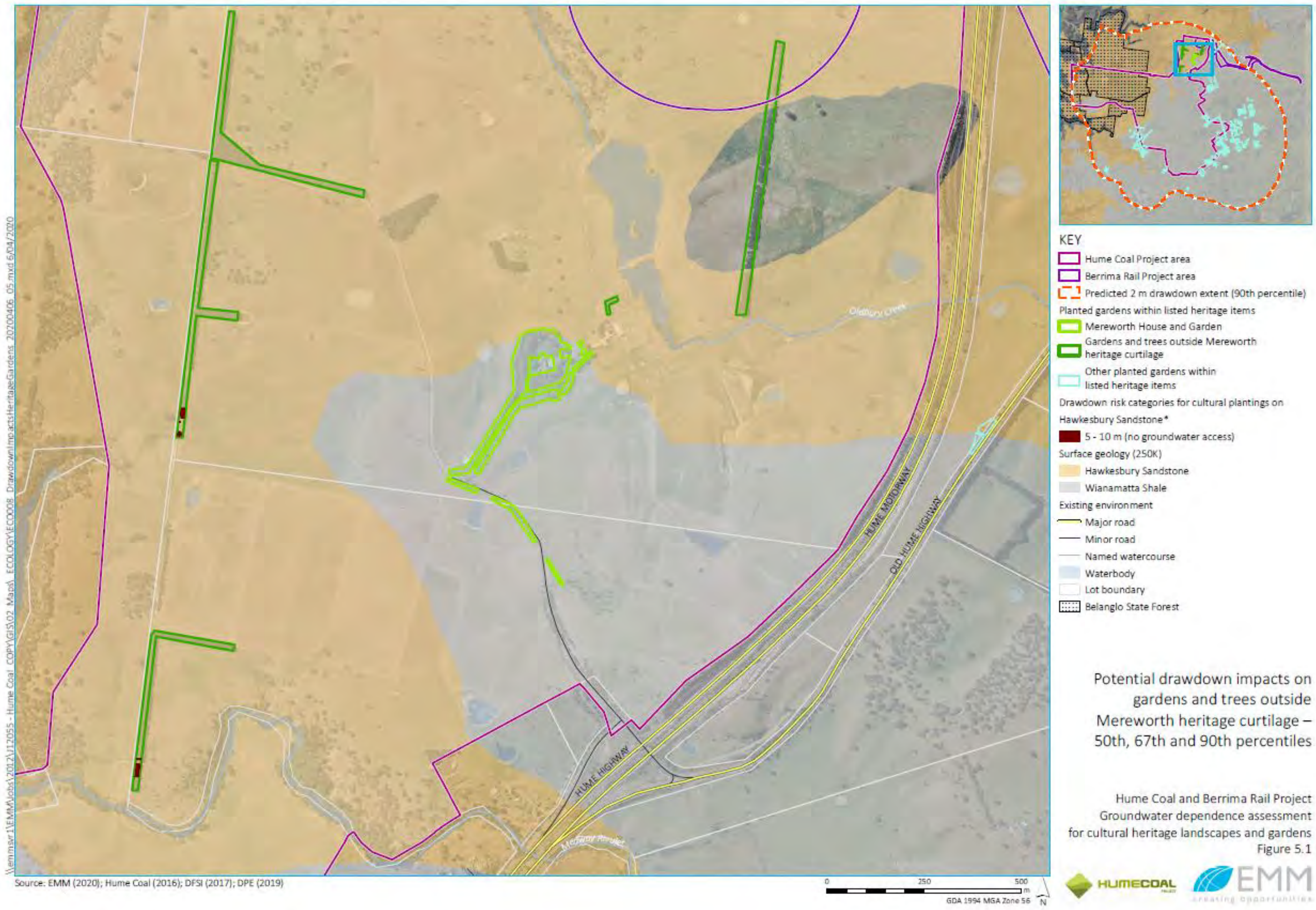

Plate 2 Figure 5.1 of the Groundwater dependence assessment (EMM 2020c)

1.5 Mereworth House and Garden Impacts – Updated Visual Impact Assessment (UVIA) Table 6.1

(Submission reference: Page 2, Paragraph 5)

Statement:

> ***Table 6.1 of the UVIA appears to be missing from the report,*** *and no conclusion was provided as to how the visual impacts upon Mereworth House and Garden were assessed (i.e. low, moderate or high). However, the report notes that visual mitigation measures are supported, via design elements, onsite and offsite treatments and post mining landform*

Response to emboldened text in above statement:

Heritage NSW identifies that Table 6.1 is missing from UVIA. Reference to Table 6.1 on p150 of the UVIA should be a reference to Table 5.4. Reference to Table 6.1 on page 172 of the UVIA should read Table 7.1.

1.6 Mereworth House and Garden Impacts – UVIA significance of visual effects

(Submission reference: Page 2, Paragraph 5)

Statement:

> *Table 6.1 of the UVIA appears to be missing from the report, and* ***no conclusion was provided as to how the visual impacts upon Mereworth House and Garden were assessed (i.e. low, moderate or high). However, the report notes that visual mitigation measures are supported, via design elements, onsite and offsite treatments and post mining landform***

Response to emboldened text in above statement:

Although viewpoints and photomontages for Mereworth House and gardens were presented in the UVIA (they were prepared in collaboration with the independent heritage assessor – Catherine Brouwer), an assessment of significance was not undertaken by the UVIA.

Instead, the determination of extant significance of the Mereworth property was firstly, assessed as representation of the body of work by the renowned gardener Paul Sorensen, secondly its heritage significance, and thirdly the effect that the Project would have on Mereworth House and Gardens, was exclusively (and quite rightly) in the remit of the independent landscape planner and registered landscape architect, Catherine Brouwer. These items are contained in Brouwer (2020a) in Annexure C, Appendix F of the Hume Coal and Berrima Rail Project IPC Response Report dated 8 April 2020. Catherine is a widely respected expert in landscape heritage, including preparation of conservation management plans and impact assessments, and in landscape character, intangible heritage and scenic assessments for strategic planning and management plans.

1.7 Mereworth House and Garden Impacts – Plantings

(Submission reference: Page 3, Paragraph 1)

Statement:

Proposed mitigative measures of planting screen vegetation to block views of this (and other) landscapes impacted by the project, is not considered to be an appropriate response. At the very least, any such 'buffer' plantings should be conditioned to be removed on completion of the project's time frame, to restore the landscape masked for the project's life. Proposed 'Plant Succession Plan' and 'activating it when necessary' is also considered to be an inadequate response.

Response:

The use of the term 'screen-vegetation' by NSW Heritage is confusing in the context of Mereworth House and gardens, and specifically the views of the landscape from the garden ha-ha as no screen planting is proposed (screen - to '*conceal,* *protect, or shelter (someone or something) with a screen or something forming a screen*') . The use of the term 'masked' clearly demonstrates the writer's bias against the project and the planting strategy proposed.

Buffer planting, undertaken in 2015-2016 occurs along external property boundaries of the Mereworth property and are generally not visible from the Mereworth House and Garden. This established planting will not be removed.

The *integration planting* described by the UVIA was formulated as a result of the additional visual analysis work undertaken by EMM (2020b) and Brouwer (2020b) in response to previous concerns about massed screen planting raised by Hertage NSW and referenced by the IPC. The integration planting strategy proposed has been developed in extensive consultation with the independent landscape planner and registered landscape architect, Catherine Brouwer. The integration planting strategy proposed went to great lengths to develop a palette, form, texture, colour, structure and planting style complimentary with, and informed by, the surrounding cultural landscape and the natural landscape elements it contains. Furthermore, the planting strategy will be further refined post approval in consultation with key stakeholders. This was detailed in Section 6 of the UVIA (EMM, 2020b).

In the context of the cultural landscape and Mereworth, it was noted by the *Hume Coal and Berrima Rail Project cultural landscape assessment* (Brouwer 2020a), that further landscape integration of the various Project elements could be achieved through implementation of tree planting around infrastructure areas. Please note there is a misalignment of terminology and to which Catherine Brouwer referred to this integration as semi-screen planting. In the context of the planting strategy identified by the UVIA this is described as visual integration planting.

At no time was there the intent of the integration planting strategy presented in the UVIA (EMM, 2020b) to create a strategy which concealed or masked the Project infrastructure; this is a unified theme of both the UVIA and the cultural landscape assessment. The strategy developed aims to integrate elements into the landscape by softening the massing of the structures, through replication of various natural vegetation patches and copses and cultivated forms. The adoption of a planting form existing in the landscape will ensure that the form is less obvious (less different) and assist visual integration.

The Conservation Management Plan (CMP) will include a succession plan. The commitment to activate a management plan where and when necessary, post approval is a common approach for managing predicted impacts on major projects throughout NSW. We do not see how a commitment such as this is considered inadequate by Heritage NSW in this instance, for this project.

2 Cultural Landscape

2.1 Berrima, Sutton Forest and Exeter Cultural Landscape

(Submission reference: Page 3, impacts Section, Paragraph 4)

Statement:

> *The views and the impact of the proposal have been investigated by photomontages in the UVIA. The UVIA concludes that the overall visual impacts of the mine infrastructure taking into account proposed mitigation measures, for motorists travelling along the Hume Highway and residences along Medway Road, will be of a moderate level.*

Response:

An analysis of visibility from the Hume Motorway and Medway Road is contained in the UVIA section 5.3.1 - receptors. The assessment concludes that for much of the Hume Motorways length which severs much of the Mereworth property from the formerly agricultural landscape to the east, views will be screened (blocked) by cuttings and landscaped screening vegetation planted (by the RTA) when the road was constructed. Where views are possible, they are dynamic, filtered glimpses between foreground vegetation (landscaped screen) and landscape vegetation of the midground (between the viewer and the proposed infrastructure). Viewing times along identified view routes (EMM, 2020b - Figure 5.3) generally range from 5 – 20 seconds duration.

The significance of the effect will diminish as integration plantings mature. The location of these potential view routes are identified by road Section 1 in the vicinity of the Medway Road overpass (EMM, 2020b - Figure 5.3) where possible viewing times of all Surface Infrastructure Area (SIA) and rail elements are possible for 5 seconds duration at 110 km/hr. At this viewing point (see Plates 5.26 – 5.29) views would only be possible to the left of and to the rear of the vehicle if the passenger turns their head (the driver would not be able to see mine infrastructure).

Most visibility occurs when travelling northbound and the most significant views are, because of the horizontal alignment of the road, only available to the vehicles' passengers. Existing established buffer planting undertaken by Hume Coal in 2015/2016 will further reduce viewing times by increasing filtering and will contribute to mitigate impacted views. Where not present, integration planting will further assist in view filtering. Table 7.1 of the UVIA identifies that for the landscape classification unit (LCU) 'undulating pastoral lands' the residual effect is 'moderate'

Medway Road has been assessed as having a low sensitivity. The report identifies that in the unmitigated state, views to the SIA will be possible and the acoustic barrier associated with the Berrima Rail Project would be visible. However, buffer planting undertaken along the Medway Road boundary by Hume Coal in 2015/2016 which is in keeping with the existing relict and roadside vegetation and which is now well advanced, will effectively mitigate views. Table 7.1 of the UVIA identifies that all residual effects for Medway Road are slight. In addition, it should be noted that historically, trains and trucks carted coal between Berrima Colliery and the Boral Cement Works (trucks on Medway Road and trains in the existing corridor on the edge of the road).

2.2 Berrima, Sutton Forest and Exeter Cultural Landscape – Planted screen

(Submission reference: Page 4, Paragraph 1)

Statement:

> ***Proposed mitigative measures of planting screen vegetation to block views of this (and other) landscapes impacted by the project, is not considered to be an appropriate response.*** *Relocation of parts of the Project away from highly-sensitive views and other landscape fabric should be considered. At the very least, any such 'buffer' plantings should be conditioned to be removed on completion of the project's time frame, to restore the landscape masked for the project's life.*

Response to emboldened text in above statement:

This has previously been addressed. Please refer to responses within **Section 1.2 Mereworth House and Garden Impacts - Curtilage** and **Section 1.7 Mereworth House and Garden Impacts – Plantings**.

2.3 Berrima, Sutton Forest and Exeter Cultural Landscape – Relocation of infrastructure

(Submission reference: Page 4, Paragraph 1)

Statement:

> *Proposed mitigative measures of planting screen vegetation to block views of this (and other) landscapes impacted by the project, is not considered to be an appropriate response***. Relocation of parts of the project away from highly-sensitive views and other landscape fabric should be considered.** *At the very least, any such 'buffer' plantings should be conditioned to be removed on completion of the project's time frame, to restore the landscape masked for the project's life.*

Response to emboldened text in above statement:

The Project has been designed from the outset to avoid environmental, heritage and social impacts.

The current configuration of the SIA is the culmination of significant design, engineering and consultative efforts between Hume Coal, engineering designers, environmental practitioners, and agency stakeholders between 2012 and the submission of the EIS in 2017. The configuration of the SIA presented in the EIS and through to this current assessment stage has, amongst other things, taken the following into account in the siting and design process: land ownership; separation distances to sensitive receptors and environmental values; location of strategic infrastructure; mining systems, equipment and extraction methods; resource recovery; hazard and risks; employee and public safety; engineering feasibility and constructability; rail loadout feasibility and logistics; and innovation.

Accordingly, the notion of relocating parts of the SIA "away from highly-sensitive views and other landscape fabric" at this stage of the assessment process is absurd. Changes to the SIA design and configuration has implications for assessment and regulatory triggers, which could in turn require additional environmental assessment and engineering and design effort, resulting in further delays to government assessment and decision making timeframes; a potential outcome that that places an unreasonable and legally questionable burden on the Project that is not supported by Hume Coal and parent company Posco Australia. EMM and Hume Coal stand by the currently proposed integration planting strategy as a method to integrate the SIA into the landscape setting.

It is also reiterated that the SIA, when viewed in the context of other industrial features in the landscape (for example the Berrima Feed Milll, Berrima Cement Works and and livestock exchange), and approved but not yet constructed developments (such as the Austral Masonry facility and shale quarry), is considered to be a western extension of these established and approved industrial land uses.

3 Archaeology

3.1 Archaeology - Updated Statement of Heritage Impact (USHI), Figure 4.1

(Page 1, Paragraph 4)

Statement:

> *Figure 4.1 of the USHI illustrates the location of the proposed site in relation to both state and local heritage listed items.*

Response:

NSW Heritage's letter states 'Figure 4.1' of the USHI. For clarification this should be 'Figure 2.1 – Listed heritage items in the local context' (Hume Coal and Berrima Rail Project) of Annexure D to the USHI. Hume Coal apologise for this inadvertent error.

3.2 USHI - Terminology

(Page 4, Paragraph 4)

Statement:

> *The terminology applied throughout the report contradicts the relevant definitions as set out in the NSW Heritage Act 1977 and by the Heritage Council of NSW. Various built heritage items are discussed as archaeological sites (Appendix G); the term 'relic' is broadly and indiscriminately applied to a variety of movable objects (e.g. p. 46-49; p. 123), works (e.g. p. 52-53; Fig. 6.2 etc.); buildings (e.g. Table 6.11) and archaeological sites (e.g. p. 11; 101). None of these items fit the definition of 'relic' as specified in S4(1) of the Heritage Act 1977 (as amended 2009) and the guidelines Assessing Significance for Historical Archaeological Sites and Relics 2009 (Heritage Council 2009, 6). The confusion resulting from the misinterpretation of terminology and particularly the term 'relic', predetermines a number of inconsistencies throughout the report and has an overall negative influence on the outcomes of the significance assessment.*

Response:

EMM refutes the above assertions.

The NSW *Heritage Act 1977* (Heritage Act) identifies that relic is defined as any deposit, artefact, object or material evidence that:

a) relates to the settlement of the area that comprises New South Wales, not being Aboriginal settlement, and

b) is of State or local heritage significance.

It is understood by consultants working in NSW, that under the terms of the Heritage Act, a relic is archaeological in nature, but an archaeological site is not necessarily a relic. However, the definition of *relic* in the Heritage Act, defines *deposits, artefacts, objects or material evidence,* as relics. Under this definition, anything that is of State or local significance could be a relic, including buildings, bridges, and roads, for instance. Based on experience, it is also understood by consultants working in NSW, that this is not the case and that relics are specifically related to archaeological sites.

No definition of a 'work' exists in the Heritage Act and repeated requests by industry and consultants to Heritage NSW in various forums have not provided a satisfactory definition. EMM's definition is:

A 'work' is the product of infrastructure building activities, such as a road, road culverts, bridge or rail cutting. While works may be buried and archaeological in nature, they are not considered relics under the Heritage Act. Works that have been assessed to possess heritage significance are treated as significant items and may be listed.

Further, if a work is buried, such as an early road alignment, archaeological excavation remains a suitable method of extracting information, but under the terms of the Heritage Act, a permit to excavate (section 140) would not be required. However, if a work has been assessed as significant, the heritage provisions of its listings apply or, if not listed, management under best practice.

The Heritage NSW website (accessed August 2020) includes the following:

Types of historical archaeological sites:

> ***Built:*** *These sites include buildings (both ruined and standing), engineering works and structures such as wells, mine shafts and bridges.*
>
> ***Movable:*** *Machinery, tools, and household objects such as crockery, bottles, personal items and toys are all of archaeological value.*
>
> ***Landscapes****: Pollen can provide evidence of past environments, parasites give us evidence of past human diet and disease and human skeletal remains can reveal details of early colonial occupation.*
>
> ***Maritime:*** *Maritime Heritage sites in NSW can include shipwrecks, and their associated relics, shore-based and port-related facilities, human remains and any evidence of human interaction with the seas, lakes and rivers that can contribute to our knowledge and history of NSW.*
>
> *In practice, an important historical archaeological site will be likely to contain a range of different elements as vestiges and remnants of the past.*
>
> *Such sites will include 'relics' of significance in the form of deposits, artefacts, objects and usually also other material evidence from demolished buildings, works or former structures which provide evidence of prior occupations but may not be 'relics'.*
>
> *The value of the site and the elements within it must be assessed, documented and recognised so that correct future management choices are made.*

https://www.heritage.nsw.gov.au/about-our-heritage/historic-archaeology/

The Heritage NSW correspondence refers to a number of pages where the word has been used 'indiscriminately' and references Table 6.1 and a number of pages but does not clearly identify the issues specifically. The term 'relic' has not been used indiscriminately.

Table 6.1 of the USHI (EMM 2020a) discusses three locations where relics were recorded: HCR1, HCR2 and HCR3. All of these features are related to the Cowley phase of the property and all are relics, as well as being different components of the one archaeological site. This is a fact, despite the exclusion of the word 'archaeology' or its derivatives in the definition of 'relic' (section 4 'Definitions') or in section 138 'Definitions' in the Heritage Act.

Where the report has identified an archaeological site, it remains so until it is assessed to be of local or State significance after which time is can be referred to as a relic, while at the same time, remains an archaeological site. The purpose of the term 'relic' appears to be related to approval under section 139 of the Act to:

> *disturb or excavate any land knowing or having reasonable cause to suspect that the disturbance or excavation will or is likely to result in a relic being discovered, exposed, moved, damaged or destroyed unless the disturbance or excavation is carried out in accordance with an excavation permit.*

An excavation permit would not be required if archaeological excavation was proposed under the terms of the Project approval. Nevertheless, the same principal has been applied to the USHI and the archaeological assessment – the term 'relic' has been used appropriately, as has 'archaeological site', and the inclusion of buildings and bridges in the report is justified.

Where an assumption has been made earlier in the technical report that it is a relic, the term is interchangeable with 'archaeological site' and 'archaeological resource'. This is why Heritage NSW and local councils request 'archaeological assessments' rather than 'relics assessments'.

It was considered appropriate by the main author to include the Three Legs 'o Man bridge in the same category as other relics, because despite being a work, may have associated relics such as a privately built causeway. This was the simplest method of including the item in the report. Construction of the Three Legs 'o Man bridge may have left an archaeological fingerprint even if not defined as 'relics' by the Heritage Act. So, while it is noted that the bridge is included in the list of relics, this does not support the argument that the main author of the technical report is confused about definitions. Despite being rebuilt, the Three Legs 'o Man bridge is a significant item; it is part of the historical/archaeological landscape and was included in the report to provide context and because it exists.

The bridge, however, is not in the Project area. Council should consider listing the remnants of the former Three Legs o' Man Bridge.

The former Southern Blue Metal rail-bridge is also included in the relic section as, while it was infrastructure, it was also a remnant structure and the only way to retrieve information associated with it that is buried would be through archaeological excavation. The distinction between relic and work was created to remove the need to obtain excavation permits for roads and similar features and is not indicative of the site type in academic terms.

Heritage NSW refers to Table 6.1 in relation to the comment below:

> *…the term 'relic' is broadly and indiscriminately applied to a variety of movable objects (e.g. p. 46-49; p. 123), works (e.g. p. 52-53; Fig. 6.2 etc.); buildings (e.g. Table 6.11) and archaeological sites (e.g. p. 11; 101). None of these items fit the definition of 'relic' as specified in S4(1) of the Heritage Act 1977 (as amended 2009) and the guidelines Assessing Significance for Historical Archaeological Sites and Relics 2009 (Heritage Council 2009, 6).*

However, in the past and on a different project, delegates of the Heritage Council have requested an archaeological assessment of an early road with the intention of determining if road features were relics. The requirement from the Heritage Council included the preparation of a historical archaeological assessment as:

> *Physical evidence that may remain in this area is likely to include evidence of the road alignments, former road fabric and engineering works such as sandstone culverts. This assessment should assess the heritage significance and archaeological potential of any physical evidence discovered and determine if they are likely to be considered relics under S139 of the Heritage Act…It is recommended Council refers a copy of the Archaeological Assessment to the Heritage Division for comment to assist Council in managing any relics, or State significant fabric linked to the Great South Road through this Project (Heritage Council reference: DOC19/53811).*

Heritage NSW refers to Table 6.1 in relation to this comment. EMM points out that relics or potential relics have been identified in the Project area and names a number of heritage listed properties with build heritage (EMM 2020d; Annexure D, p.115). As pointed out by EMM and then by Heritage NSW, these historic properties have the potential to contain relics, which is why the term 'possibility of relics' has been used in the overview (EMM 2020d; Section 6.3.1, Annexure D, p.115). All the properties with build heritage that are discussed in the report have the potential to contain relics. It is not the buildings that are of concern but the possibility that there are relics associated with them.

The word *relic* has been used appropriately in the archaeological assessment and the USHI. Despite the attempt by Heritage NSW to discredit the study, EMM stands by the assessment of archaeological potential and the assessment of significance and disputes the statement.

Heritage NSW has not been able to point out how these alleged inconstancies have influenced the significance assessment:

- Relics related to the Cowley phase of the current Mereworth property have been assessed at a local level of significance; these are inside the Project area but not inside the impact area;
- The potential site of the former *Three Legs o' Man Inn* has been assessed to the extent that it can be without archaeological test excavation. The fact that archaeological resources were not visually assessed is not relevant in this context as the site of the former *Three Legs o' Man Inn* is not in the Project area, and will not be affected by the proposal. The reach of Heritage NSW is questioned with respect to this statement; and

- The assessments of significance for other heritage items inside the Project area are as per the published levels of significance because impacts are not predicted and archaeological and built heritage assessments are guided by the subsidence assessment[1].

3.3 USHI - Fieldwork

(Page 4, Paragraph 5)

Statement:

> *The fieldwork undertaken for the assessment as detailed in the report is insufficient. Large portions of the Project area above the underground mining area, were not accessed by the consultant and a number of locally listed items deemed 'likely' and 'highly likely' to contain relics, including relics of potential State significance have not been inspected, but viewed from the public domain (e.g. p. 37; p. 52; p. 66-71; Appendix G). This suggests that an appropriate level of understanding of the archaeological potential and sensitivity of numerous locations within the Project area was not achieved.*

Response:

<u>Inadequate level of fieldwork</u>

Field assessment was conducted from locations that the consultants were permitted to access. Locations were 'viewed from the public domain' because access was not permitted by respective landholders. The sites that could be viewed from the public domain were photographed from the fence line. Given no access was provided, EMM took all reasonable means to review of available historical information, aerial imagery, field observation from public domain. No other means were available to the consultant.

Heritage NSW has also been approached on the archaeological component for past projects and the level of opposition from the agency (or individuals that represent the agency) reduces any benefits that might ordinarily be gained from consultation.

An assessment using archival sources is common practice, with or without field survey and does not detract from the validity of the findings as:

- No other project of this size that the archaeological assessment author is aware of, or has worked on, has had 100% field survey coverage; survey is targeted in projects with large surface areas.
- Predicted subsidence impacts have been calculated to be a maximum of 20 mm, which is the impact that the assessment is predicated on.
- Regardless of the archaeological sensitivity of the *Three Legs o' Man Inn* site, it is not in the Project area and will not be undermined.
- Construction of the existing dwelling, built in the 1980s, on the *Three Legs o' Man Inn* site may have detrimentally impacted relics, as it was not assessed.
- The core building group of *Newbury* is approximately 750 m outside the Project area; it will not be undermined.
- A structure in the paddocks of *Newbury* in the Project area and over the mine plan appears to be a shed, and a stockyard is located by a group of trees to the east of Golden Vale Road; the report discusses the predicted

[1] As described in Volume 7, Appendix L, of the Hume Coal and Berrima Rail Project EIS (EMM, 2017), predicted impacts associated with: vertical subsidence is a maximum of 20mm; and mining induced ground tilt is expected to be 0.26 mm/m. This level of subsidence will not cause detrimental impacts to the archaeological landscape or relics in the project area and given separation distances between listed State Heritage Items and underground workings, the potential for damage to these items is considered negligible. Accordingly, the conclusion of the archaeological assessment that recorded and unrecorded relics are unlikely to be impacted by the project is reiterated here.

Hume Coal is committed to the verification of predicted rates of subsidence, as outlined Appendix 2 of the RTS (EMM, 2018) and will be installing real-time subsidence monitoring before the commencement of underground mining.

subsidence impacts relative to the *Newbury* paddocks; the homestead site and any associated relics are not in the Project area.

- Relics are often not visible on the ground surface; therefore, field survey cannot always provide answers to a significant archaeological site's level of preservation.
- Where surface expressions of buried relics do not exist, their survival *in situ* cannot be ascertained without a controlled archaeological excavation.
- No sites within the Project area have been identified through documentary sources.
- Archaeological excavation has not been recommended, as no archaeological sites have been identified.
- Archaeological excavation is not undertaken, and would not be authorised by the Heritage Council without impacts to the potential site being proposed.
- All other heritage listed properties and potential archaeological sites (including potential relics) are above the mine plan, which a subsidence prediction of 20 mm maximum.

Inappropriate level of understanding of the archaeological potential and sensitivity.

The consultant who prepared the majority of the archaeological assessment has over twenty of years of experience in archaeological and historical heritage consulting in NSW and abroad. This experience includes field survey and archaeological excavation and monitoring, as well as analysis of documentary sources for major projects, local development applications and reviews of environmental factors. The archaeological assessment author has no experience in government but her expertise has been gained in consulting archaeology where she has worked with a number of highly experienced archaeologists and has also provided peer review for external consultants. While there is always something to learn, the methods of assessment of potential and sensitivity have thus far held up to scrutiny in the reports prepared by EMM.

This assessment of archaeological sensitivity and/or potential that was applied to the report assessing the impacts of the proposed Hume Coal Project has been applied to other reports, which have been accepted by the Heritage Council and by DPIE. The assertion that there is a lack of understanding of archaeological potential and sensitivity is highly refuted, and it is suggested that this comment is attempting to make a distinction where a distinction is irrelevant. This distinction does not add value to the comments of Heritage NSW or to the report.

The use of the word 'inappropriate' is also incorrect in this context; the word that the reviewer was potentially looking for is 'inadequate', which is refuted for the same reasons outlined above.

3.4 USHI – Mapping

(Page 5, Paragraph 2)

Statement:

> *The relevant mapping does not clearly demonstrate the assessed locations of potential archaeological resources which may contain relics within the Project area. No survey coverage mapping has been provided and no archaeological sensitivity mapping has been prepared. The recurring argument that structures and potential archaeological resources identified by the consultant within locally listed heritage items, portions of which fall within the Project area, are in fact outside of the Project area is not demonstrated (p. 66-71; Appendix G).*

Response:

The relevant maps show where areas of archaeological potential were located. Survey coverage mapping is not a standard inclusion in historical archaeological assessments but was included in the original statement of heritage impact (EMM 2017; Volume 10, Appendix T, Figure 4.1), which also assessed the archaeological component of the Project area.

Archaeological sensitivity mapping was not included as impacts are: a) not predicted in areas other than where surface infrastructure is proposed; and b) access was not permitted to the properties that were not included in the field survey.

3.5 USHI – Archaeological potential

(Page 5, Paragraph 3)

Statement:

> *Based on the outcomes of the above, a detailed assessment of archaeological potential has not been appropriately undertaken. This is acknowledged by the consultant: Nevertheless, the archaeological potential of the Three Legs of Man property will only be determined through thorough archaeological survey within the property boundaries (p. 57). This statement is valid for all areas of archaeological potential as identified by the consultant that were not inspected, but viewed from the public domain, or not viewed at all (e.g. Eling Forest Winery, Comfort Hill, p. 71 and Appendix G). As a result, while archaeological potential is mentioned on various occasions throughout the report, it is usually defined by overarching statements: 'Given the history of the area it is possible that unrecorded relics exist, particularly where they may be associated with the larger estates or where early industry may have left the ruins of ephemeral structures' (p. 79), or 'the potential for unrecorded relics exists as in any area that has the history of the Project area' (Appendix G; Table 6.4.; E.23). This level of assessment is inadequate for the purposes of this report as it impedes an accurate impact assessment.*

Response:

As discussed in **Section 3.1** to **Section 3.3** above, the level of assessment has been completed to a degree suitable to confidently state that archaeological potential exists across the landscape in areas that were not visually inspected. It is a given that this is the case in an area that was settled early in the early nineteenth century. Field survey was undertaken where impacts are predicted, which is standard practice and where access was permitted (which was on all areas that have the potential for impacts). Further, the archaeological features, assessed as being relics, on Mereworth that are attributed to the Cowley phase of the property were found after additional survey during drought and were recorded to confirm their existence, rather than because they will be prone to project-related impacts, which they will not be.

It is reiterated here that the site of the Three Legs o' Man is not inside the surface infrastructure area and is a substantial distance from where underground mining is proposed. Other properties were not visually assessed because access was not permitted, which is considered to be acceptable as impacts arising from subsidence are not predicted[2].

Confirmation of relics will also not make a difference to the impact assessment, as the predicted impacts of subsidence are negligible. Further and also as discussed in **Section 3.3**, visual inspection, while useful much of the time, does not always pick up areas with archaeological sensitivity as relics are often buried. Confirmation through archaeological excavation is not a common recommendation by consultants or an action accepted by Heritage NSW for sites that have not been identified as being susceptible to impacts.

The assessment of impacts has been undertaken to an appropriate level as despite the existence of relics, or built heritage, works, ruins, built non-heritage, subsidence has been assessed as being a maximum of 20 mm in some areas; in other areas, subsidence has been assessed as nil. This is the information that has been used for the assessment of impacts to relics.

The level of investigation of archaeological potential in the Project area has adequately characterised the archaeological landscape given the level and types of impacts that have been identified. The remarks by Heritage NSW have been made to cast doubt on the adequacy of the report, but have not actually identified where those inadequacies are.

3.6 USHI – Comparative analysis

(Page 5, Paragraph 4)

Statement:

> *Chapter 5, entitled 'Site evaluation' contains a section devoted to comparative analysis (5.2, p. 72-79). The purpose of comparative analysis is to assess the known parameters of potential archaeological resources against comparable sites from the available sources and thus inform significance assessment. In the report*

2 Real time monitoring of predicted subsidence as described in Appendix 2 of the RTS to ensure subsidence impacts do not exceed acceptable limits (refer Volume 7, Appendix L, of the Hume Coal and Berrima Rail Project EIS (EMM, 2017)).

under consideration, comparative analysis is limited to three items: Mereworth House and Garden, the Kentish Arms/Three Legs of Man Inn and the Three Legs of Man Bridge. None of the other areas identified as likely to contain archaeological resources and relics are included. The analysis consists of a list of the above-mentioned items followed by a list of broadly similar items (mostly built heritage items) with short notes on their chronology and main features, as detailed in the relevant listings. No discussion is included in this section. The following section, entitled Discussion of archaeological sensitivity (5.3), which contains the actual comparative analysis, is also limited to the above three items and concluded with broad statements, e.g. 'The existence of archaeological sites across the landscape should not be discounted and should be recorded when encountered. Conservation or protection of such features is only possible if their location is known, and in many cases, small or vernacular structures were not recorded.' (p. 92). This statement indicates that the aims of the comparative analysis are not achieved.

Response:

A fully comprehensive comparative analysis would ideally or theoretically encompass a study of all archaeological items of the Project area and surrounds. Such a project would require significant time and effort beyond the remit of a typical environmental assessment as it would include: investigative research for locations and the owners to contact; inquiries for visits; visits at a time that suits the owners; time to perform recording of values, preparation of the study and documents; time for owners to review and approve the text about their properties (considering privacy requirements); and other associated logistical and documentation tasks. That scope of study would not be practically feasible for this Project report and time available. Such a scope is not considered necessary for meeting the IPC recommendation as written.

The comparative analysis in the archaeological assessment included 31 items that were reviewed for their potential to contain relics, which can coexist on sites that also contain built heritage. It is reiterated here that *detailed* archaeological assessment for each and every property is not necessary in an area where impacts have been predicted, by experts, to be negligible. Where impacts may occur, the Project area has been visually inspected, compared and assessed for significance and impacts. Undermining items on the SHR would require more detailed assessment given the extent of legal SHR curtilages but mine design specifically avoids undermining SHR items.

3.7 USHI – Significance assessment

(Page 5, Paragraph 5)

Statement:

The *significance assessment provided in Section 5.4. While some items are assessed against the criteria by the consultant (Tables 5.2; 5.3; 5.4; 5.5), others are detailed with their statements of significance, cited from the relevant statutory listings (5.5.9; 5.5.24). The latter is inappropriate as it unconditionally reiterates statements potentially out of date with regard to the current state of art and does not re-evaluate the relevant items' significance against the new information that would have been gained via this assessment. Items that were not inspected by the consultant are assessed against the criteria (Tables 5.6; 5.7; 5.8; 5.9; 5.10; 5.11; 5.12). Archaeological resources identified by the consultant are not assessed against the criteria (5.5.8). One item that has not previously been discussed in the report (Former Berrima Coal Rail Corridor) appears in this section and is assessed against the criteria in Table 5.13 (p. 109). In general, items are assessed mainly for built heritage values and archaeological potential is discussed only under criteria e) Research and f) Rarity which is insufficient. The significance assessment as presented in the report is to a large extent a function of the confused terminology and the level of understanding of archaeological potential. It is inadequate for the purposes of the report, and does little to facilitate an adequate assessment of potential impacts.*

Response:

<u>*Assessment of archaeological potential*</u>

Caveats relating to the presence of relics are a valid and common feature of archaeological assessments, hence the requirement for unexpected finds procedures in approval documentation. Further, as confirmed elsewhere and by reviewing the Project boundary in the figures prepared for the report, the *Three Legs o' Man Inn* archaeological site is not in the Project area.

Further, as noted in the section on fieldwork (above), field assessment can provide more information, but it does not always. Archaeological sites are not always represented by surface expressions and total survey coverage of a project area of this size is not standard procedure. Areas for survey were targeted based on documentary sources, landholder knowledge and landscape assessment. Where access is not possible and community information is not provided, which is a landholder right, field survey cannot be undertaken. The level of field assessment is considered by the consultant to be suitable.

Given also that potential subsidence impacts, described by the client's subsidence experts, will be negligible to nil at 20 mm, impacts to the ground, whether they possess relics or not can only be assessed to be negligible to nil.

Assessments of significance are inadequate or missing

The assessment of significance for a number of items starts on page 95 of the revised archaeological assessment (EMM 2020d; Appendix F, Annexure D,). It includes items that are not in the project area as requested by Heritage NSW. These assessments have been developed using historical information, comparative analyses and, where available, site inspection results. This is the standard that is set in the documents "Assessing heritage significance" published by the Heritage Council. This is the standard that has been applied to other assessments prepared by EMM, which have been adequate and have received little to no comment.

The assessments of significance for other properties, which are listed either on Schedule 5 of the WLEP, and/or on the State Heritage Register were largely transcribed from the existing assessments. These existing significance assessments and ratings were considered during the preparation of the technical report and, and in most part, were not reassessed in any great detail because of the level of predicted impacts – this is also standard procedure where impacts are predicted to be negligible to nil. It is a misuse of time and budget for any project to be expected to fully assess items that are not going to experience impacts from a project; this is what the listing information is for. It is acknowledged that many state heritage inventory forms are incomplete, and in these cases, EMM contributed to the assessments of significance (refer to pages 95 to 109). However, where impacts are not anticipated, the assessments in the state heritage inventory forms and the technical report prepared by EMM are considered adequate and suitable.

Where, for instance, a property was identified as having the potential to experience impacts due to project activities, it would have been fully reassessed, which would include comparative and historical analysis. This process has been applied to the *Mereworth House and Garden*; demonstrating potential impacts are limited to be visual in nature. The landscape surrounding the house and garden has been analysed in the landscape assessment prepared by Catherine Brouwer Landscape Architects, a highly experienced consultant, to the specification of the Heritage NSW. Despite this, Heritage NSW disagrees with the conclusions.

In the case of the SHR items, inclusion on the register means that the item has undergone rigorous assessment and has been tested against the criteria for listing, as final sign off is by the Minister. The level of investigation and assessment for listing on the SHR is well understood by the main author, having prepared a successful nomination for the White Hart Inn archaeological site and was commended by Heritage NSW for the quality of the nomination. As no items on the SHR are inside the Project area, and none outside the Project area have been identified with the potential to be impacted, a reassessment of the items in the vicinity would not be an appropriate use of time or funds.

3.8 USHI – Identification of Impacts

(Page 6, Paragraph 2)

Statement:

> *An impact assessment is provided in Chapter 6 Potential Impacts to Relics. While on numerous occasions throughout the report, it is stated that potential unrecorded relics are assumed to exist throughout the project area, potential impacts by surface infrastructure are assessed as unlikely (p. 118). Impacts to potential archaeological resources above the underground mining area are assessed based on an overarching assumption that due to the mining method adopted, subsidence will be negligible and therefore impacts to potential archaeological resources will be very unlikely (p. 119-121; Appendix G). Two potential versions of a subsidence prediction report by Mine Advice Pty Ltd (2015 and 2016) are referred to within the report (p.111, 114, 120), however the relevant entries are missing from the reference list. The relevant report has not been appended to this report. No subsidence prediction mapping has been supplied. It is therefore difficult to ascertain the validity of this assessment. Potential impacts of the 'mine pipe-line' as detailed in Figure 6.1 and discussed on p. 118,*

122 and 123 are not sufficiently discussed. Due to the above and with regard to the already mentioned concerns about the level of understanding of archaeological potential and significance throughout the project area, the impact assessment as presented in this report is considered inappropriate.

Response:

The Mine Advice Pty Ltd report referred to in the statement above was contained in full in Volume 7, Appendix L, of the Hume Coal and Berrima Rail Project EIS (EMM 2017). This document, like all other documents prepared for the Hume Coal Project EIS and RTS, are publicly available on DPIE's website. Hume Coal invites Heritage NSW to consult this document and Volume 1, Part C, Section 16.8 of the RTS (EMM 2018) to better "ascertain the validity of this assessment".

As described in Volume 7, Appendix L, of the Hume Coal and Berrima Rail Project EIS (EMM 2017), predicted impacts associated with: vertical subsidence is a maximum of 20 mm; and mining induced ground tilt is expected to be 0.26 mm/m. This level of subsidence will not cause detrimental impacts to the archaeological landscape or relics in the Project area and given separation distances between listed State Heritage Items and underground workings, the potential for damage to these items is considered negligible. Accordingly, the conclusion of the archaeological assessment that recorded and unrecorded relics are unlikely to be impacted by the Project is reiterated here.

Finally, Hume Coal is committed to the verification of predicted rates of subsidence, as outlined in Appendix 2 of the RTS (EMM 2018) and will be installing real-time subsidence monitoring before the commencement of underground mining.

3.9 USHI – Mitigation and management measures

(Page 6, Paragraph 3)

Statement:

> Determined *by the level of assessment, the mitigation and management measures proposed in section 7 are correspondingly vague, proposing a blanket approach rather than a focused method to mitigation and management of impacts. The overarching strategy detailed on p. 122 consists of five points which are repetitive (p. 3 and 4) and in the case of point 1 suggest two contradicting outcomes. The Specific management measures proposed in section 7.1 consist of a historic heritage management plan (HHMP), which would be a requirement under the relevant approval, and Site-specific management (7.1.2) containing recommendations for the all heritage items as identified by the consultant within the project area. Apart from the few measures outlined for Mereworth House and Garden, The Three Legs of Man bridge piers and Evandale, monitoring on a yearly or half-yearly basis is recommended for all sites without any specification as to the methods, techniques or technologies to be utilised. This is insufficient for the purposes of this report. An appropriate historical archaeological assessment identifying historical archaeological potential, significance and impacts to significance by the proposal throughout the project area is still outstanding and will be required in order to propose adequate mitigation and management strategies and guide the HHMP. Heritage NSW does not recommend deferring the project's management of archaeological sites and impacts to a post approval suite of conditions at this stage as outlined above. These matters should be clarified and resolved ahead of a decision on this SSD.*

Response:

The Conservation Management Plan (CMP) will include a succession plan. The commitment to activate a management plan where and when necessary, post approval is a common approach for managing predicted impacts on major projects throughout NSW. We do not see how a commitment such as this is considered inadequate by Heritage NSW in this instance, for this project. In fact, this approach is consistent with all other projects at this stage of the approval process, and therefore, can only be described as adequate.

There are no identified archaeological sites or relics that will be impacted or affected by the Project or Project activities. Where a water pipeline is proposed to be installed (north of Mereworth House), an archaeologist will be present to monitor trenching and to advise on the statutory process.

3.10 USHI – R17 of the IPC Report not adequately addressed

(Page 6, Paragraph 6 and Page 7, Paragraph 1)

Statement:

> *Heritage NSW is also of the opinion that appropriate historical archaeological assessment has not been undertaken and therefore recommendation **R17** of the IPC Review has not been fulfilled. HNSW recommends to DPIE that the archaeological management of the project should NOT be deferred to a post approval approach without the adequate resolution of the historical archaeological sites, their potential, significance, impact and clear mitigation proposed by the project.*

Response:

The report addresses, in full, the requirements of R17 and the assessment notes the limitations of the study. The key limitation was being refused access to a number of properties. NSW Heritage cannot hold Hume Coal/EMM responsible for private landholders exercising their rights and must therefore assess the study on its merits. It is not appropriate for Heritage NSW to:

1. argue that the study is incomplete (orchestrated discrediting) and therefore the result are null and void because access was not possible; and

2. assess the report with a preconceived notion that mining methods are untested in the Australia context and therefore there will be subsidence impacts.

The archaeological assessment for the Project fulfils the requirements of the SEARs and responds to the comments of the Heritage Council in the letter dated 2018. The report was prepared by historical archaeologist Pamela Kottaras with assistance from Amelia O'Donnell. Pamela has over 20 years' experience in the field of historical archaeological management and peer review. Her responsibilities have put her in the field assessing sites and archaeological landscapes for as long as she has been a consultant.

This attempt to diminish the quality of the work is a common theme in communication with Heritage NSW on this project. There appears to be a pre-conceived outcome for Heritage NSW, who will not accept a rational argument that identifies impacts against predicted subsidence and construction of surface infrastructure.

4 Conditions of Consent

4.1 Conditions of Consent – Conservation Management Plan

(Page 7, Bullet 1)

Statement:

> *A conservation management plan (CMP) for Mereworth estate, including the house, garden, estate drive, former drive and rural landscape, is to be prepared within 12 months of the approval. The CMP shall identify appropriate uses for the house, include a schedule of conservation works, as well as a maintenance schedule for house, garden and surrounding farm estate. The CMP shall specifically re-look at the proposed curtilage for Mereworth, noting deliberate view manipulation in the design and location of its access drives, outlooks from key parts of both house and garden surrounds. Conservation policies to conserve and maintain these views, including pruning reinstatement of horizontal elm trees on the 'ha-ha' terraces west of the house, tree removal and replacement plantings, and staging of these, must be included. Prioritised staged works and implementation of those works must be tied to specific development consent conditions to ensure adequate implementation and oversight occurs;*

Response:

Hume Coal has consistently supported the preparation of CMP for Mereworth House and Garden as a future condition of consent within 12 months of the approval. This CMP forms part of Hume Coal's existing post approval commitments for the management of historical heritage values of the Project area and will be developed in consultation with DPIE and Heritage NSW. It is anticipated that this consultation will lead to mutually beneficial heritage conservation outcomes for all relevant stakeholders through balancing:

- the constructability of the proposed mine;
- the ongoing viability of the existing agricultural land uses; and
- the retention of important heritage features present on Mereworth house and garden as described in the extensive investigations that have been completed through the EIS, RTS and IPC response phases.

However, Hume Coal contests the proposed condition as written, particularly the statement Heritage NSW are seeking the CMP to cover "*Mereworth estate, including the house, garden, estate drive, former drive and rural landscape*". Hume Coal does not support the extent of coverage described in this proposed condition. It is requested that the extent of coverage is limited to the curtilage of Mereworth house and garden as described in the legal advice detailed in **Section 1.2 Mereworth House and Garden Impacts - Curtilage**. Please note that any request for a CMP to cover the entire Mereworth property will need to acknowledge the proposed mining land use, future mining operations and appropriate post mining land use(s).

It is also reiterated that Mereworth property will remain in Hume Coal ownership for the life of the Project and will continue as an operating agricultural land use for the duration of this time.

4.2 Conditions of Consent - Curtilage

(Page 7, Bullet 2)

Statement:

> *Detailed project treatment of areas of Mereworth's (as presently defined) curtilage for the life of the project shall be reviewed and adjusted based on the outcomes of the CMP. This may include planting treatment, propagation and replacement plantings, monitoring of condition and damage, conservation and reparatory works*

Response:

As described in **Section 1.2 Mereworth House and Garden Impacts - Curtilage**, Hume Coal have received independent legal advice describing the presently defined curtilage of Mereworth house and garden (see Attachment 1). The CMP will be developed in accordance with stakeholder consultation described above and periodically reviewed throughout the life of the Project to address the evolving needs of managing heritage values within Mereworth house and garden. These periodic reviews will coincide with Mine Operation Plan (MOP) revisions. The CMP shall include a succession plan that will address such items as: planting treatment, propagation and replacement plantings, monitoring of condition and damage, conservation and reparatory works.

4.3 Conditions of Consent - Reassess and relocate – Infrastructure

(Page 7, Bullet 3)

Statement:

> *The project proposal's treatment of and project impacts on Mereworth's cultural landscape is not considered acceptable. This project will have major adverse impacts on this arguably state-significant designed landscape. Alternative locations for project elements do not appear to have been adequately considered. Specific approval conditions requiring such reassessment and relocation, so as to avoid or minimise adverse impacts on Mereworth's cultural landscape are recommended.*

Response:

Very clearly, this is a condition by design to stymie the Project and contains inaccurate claims regarding:

- the impacts on the landscape – the postulation that Mereworth house and garden contains heritage values of state significance has been thoroughly refuted by the extensive investigations that have been completed throughout the EIS, RTS and IPC response phases and **Section 1.1 Mereworth House and Garden – Significance** of this response; and
- that alternative locations for Project infrastructure have not been considered – significant time, effort and resources were invested in developing a surface infrastructure area that is sympathetic to the surrounding environmental and historic heritage values and to avoid impacts to these values to the greatest extent practicable as described in **Section 2.3 Berrima, Sutton Forest and Exeter Cultural Landscape – Relocation of infrastructure** of this response.

Finally, the assertion by Heritage NSW that the depth of historical archaeological assessment performed throughout the EIS, RTS and IPC response phases is inadequate as to require reassessment and relocation is refuted by EMM and Hume Coal. The reasons for this refutation are discussed and exemplified in the preceding paragraphs of this response.

4.4 Conditions of Consent - Dilapidation

(Page 7, Bullet 4)

Statement:

> *A dilapidation report is to be undertaken prior to the commencement of both the Hume Coal Project (SSD 7172) and the Berrima Rail Project (SSD 7171) of each of the State Heritage Register items adjacent to the Hume Coal Project, being Oldbury Farm (SHR no. 488), Golden Vale (SHR no. 489), Hillview (SHR no. 442) and each of the locally significant heritage items listed on Schedule 5 of the Wingecarribee Local Environmental Plan (LEP) 2010 adjacent to the Hume Coal Project. This study is to report on the condition of the properties prior to any construction or excavation. It is to record any existing damage, and the state of any particular aspects of the property that are likely to be affected by construction work, excavation or demolition*

Response:

Hume Coal has already committed to number of management measures that included dilapidation reports, inspection and monitoring of properties inside the Project area, the preparation of a CMP for Mereworth House and Garden, which would include a Plant Succession Plan and other measures proposed by the landscape expert that develops it. These mitigation commitments were reiterated and expanded upon in the IPC Response Report (EMM 2020). With regards to the dilapidation report, Hume Coal supports in principle the condition as it is currently worded. However, Hume Coal would like to remind Heritage NSW that no mining is proposed underneath any state heritage item.

Should a condition of approval on this theme be required, the following clarifications and caveats would be required:

- Hume Coal will need to rely on the consenting authority to organise and coordinate access to these properties in advance of construction commencing after project approval.
- Commencement of construction will not be delayed should access to these state heritage items not be afforded.
- Consultation with Hume Coal is requested to define each of the locally significant heritage items “adjacent to the Hume Coal project”. A definition for “adjacent” could include *overlain by the mine plan with adjoining boundary.*
- The dilapidation report shall be limited to buildings and structures on the listed heritage items.

4.5 Conditions of Consent – Groundwater inspection and monitoring program

(Page 7, Bullet 5)

Statement:

> An inspection and monitoring program should be established for all such properties to ensure that any structural changes are identified. This program is to inspect and monitor the condition of the buildings, structures **as well as the level and extent of ground water for the full duration of the mine, from inception to final decommissioning and for two years following decommissioning and site remediation**.

Response to emboldened text in above statement:

Hume Coal considers the emboldened text within this proposed condition unnecessary for the following reasons:

1. As clearly demonstrated in the groundwater dependence assessment for cultural heritage landscapes and gardens (EMM, 2020c), all listed heritage items occur in areas where the Wianamatta Shale outcrops at surface and therefore have a negligible risk of drawdown. The Groundwater dependence assessment for cultural heritage landscapes and gardens (EMM, 2020c) was conducted by a team comprising an ecologist, an archaeologist, a landscape planner/registered landscape architect, arboricultural specialist, a hydrogeologist and a spatial analyst, using the inputs from the Updated Statement of Heritage Impact (EMM, 2020a) and Updated Water Assessment (EMM, 2020). This interdisciplinary approach provided a robust impact assessment that addresses the IPC recommendations R16 and R19.
2. Unless the listed heritage item has a registered groundwater bore, the property in question is not afforded Make Good protections under the NSW Aquifer Interference Policy;
3. The installation of new groundwater monitoring bores on listed heritage items that presently do not have access to groundwater may inadvertently interfere with previously unidentified archaeological values.

Accordingly, Hume Coal considers the emboldened text within this proposed condition neither reasonable nor relevant to Heritage NSW’s remit, nor to the likely impacts of the project.

4.6 Conditions of Consent – State Heritage Register items adjacent to the Hume Coal Project

(Page 7, Bullet 6)

Statement:

> *Any damage to State Heritage Register items adjacent to the Hume Coal Project, being Oldbury Farm (SHR no. 488), Golden Vale (SHR no. 489), Hillview (SHR no. 442) and each of the locally significant heritage items listed*

on Schedule 5 of the Wingecarribee Local Environmental Plan (LEP) 2010 adjacent to the Hume Coal Project, due to mine construction and operation and for two years following decommissioning should be firstly prevented. Any damage must be carefully rectified immediately in accordance with conservation standards such as the Australia ICOMOS Burra Charter, best industry practice and Heritage Council of NSW guidelines. ***This includes damage to buildings' structure, external and internal claddings, finishes, built in fittings, external paths, retaining or other walls, sheds, fences and other significant landscape elements including trees due to any movement, contamination, leaching, accelerated corrosion and deterioration, or discolouration****. This program should be included in the proposed Historic Heritage Management Plan for both the Hume Coal Project (SSD 7172) and the Berrima Rail Project (SSD 7171).*

Response:

As previously stated in the response, the Project has been designed from the outset to avoid environmental and heritage impacts. The concept of 'mitigation by design' is a strategic approach to environmental management, which incorporates the avoidance (rather than management) of environmental impacts in the design of the Project.

Further to **Section 4.4 Conditions of Consent - Dilapidation** above, Hume Coal is happy to reinstate any damage to listed heritage items in accordance with conservation standards such as the Australia ICOMOS Burra Charter, best industry practice and Heritage Council of NSW guidelines where that damage can be solely attributed to Hume Coal operations.

However and please note, Hume Coal does not support the wording of this condition as it currently stands. The implication that the Project may lead to "damage to buildings' structure, external and internal claddings, finishes, built in fittings, external paths, retaining or other walls, sheds, fences and other significant landscape elements including trees due to any movement, contamination, leaching, accelerated corrosion and deterioration, or discolouration", is factually incorrect and appears to be written to trigger additional studies such as arborist, geochemical and contamination assessments.

Again, Hume Coal would like to reiterate that all listed state heritage items:

- are located outside of the Project area – therefore outside any zone of influence;
- will not be undermined – therefore negating the already negligible subsidence risk (see **Section 3.8 USHI – Identification of Impacts**); and
- are located in areas where the Wianamatta Shale outcrops at surface – therefore minimising any risk of potential groundwater interaction with heritage gardens.

4.7 Conditions of Consent – Excavation reports

(Page 8, Bullet 2)

Statement:

The proposed Historic Heritage Management Plan should:

a) Include map-based specificity about sensitive views, which screening plants are proposed for screening which views;

b) Be specific about staging, monitoring and progressive sign-off of any succession plan;

c) Specify where monitoring reports (on structural stability of items inside and outside the project area, again, first specifying which items, where) shall be sent, and for whose approval or sign-off in each stage of the project;

d) Specify where excavation reports within the Mereworth curtilage shall be sent and for what approval signoff in each stage of the project.

Response:

Hume Coal has long been supportive of the preparation of a Historic Heritage Management Plan (HHMP) for the project. The HHMP will reflect the findings of all archaeological, historic heritage, cultural landscape and visual assessments prepared for the project. Accordingly, the HHMP will include subordinate management plan including the Mereworth House and Garden Conservation Management Plan (CMP) and the proposed Plant Succession Plan.

As with all HHMPs for major projects, a draft will be provided to DPIE to forward to Heritage NSW for review and comment at their discretion. Consultation between Hume Coal or Hume Coal's representative may also be directed by DPIE. It is anticipated that consultation between relevant stakeholders will lead to mutually beneficial heritage conservation outcomes through balancing:

- the constructability of the proposed mine;
- the ongoing viability of the existing agricultural land uses; and
- the retention of important heritage features present on Mereworth house and garden as described in the extensive investigations that have been completed through the EIS, RTS and IPC response phases.

The HHMP and any subordinate plan will include monitoring and reporting requirements to demonstrate compliance with relevant study findings and conditions of consent and will reflect the Mereworth curtilage as defined in **Section 1.2 Mereworth House and Garden Impacts - Curtilage**.

5 Conclusions

The advice contained in this letter refutes and corrects a number of Heritage NSWs representations as to the content, adequacy and competence of documentation within the IPC Response Report prepared by EMM and Hume Coal, dated 8 April 2020. Central to Heritage NSWs argument are three broad themes:

- The heritage listing for Mereworth House and Garden should include the allotments which contain them;
- Mereworth House and Garden *may* be of state significance; and
- The USHI is inadequate and not competently prepared.

EMM has presented compelling material refuting these misconceptions and misrepresentations. Hume Coal expresses in principle support to some of the conditions of consent presented but not in their present form. This letter identifies the conditions Hume Coal object to.

We therefore request DPIE disregard much of Heritage NSWs submission and it objections to the project.

Yours sincerely

Dylan Falconer
Hume Coal Project Manager

dfalconer@emmconsulting.com.au

Acknowledgments:

1. Andrew Dickinson (Mereworth House and Garden and Cultural Landscape);
2. Catherine Brouwer (Mereworth House and Garden and Cultural Landscape); and
3. Pamela Kottaras (Archaeology).

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Brouwer, 2020a, *Sorensen Garden Comparative Analysis & the Garden at Mereworth*. Catherine Brouwer Landscape Architects for Hume Coal Pty Ltd.

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Heritage NSW Website: Mereworth House and Gardens https://www.heritage.nsw.gov.au/about-our-heritage/historic-archaeology/ accessed Friday 21/8/20.

Sparke Helmore Lawyers, 2020, *Heritage Advice – Mereworth House and Gardens.* Prepared for Hume Coal 18 August 2020. Sparke Helmore Lawyers, Sydney.

WLEP, 2010, *Wingecarribee Local Environmental Plan.*

Attachment 1: Sparke Helmore Lawyers, 2020, Heritage Advice – Mereworth House and Gardens.

18 August 2020

Mr Chris Kim
Hume Coal Pty Limited
PO Box 1226
Moss Vale NSW 2577

By email:
ckim@humecoal.com.au

Dear Chris

Heritage Advice – Mereworth House and Garden
Our ref: APM: HUM009/00059

1. Advice Sought

1.1 Hume Coal requires advice about the status of the local heritage item on Mereworth, in particular, what constitutes the listed heritage item and what restrictions apply.

2. Summary of advice

2.1 The heritage item is limited to the Mereworth house and garden (which may extend to the driveway).

2.2 The Council is incorrect in its suggestion that the whole of the cadastral lots that comprise the Mereworth property are heritage listed.

3. Background

3.1 Hume Coal Pty Ltd (**Hume Coal**) owns a substantial rural property at Berrima called 'Mereworth'. The Mereworth property is made up of Lot 200 (**Lot 200**) and Lot 201 (**Lot 201**) DP839314 and Lot 2 DP1138694 (**Lot 2**). The Mereworth land is severed by the Hume Highway.

3.2 The part of Lot 2 on the east of the Hume Highway is zoned RU2- Rural Landscape under the *Wingecarribee Local Environmental Plan 2010* (**WLEP**). The land on the west of the Hume Highway is zoned E3 - Environmental Management. Lot 200 and Lot 201 are also zoned E3 – Environmental Management.

3.3 The WLEP contains provisions dealing with heritage conservation. Heritage items are described in Schedule 5 of the WLEP. Heritage Conservation Areas are shown on the heritage map as well as being described in Schedule 5.

3.4 The following entry appears in Part 1 in Schedule 5 of the WLEP:

Suburb	Item name	Address	Property description	Significance	Item No
Berrima	"Mereworth" house and garden	Old Hume Highway	Lot 100, DP 839316; Lot 200, DP 839314	Local	I351

3.5 Lot 100 DP 839316, referred to in the listing, is the same land as Lot 2.

3.6 Although Lot 2 and Lot 200 are coloured brown on the WLEP Heritage Map, which indicates there is a heritage item on the property, they are not identified as being within any form of conservation area.

3.7 The Mereworth house and garden are not listed on the State Heritage Register.

3.8 On 19 May 2020 a review on the Hume Coal Response to the IPC Review Report for the Hume Coal Project (SSD 7172) and the related Berrima Rail Project (SSD 7171) was requested by the Department of Planning and Environment from Heritage NSW (**the Response**).

3.9 On 19 June 2020 a response was received and uploaded to the Major Projects website. The Response from Heritage NSW states the following of relevance to the status of Mereworth house and garden:

> ***"Mereworth House and Garden***
>
> *Significance*
>
> …
>
> The report therefore concludes that the Mereworth garden is a place of local significance. Heritage NSW does not agree with this assessment, instead an assessment by Heritage NSW has indicates that the site may be of state significance.
>
> *Impacts*
>
> The Updated Statement of Heritage Impact (**USHI**) Groundwater Dependence Assessment includes an assessment of shallow groundwater access making a distinction between firstly Mereworth's house and garden and secondly the gardens and trees located within the heritage listed item described as 'outside Mereworth heritage curtilage'. Consultation with Wingecarribee Council has clarified that no curtilage studies have been undertaken for the locally listed Mereworth House and Garden, and that the entire allotment was listed. It was also clarified that the significance of the views and vistas, including the use of the ha-ha walls to ensure retention of uninterrupted views, could be considered in a curtilage assessment; therefore, the surrounding landscape could be considered part of the heritage item's curtilage.
>
> …
>
> Figure 5.8 and 5.9 of the Updated Visual Impact Assessment (**UVIA**) illustrate the proposed site in relation to Mereworth House and Garden, demonstrating that the majority of the coal infrastructure is proposed within the boundaries of this locally heritage listed item…"

4. Status of Mereworth Heritage Item

Definition

4.1 Mereworth house and garden are not listed on the State Heritage Register, notwithstanding the comments from Heritage NSW above. Because the Mereworth house and garden are listed as a "local" heritage item, the restrictions that apply to it are contained in the WLEP.

4.2 To determine the extent of what is listed, it is necessary to have regard to the definitions in the WLEP, the words used in Schedule 5, and the nature of the restrictions that apply to the item which provide context for the proper construction of the listing.

4.3 The expression "heritage item" is defined in the WLEP as:

> ***heritage item*** *means a building, work, place, relic, tree, object or archaeological site the location and nature of which is described in Schedule 5.*

Legal status of Heritage Map

4.4 What constitutes a "heritage item" is defined by the Dictionary to the WLEP, and nothing else. The definition of "heritage item" and Schedule 5 make no reference to the colour-coded Heritage Map attached to the WLEP. Therefore, the colour-coded Heritage Map does not have a bearing on what constitutes a "heritage item".

4.5 In contrast, the definitions for "Aboriginal place of heritage significance" and "heritage conservation area" in the Dictionary to the WLEP specifically provide that the Heritage Map has the effect of defining what those items are:

> ***Aboriginal place of heritage significance*** *means an area of land, the general location of which is identified in an Aboriginal heritage study adopted by the Council after public exhibition and that may be shown on the Heritage Map, that is—*
>
> *(a) the site of one or more Aboriginal objects or a place that has the physical remains of pre-European occupation by, or is of contemporary significance to, the Aboriginal people. It may (but need not) include items and remnants of the occupation of the land by Aboriginal people, such as burial places, engraving sites, rock art, midden deposits, scarred and sacred trees and sharpening grooves, or*
>
> *(b) a natural Aboriginal sacred site or other sacred feature. It includes natural features such as creeks or mountains of long-standing cultural significance, as well as initiation, ceremonial or story places or areas of more contemporary cultural significance.*
>
> ***heritage conservation area*** *means an area of land of heritage significance—*
>
> *(a) shown on the Heritage Map as a heritage conservation area, and*
>
> *(b) the location and nature of which is described in Schedule 5,*
>
> *and includes any heritage items situated on or within that area.*

4.6 The fact that the definition of "heritage item" makes no reference to the heritage map, but the two abovementioned definitions do, clearly indicates that the drafters of the WLEP intended for the heritage map to have no bearing on what constitutes a "heritage item".

4.7 Since the Mereworth property is not an "Aboriginal place of heritage significance" or "heritage conservation area", the Heritage Map has no relevant application to the Mereworth property.

4.8 The Mereworth item involves a building (the house) and a place (the garden).

4.9 The item is identified as Item I351 (which appears to be a reference to the Council's Heritage Inventory). We have been provided with the relevant entry from the Council's Heritage Inventory. The Statement of Significance for the item provides:

> "1965 house with important early nineteenth century historical connections. The garden is important for its connection with Paul Sorensen, the renowned cold-climate designer."

4.10 Material on the Office of Environment and Heritage contains the following detail about the "heritage item":

> "Situated on a rise in gently undulating open pasture country south of Berrima. Visually dominates the immediate area and is recognisable for some distance through the bold conifers and golden elm driveway that feature significantly in the layout. The house is reached via a long driveway planted with golden elms foward of a dark green cypress "hedge". The house and

> garden are enclosed on 3 sides but open to the west offering views across to distant hills. The style and layout of the garden reflects the period of its construction and it has a number of significant landscape elements including a curved swimming pool and formal rose garden and raised pedestal fountain from which a cherry walk leads to the house. Plantings around the immediate house are bold with a row of purple acer palmatums hugging the wall near the pool. An enclosed courtyard off the driveway leads to the house."

4.11 The provisions of the WLEP and the heritage inventory support the proposition that the "heritage item" is limited to the actual house and garden – not the curtilage. Notwithstanding that Schedule 5 refers to both Lot 2 and Lot 200, it is not the property which is listed. It is the items themselves.

Clause 5.10 of the WLEP

4.12 Clause 5.10 of the WLEP (dealing with heritage conservation) also supports the construction that it is the actual house and garden which are listed not the cadastral lots. As set out above Mereworth is not an archaeological site, an Aboriginal place of heritage significance or within a heritage conservation area. In the case of a listed building and place, as is the case with Mereworth, development consent is only required under clause 5.10 where:

(a) demolition of the item is proposed (Clause 5.10(2)(a)),

(b) there are physical changes to the heritage item (clause 5.10(2)(b)),

(c) there is the proposed erection of a building on the land identified in Schedule (clause 5.10(2)(e)), and

(d) there is a proposed subdivision of the land identified in Schedule 5 (clause 5.10(f)).

4.13 Although the development control applies to two cadastral lots (being "land identified in the Schedule") that does not make that land part of the "heritage item". The controls provide an extra level of protection for the "heritage item" but do not make the land itself part of the "heritage item".

Case law

4.14 Unless one of those triggers is met, then clause 5.10 has no operation for any other development at Mereworth.

4.15 In the recent decision of *Stamford Property Services Pty Ltd v Mulpha Australia Ltd* [2019] NSWCA 141, the Court of Appeal considered the prohibition in the *Heritage Act 1977* on "carrying out development in relation to the land on which" a building listed on the State Heritage Register was situated.

4.16 Leeming JA expressed support for the following statement in Scully v Leichardt Council (1994) 85 LGERA 109:

> The word 'land' is a word of general meaning. It does not of itself suggest any specific limitation of size or measurement or any specifically identifiable area, such as is suggested by the word 'allotment'. It is necessary, then, to consider the context in which the word appears, and the scope and purpose of the relevant statutory provisions, in order to determine how the word 'land' is to be construed.

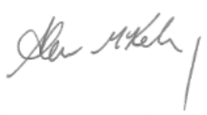
4.17 After considering the context of the term, the Court determined that the prohibition on carrying out development without heritage approval applied "only to the part of the land on which the heritage listed building stands, and not to the whole of the cadastral lot".

4.18 Emmett AJA also stated at [148] that the proscription contained in s 57(1)(e) is concerned with the specific heritage item, and should not refer to anything beyond the land on which the specific item is actually situated.

4.19 This position was also recently applied by Commissioner Bish in *Arcidiacono as Trustees for the Arcidiacono Family Trust v Blacktown City Council* [2019] NSWLEC 1264.

4.20 It follows that while the planning controls in clause 5.10 apply to the lots identified in the schedule (triggering a requirement for development consent in certain circumstances), the “heritage item” is the physical part of the land on which the “heritage item” (Mereworth house and garden) is located and not to the curtilage or the whole of the castradal lot. The Council is incorrect in its suggestion that the whole of the cadastral lots that comprise the Mereworth property are heritage listed.

Yours faithfully



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Appendix B7 – Applicant Response to Wingecarribee Shire Council advice

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

13 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS
RESPONSE TO AGENCY COMMENTS – THE WINGECARRIBEE SHIRE COUNCIL – MR BARRY ARTHUR

Dear Mandana,

Thank you for providing the Agency comments. Hume Coal, while disappointed, with the adopted position of the Wingecarribee Shire Council (WSC) acknowledge that if nothing else they have remained consistently opposed to our State Significant Development Projects.

Hume Coal's "Consultation Manager" records file notes, events, presentations, discussions and contacts that we have held with the WSC over the last 10 years and has in excess of 300 pages of details.

Hume Coal have endeavoured to discuss a Voluntary Planning Agreement (VPA) with the WSC, without success. Hume Coal have made some correspondence available to DPIE regarding this matter. Nevertheless, if the Hume Coal Projects are approved we will continue to reach out to the Council in an attempt to seek a constructive approach to the benefit of the regions rate-payers.

Regards,

Rod Doyle
Project Manager

Hume Coal Pty Limited

Hume Coal Pty Limited
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Appendix B8 – Applicant Response to Independent Expert advice (economics)

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

17 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS
RESPONSE TO AGENCY COMMENTS – BIS OXFORD ECONOMICS.

Dear Mandana,

Thank you for providing the Agency comments.

Please find attached the response from Hume Coal regarding the BIS OXFORD ECONOMICS report – "Review of 2020 Economic Impact Assessment Hume Coal and Berrima Rail Project – July 2020.

Regards,

Rod Doyle

Project Manager

Hume Coal Pty Limited

Hume Coal Pty Limited
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19 August 2020

RESPONSE TO A REVIEW OF HUME COAL 2020 ECONOMIC ASSESSMENT BY DPIE REVIEWER BIS OXFORD ECONOMICS (BISOE)

A. Hume Coal project overview – Economic Benefits

BAEconomics prepared an updated 2020 economic assessment of the Hume Coal and Berrima Rail Projects (Projects) as a combined development.

A cost-benefit assessment (CBA), following the Department of Planning Industry & Environment's (Department) 2015 Guidelines for the Economic Assessment of Mining and Coal Seam Gas Proposals (2015 Mining Guidelines), was prepared.

As an adjunct to the CBA, BAEconomics commissioned Cadence Economics (now Ernst & Young) to conduct CGE modelling to assess the regional and economy-wide impacts of the Projects.

In summary, the Hume CBA highlighted some anachronistic observations in applying the 2015 Mining Guidelines to a 2020 project.

- All economic benefits of the Hume Coal project have been discounted by 7% per annum over and above inflation, compounded annually, following the 2015 Mining Guidelines.

- The use of a 7% discount rate underestimates the net benefit to NSW, considering interest rates are approaching zero, have been historically low for the last decade, and are projected by the Reserve Bank to continue to be low for many years.

  The NSW Treasury Circular for determining NPV[i] requires the following:

  > *"The discount rate is to be based on the market yield on Commonwealth government bonds as published by the Reserve Bank of Australia. See Indicative Mid Rates of Commonwealth Government Securities (Table F16)"*[ii].

  These rates are significantly less than the discount rates required by the 2015 Mining Guidelines of (7% nominal and a sensitivity assessment at 10% and 4%).

- Application of a 7% discount rate to the Hume project is very conservative, since the NSW government-mandated nominal discount rate is 3.6%, and the real discount rate is 1.3% for local governments[iii].

  Although the NSW Government does not publish specific discount rates for specific government projects and programmes, therefore lacking transparency, it can be surmised that the discount rate applied is considerably below that used in the 2015 Mining Guidelines, thus creating an uneven playing field for CBA assessment of private sector mining projects, as opposed to taxpayer funded public projects.

It is known that governments have adopted a 1.3-2.0% discount rate to justify publicly funded climate-change initiatives, using the Stern Report[iv] as a justification.

- If 4% discount rate is applied, being the lower sensitivity band of the 2015 Mining Guidelines, the net benefit of the project to NSW increases by $108 million NPV (broader cost-benefit analysis (CBA) interpretation[1]) or $84 million (narrow interpretation[2]). See Table 1.

Table 1: Net Economic Benefits to NSW (Comparison of Discount Rates)

Discount Rate Assumption	2015 NSW Cost-Benefit Guidelines for Mining Projects (NPV A$ m 2018)	
	Narrow Interpretation	Broader Interpretation
7 per cent	$192	$290
4 per cent	$276	$398

Economy-Wide Modelling: Computable General Equilibrium (CGE)

Hume Coal adopted a comprehensive assessment of using the 2015 Mining Guidelines. However, in recognition of a need for more appropriate tools, for assessing the economy-wide impact of the Hume Coal project, Cadence Economics was commissioned to apply CGE modelling. CGE is the preferred technique to assess the impacts of large projects in an economy-wide framework in comparison to the base case (i.e. no project).

CGE modelling shows the Hume Coal project from 2020 to 2042 will result in:

- An increase in **Gross State Product (GSP) by $1.9 billion (NPV)**
- An increase in **Gross State Income (GSI) by $2.2 billion (NPV)**
- An increase in **Household consumption by $1.3 billion (NPV)**

Updated Economic Assessment 2020

To address recommendations by the Independent Planning Commission (IPC), an updated Economic Impact Assessment (EIA) was prepared by BAEconomics in March 2020.

Summary of the EIA 2020:

- **$922 million ($640 million NPV) in total capital expenditure** (including for sustaining capital and rehabilitation expenditures).

- **$1.65 billion (undiscounted) ($747 m NPV) in total operating expenditures** (materials & consumables - excluding labour). Of this, up to $349 million NPV could be sourced from suppliers in the Southern Highlands SA3 Region. Hume Coal estimates that 25 percent ($147 million) of pit-top ROM and 24 percent ($203 million) of CHPP to FOB materials and services could be sourced locally. This estimate is based on the 83 of expression of interest Hume Coal has received from local businesses who wish to become a supplier for the Hume project.

- **Peak construction and operational workforce for both mine and rail operations will be 454 and 316** respectively.

- **Royalties to the NSW Government are estimated to be $339 million** (undiscounted) ($148 m NPV).

- **Total company tax is estimated to be $142 million NPV** ($45 m for NSW share).

- **Total net economic benefit to NSW will be $290 million NPV**, based on a broad interpretation of the 2015 Guidelines ($192 m NPV based on a narrow interpretation).

- **Labour costs are calculated to be $925 million (undiscounted) ($451 m NPV)**. Disposable income to the operational workforce is about $272 million NPV ($63 m NPV to NSW workers)
  - Disposable income to operational workers (128-175) in the '45-minute workforce catchment' is $58-$75 million NPV.
  - Disposable income to operational workforce (68-93) in the Southern Highlands SA3 Region is $31-$42 million NPV.
  - If the broader income flow-on effects applicable to the Southern Highlands SA3 Region apply, total local income effects are estimated to be $59-80 million NPV.

- **Local government rates are estimated to be $3.7 million (undiscounted)** or $2 million NPV over the mine life (including construction and decommissioning).

- Loss of **agricultural production** from the 117 ha of land required for surface operations is estimated to be $124,000 NPV. When converted to an annual amortised value, this is approximately $10,000 per annum or less than 0.2 jobs.

Net Economic Benefits to NSW:

The updated Economic impact Assessment 2020 identified the following NPV benefits to NSW from the Hume project (Table 2)

Table 2: Net Economic Benefits to NSW

NET ECONOMIC BENEFIT TO NSW	$AU 2018 NPV (Millions)
NSW Government Royalties	148
NSW Share Company Income Tax	45
NSW Share Personal Income Tax/Medicare Levy	15
Benefit to NSW Workers	63
Payroll Tax	18
Land Tax	1

Local Government Rates	1
Less:	
External Effects (Greenhouse Gas)	0.1
Lost Agricultural Production	0.9
NET BENEFITS TO NSW	290

Note: Totals may not sum precisely due to rounding.

B. BISOE's Review of the Hume 2020 Economic Assessment – Summary of Response

BIS Oxford Economics (BISOE) was commissioned by the Department to review the 2020 economic assessment prepared by BAEconomics.

In summary, BISOE found:

1. **Overall -** *"As was the case for the 2017 CBA, on the whole, the 2020 CBA is well researched and presented"*, but was critical of the 'broader interpretation' of the CBA.

   The 'broader interpretation' of economic benefits has been adopted for other government projects. For example, the business case for the WestConnex transport project determined the Benefit-Cost Ratio (BCR) without wider economic benefits at a Ratio of 1.71. The BCR with wider economic benefits as determined to be 1.88[v]. It is generally conceded that a project with a BCR of >1 provides net economic benefits to the State. The BCR for the Hume projects is considerably greater than government projects, even if a CBA 'narrow interpretation' is applied, after disregarding employment benefits, associated taxes, and making no allowance for royalties.

   Using the 'narrower interpretation' of project benefits, as concluded by BISOE, "the project records net positive benefits for NSW in NPV terms, even when the benefits to workers and accompanying tax benefits are excluded. We also note that this sum is $67 million larger than the equivalent 'narrower' definition of net benefits cited in the First review ($127 million)".

   BISOE reinforces that, irrespective of an increase in contingencies for externalities and the adoption of the narrow interpretation of the guidelines, the coal price would need to fall by 65% before no net benefits to NSW are received.

2. **Royalties** – *"Overall the analysis seems reasonable"* but failed to take account of "geopolitical tensions and opposition to thermal coal extraction and consumption".

   Even BISOE would have to concede that modelling for unforeseen events is fraught with difficulty, although past examples of international conflict have led to an increase in volume and prices for energy, steelmaking materials, and other commodities.

3. **Company Income Tax** – *"the analysis here seems reasonable"*.
Noted

4. **Costs** – *"not possible to offer detailed commentary ….as these were obtained from the commercial estimates made by Hume Coal".*

   Capital and operating costs were sourced from external independent parties from recognised cost databases that are regularly updated. These are commercial-in-confidence and have been robustly applied to ensure the integrity of the financial model that will be used to make private sector investment decisions and to prepare the bankable feasibility.

5. **Benefits to Workers** – *"The assessment of economic benefits to NSW workers has fallen considerably compared to that proposed in the 2017 EIA (by $71million or 53%). This is apparently due to the more conservative assumptions in the 2020 EIA".*

   BISOE offers consistent criticism of the need for sensitivity analysis, but when BAEconomics adopted an overly conservative assumption on labour benefits, it is dismissed as proof of benefits being the subject to changes in assumptions.

   BISOE recommends that *"benefits to workers be disregarded*". This is inconsistent with the approach taken by the Department with the greater majority of mining projects. For example, the Department in its advice on the Wallarah 2 coal project stated:

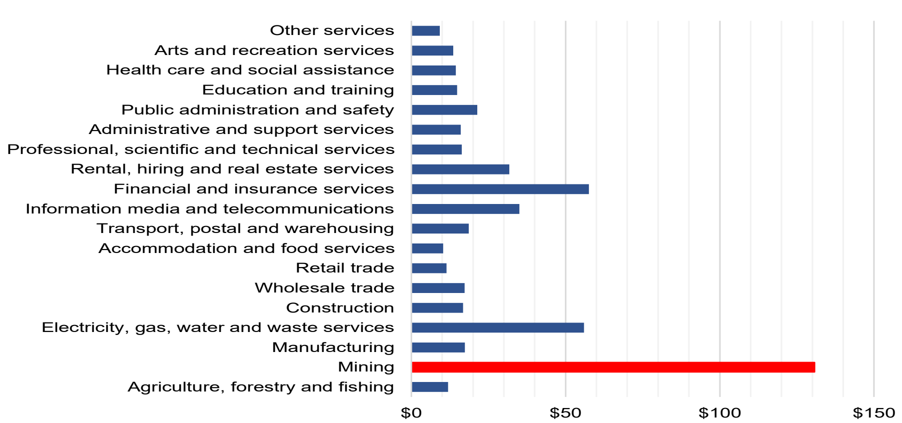
   > *"However, overall the Department believes that mining projects have large flow on effects for regional economies as they have large operating costs (some of which is spent on suppliers in the local region) as they pay higher than average wages (much of which is spent in the local region). The Department therefore maintains its general view that flow-on employment benefits are significant benefits from mining in NSW, which should be given weight in assessing the projects overall merits".*[vi]

   In response to BISOE's demand for evidence of wage premium, the simple economic reality is the wage premia paid to mine workers is high by wage levels for other workers in regional areas. The mean employee income for the Wingecarribee LGA is $45,527 or 37% of that paid to miners. Interestingly, mean employee income in Wingecarribee is 16% less than Wollondilly LGA to the north and 5% less than Goulburn Mulwaree LGA[vii] to the south, highlighting the predominance of lower-paid jobs in the accommodation, food services, and aged care sectors.

   To date, 667 applicants have lodged employment 'expressions of interest' Hume Coal, demonstrating the pent up demand for local employment the lack of real employment, particularly for higher paid and skilled jobs.

   Further, to disregard the benefits of $925 million (undiscounted) in wages paid during operation, assuming Hume will compete with full-time workers in other parts of the economy, ignores the impacts of the post-COVID economy where unemployment has dramatically increased, and productivity from every other employment sector is unable to compete with mining. The major industry sectors represented in the Southern Highlands have the lowest of all productivity, seen in Table 1 below.

TABLE 1: LABOUR PRODUCTIVITY BY SECTOR (2019)[viii]



In March and April alone, the rate of increase for Jobseeker in the Mittagong-Bowral Centrelink region was the second-highest regional increase in the nation, 92% and just trailing the Gold Coast at 93%[ix]. An analysis of data from the JobSaver scheme (March-May 2020)[x] further highlights the dramatic increase in JobSeekers claims in the local region, compared with neighbouring areas (Table 2).

TABLE 2: JOBSAVER CLAIMS INCREASE (MARCH-MAY 2020)

JobSeeker Catchment	Percentage Increase
Southern Highlands	129
Robertson/Fitzroy Falls	110
Moss Vale/Berrima	119
Mittagong	157
Picton/Tahmoor	96
Goulburn	74

Also, the real state of the local labour market is masked by the fact that one-in-four businesses in the Southern Highlands are now the recipient of JobKeeper.

6. **Tax Benefits** – As with Worker benefits, BISOE recommends that personal income tax, payroll tax, and Medicare levy should be disregarded. In effect, BISOE is discounting the project by $96 million NPV by recommending the Department disregard worker benefits, personal income, and

payroll taxes. This is not credible in a post-CIVID environment and, discounting worker benefits in regional areas cannot be supported where labour markets are less fungible.

7. **Externalities** – BISOE stated that "…it is unclear, how (or if) the assessed externalities reconcile with the NPV of $13 million in environmental mitigation costs referred to on p.28 of the 2020 EIA*"*.

   Unfortunately, BISOE has confused the direct costs of 'environmental costs' to calculate the 'net producer surplus', and the indirect costs of the 'environmental externalities' to calculate the net benefit to NSW.

   To demand that direct costs be reconciled to indirect costs is confusing the basic concepts of indirect and direct costs. Direct costs should not be reconciled to indirect costs, since those two are mutually exclusive.

   Further, because 'net producer surplus' forms part of the calculation for determining the net benefit to NSW, to do as BISOE demands is to double count the environmental costs, which leads to a wrong outcome.

8. **CGE Modelling** – *"this modelling should be disregarded"*

   BISOE argues that CGE modelling, should be disregarded because it is not an alternative to the input-output analysis consistent with the 2015 Guidelines: *"As noted by the Treasury guidelines, CGE does not replace CBA…and as noted in our first review, the Guidelines do not call for a state-wide analysis of flow-on effects".*

   This is a red-herring because neither Hume Coal nor BAEconomics argued that CGE replaces CBA. Such a suggestion can mislead the IPC and DPE to think that Hume Coal seeks to replace CBA with CGE, when no such thing was suggested or occurred.

   CGE modelling is now used as an additional tool to examine the economy-wide impacts of major investments on a regional and state-wide basis. It is not a substitute for, but an adjunct to input-output analysis. The latter being a requirement of both the 2015 Mining Guidelines and the NSW Treasury Guidelines.

   To quote from the NSW Treasury CBA 2017 Guidelines:

   > *"A general equilibrium Approach to assessing economic impacts takes a comprehensive view, and entails the use of whole-of-economy models …….. that represent the relationships among key variables in the economy. This approach aims to estimate the effect of a change in one variable on all other interrelated variables"*

   CGE does the very thing BISOE seeks to do, that is to remove the impact of changes to one variable on an economy-wide level, providing a more robust output to support the ultra-conservative outputs of input-output models.

The Department has endorsed the use of CGE modelling in other projects. For example, in its assessment on the Bylong mine it said:

> *"The CGE modelling supports the conclusion that the project would provide a significant increase in regional employment opportunities during mining operations, with the lower bounds of the CGE modelling still showing significant benefits".*[xi]

The Department's report to the IPC also states:

> *"This additional CGE modelling should provide further confidence to the Commission that the project as proposed would provide significant benefits to the regional and NSW economies"*[xii]

More recently, the Department's economics peer review into the Vickery Mine Extension Project, its reviewer, Marsden Jacobs made the following observation:

> *"…we are less sanguine regarding the use of input output assessment techniques to demonstrate the effects of the mine for the local area – our preference would be for a regional CGE model to be applied"*[xiii]

Marsden Jacob concluded that the CGE approach would provide "some valuable insight over and above the input output analysis"

> *"The CGE approach would also provide some insight into the underlying counterfactual that there would be no development in the absence of the mine. Under the non-development scenario current activities continue and the CGE approach could estimate the net affect of any change. The CGE approach also addresses the underlying problem with a no change counterfactual which can imply there is no opportunity cost with proceeding with investments and capital and labour in the economy would be used elsewhere in NSW or the local economy. The CGE approach can also provide more insight into the temporal dimensions of flow on effects through different stages of mine development"*[xiv]

Use of Treasury Cost-Benefit Guidelines

BISOE's reliance on the NSW Treasury Guidelines for Cost Benefit Analysis being applicable to the Hume Coal project should be disregarded by the Department in its assessment report.

The detailed reasons are contained in Section C: Full Response to the BISOE 2020 report Section 1 below.

C. Full response to the BISOE 2020 report

Contents

1. NSW Treasury Guidelines NSW Government Guide to Cost-Benefit Analysis (2017)

BISOE in its response to the Hume Coal response to IPC recommendations maintains that labour and associated income tax and medicare benefits should be excluded from the economic assessment of the Hume project.

DPIE's (the Department's) Preliminary Assessment Report[xv] stated:

> *"One of the keys points of difference is the inclusion of 'employment benefits' and 'associated tax benefits', which Mr Tessler considers should not be included in the cost benefit analysis. This is based on NSW Treasury Guidelines that make it clear that, on first principles, labour should be considered a cost rather than a benefit. That is because it is assumed that labour is already fully employed and must be drawn away from elsewhere".*

The EP&A Regulation 2000 requires the proponent to request the Secretary's Environmental Assessment Requirements (SEARS). The SEARS did not list the Treasury Guideines.

The Department in 2015 adopted sector-specific cost-benefit guidelines for coal mining and coal seam gas proposals[xvi]. The 2015 Guideline specifically states:

> *"To support a triple bottom line assessment, the standard SEARS require an economic assessment of the project in accordance with **these** (emphasis added) guidelines".*[xvii]

Did the Department require BISOE to assess the Hume projects against NSW Treasury Guidelines? BISOE stated in its 2017 report the scope of works directed to BISOE:

"Consistency of the assessment with any relevant government guidelines (e.g., NSW Treasury (2017) NSW guide to cost-benefit analysis and/or the NSW Government (2015) guidelines for economic assessment of mining and coal seam gas proposals".

Hume Coal has written to the Department seeking clarification on this matter, as this would be a substantial departure from previous practice, and demonstrates an inherent bias not applied to all other mining projects. No response has been received.

Guideline to the Treasury Guidelines

To understand to role of the NSW Treasury CBA Guideline (2017), it is useful to obtain guidance from NSW Treasury. The Government Guideline[xviii] to the Treasury Guidelines specifically states who needs to comply with the Treasury Guidelines, which excludes private corporations:

Overview

Who needs to know and/or comply with this?	
Departments	Executive agencies related to Departments
Advisory Entities (including Boards and Committees)	Separate agencies
State Owned Corporations	Statutory Authorities/Bodies
Subsidiaries of the NSW Government established under the Corporations Act	Councils under the Local Government Act
Universities	

This is an unequivocal statement from the NSW Government that the Treasury Guidelines do not apply to private projects.

It also states under the 'Description' that the Treasury Guidelines apply to government projects (emphasis added):

"Description

The purpose of this Treasury policy and guidelines paper is to provide guidance and promote a consistent approach to appraisal and evaluation of public projects, programs and policies across the NSW Government. Agencies should use this NSW Government Guide to Cost-Benefit Analysis (Guide) when assessing all significant government on projects, programs, policies and regulations."

The concept of applying "government initiative" guidelines to a private project is nonsensical, and impossible. For example, Appendix 1 of the Treasury Guidelines state that "analyst should consider the reasons for government action before conducting a CBA".

But since the Hume Coal project is not government action, it is not possible to consider what reasons the *NSW government* had before *Hume Coal* decided to undertake the Hume Coal project. Therefore, if the Treasury Guideline was to be followed as BISOE argues on page 6, then the CBA cannot be undertaken since Appendix 1 states on page 22 that the reason for the government action must be considered first *before* a CBA is conducted. It beggars belief that BISOE repeatedly asserts that the Treasury Guidelines be applied to Hume Coal, despite the clear words of the Treasury Guidelines and the Guide to the Treasury Guidelines.

BISOE's argument:

BISEO at page 6[xix]:

> *"While the Treasury Guidelines refer to government initiatives and indicate that these initiatives are not intended to replace agency-specific advice, they also note that they are intended to encourage a common analytical approach to CBA across NSW Government (p. 6). In this context, the Treasury Guidelines (p. 6) also refer to the Guidelines for the Economic Assessment of Mining and Coal Seam Gas Proposals as publicly available sector-specific guidelines. Accordingly, the Treasury Guidelines are also relevant in the context of this review."* (emphasis added)

Page 6 of the Treasury Guideline actually states:

> This Guide acknowledges that individual agencies have developed their own CBA guidelines[5], often jointly with Treasury. Where those agencies' CBA guidelines are consistent with the framework and principles in this document, this Guide is not intended to replace existing agency-specific guidance. Rather, **the aim of this Guide is to apply a common analytical approach across the NSW Government** that will enable comparison and evaluation of Government initiatives on a 'like-with-like' basis. Analysts are encouraged to consult Treasury on project or portfolio specific issues. Publicly available sector-specific guidelines are listed in Appendix 10.

BISOE para-phrase at page 6	*"…they also note that they are intended to encourage a common analytical approach to CBA across NSW Government (p6)."*
Actual words of the Treasury Guideline	*"…common analytical approach across the NSW Government that will enable* ***comparison and evaluation of Government initiatives*** *on a 'like-with-like' basis."*

It is striking that BISOE has chosen to remove reference to "evaluation of Government initiatives" in its paraphrasing of the aim of the Treasury Guidelines. BISOE's decision to cherry-pick what parts of the sentence to paraphrase misleads the DPIE and the IPC, whether intentional or not.

Page 6 of the Treasury Guideline specifically states that it is to enable evaluation of "Government initiative". But Hume Coal is ***not*** a Government initiative. Applying the Treasury Guidelines to a private proposal to enable 'like-with-like' comparison and evaluation with "government initiatives" is appropriate where sector-specific CBA guidelines have been adopted by the Department for all other mining projects.

BISOE also states that because the Treasury Guidelines, state on page 6, that sector-specific guideline is at Appendix 10 that lists the *Guidelines for the Economic Assessment of Mining and Coal Seam Gas Proposals,* the corollary is that the Treasury Guidelines are relevant to Hume Coal project. This logic is not supported by the text of the Treasury Guidelines.

Appendix 10 of the Treasury Guidelines simply lists sector-specific guidelines as being the appropriate sector-specific guidelines applicable for mining projects. It does not say that NSW Treasury CBA guidelines are applicable when assessing private coal mining projects

Put another way, just because the Treasury guideline lists the 2015 Mining Guideline as one of the sector-specific guidelines, that does not make the Treasury Guideline, which aims to "enable comparison and evaluation of Government initiatives", does not mean the latter should ipso facto apply to private investment projects. Nor should an assumption that labour as a cost to government, taxpayer-funded projects should therefore apply to private investment projects, where the risk is not borne by the taxpayer, but private shareholders and investors.

Yet that's the corollary that BISOE attempts to draw on page 6, by stating that just because the Treasury Guideline refers to the 2015 Mining Guidelines, and Hume Coal is a mine, the Treasury Guideline is relevant to Hume Coal project, even though Hume Coal project is not a 'government initiative'. BISOE's corollary does not follow. The text of the Treasury does not support such an argument.

The Treasury Guidelines – other references

Below are 18 additional excerpts from the Treasury Guidelines that state that the Treasury Guidelines apply to "Government initiatives", "Government actions", "Government agencies", "public policies" and "Government regulations" (Emphasis added unless stated otherwise):

Quote	Page
The purpose of this Treasury policy and guidelines paper is to provide guidance and promote a consistent approach to appraisal and evaluation of public projects, programs and policies across the NSW Government. Agencies should use this NSW Government Guide to Cost-Benefit Analysis (Guide) when assessing all significant government projects, programs, policies and regulations.	i
The terms above are used interchangeably as necessary throughout this Guide, but the overall premise is that this Guide applies to all significant Government actions and decisions.	ii
This Guide applies to all Government actions including any new or altered capital, recurrent or regulatory actions.	ii
This Treasury policy and guidelines paper provides guidance and promotes a consistent approach to the appraisal and evaluation of projects, programs and policies across the NSW Government. Agencies should use this Guide when assessing all significant government projects, programs, policies and regulations. The terms above are used interchangeably as necessary throughout this Guide, but the overall premise is that this Guide applies to all Government actions and decisions.	1
A CBA is required for: ♣ All new projects, programs and policy proposals or significant changes to existing projects, programs or policies that meet specified value thresholds as per the Business Case Guidelines, and which are funded by Government, including capital or recurrent expenditure.	3
As discussed in Section 1.2, analysts should begin by clarifying the reason for Government action (e.g. addressing a market failure). This should be followed by a high-level pre-planning and program logic analysis before doing a CBA for a project, program, policy or regulatory proposal.	8
Where the government initiative relates to regulation, the benefits may include:	14

♣ Improvements in product and service quality ♣ Improvements in public health and worker safety ♣ Improvements in environmental amenity ♣ Reductions in compliance costs for businesses, and/or ♣ Reductions in administrative costs for government.	
Table 2.3: Treatment of readily valued and non-readily valued impacts Type of valuation Examples Treatment Impacts where both quantity (volume) and unit prices are available value of additional electricity supplies to users; capital outlays; operating costs All major project or program-related costs and benefits should be included, even if they are not government expenditure and revenue.	16
In most cases benefits will focus on use benefits (derived from the provision of a Government asset or service). This Guide specifies the circumstances under which non-use benefits should be included in the central estimate. In all cases the benefit estimates, particularly non-use benefits, should be subject to appropriate validity and reliability tests that are documented in the CBA. In general, impacts in the state of NSW should comprise the central estimate. Separate scenarios can show any local impacts and interstate impacts, respectively (see Box 2.6). For example, in cases where a Government proposal generates costs or benefits affecting neighbouring Australian jurisdictions, the central estimate should only include impacts to the NSW community and a separate scenario can include the impacts on neighbouring jurisdictions.	19
Box 2.6: Cross-border costs and benefits In cases where a Government proposal generates costs or benefits affecting neighbouring Australian jurisdictions, the CBA should report both: ♣ A central estimate showing costs and benefits to the NSW community, and ♣ Separate results showing interstate costs and benefits.	20
2.9 Undertake post evaluation In line with NSW Government Program Evaluation Guidelines, major programs undertaken by NSW government agencies are expected to be evaluated at an appropriate point in their life cycle. The most comprehensive form of evaluation includes process, outcome and economic evaluation. Cost benefit analysis is the preferred approach for economic evaluation.	20
Similarly, ***regulatory initiatives*** should be subject to review after they have been in operation for a sufficient number of years. Major pieces of legislation normally include a requirement for periodic review (usually five years) and evaluation timing could be aligned to this review timeframe.	21
Appendix 1: Reasons for Government action This appendix outlines the reasons for Government action: ♣ Analysts should consider the reasons for government action before conducting a CBA. ♣ The two main reasons for government action are when the market cannot deliver a socially optimal outcome on its own and to support less well-off members of the community.	22

♣ The main types of market failure are public goods, externalities, market power and imperfect information. ♣ Because government action has costs, action should only be taken if there is a net improvement to social welfare i.e. an improvement in the wellbeing of the relevant community.	
Market power is best addressed by an independent economic regulator rather than a general government agency. Where government regulation itself creates market power, this should be addressed by more rigorous assessment of the regulation through CBA in accordance with NSW Better Regulation Guidelines14 .	25
1.2 Equity objectives The government may also intervene to promote equity and support less well-off members of the community. For example, governments may provide energy rebates to assist low income earners to pay energy bills. Before an agency intervenes, an assessment should be made of the extent of the inequality to be redressed, and the reasons it exists. In such cases the CBA should explain the extent of the inequality to be redressed, the reasons why it exists and the role of the initiative in its mitigation.	26
Opportunity Cost Committing resources to a particular project or program will preclude their use elsewhere. The value of the resources used is their 'opportunity cost'. This is the value of those resources in their most attractive alternative use. In general, market forces will generate a price for capital, labour or other inputs that reflect the opportunity cost of the resources. The principle also applies if an agency can access an input at a cost that differs from its market value. For example, where an agency proposes to use land that the agency already owns, the land should generally be valued at its highest opportunity cost equivalent to its maximum market value under current or likely land-use zoning (e.g. cost of urban parkland is the value of housing land that is forgone). Based on the opportunity cost principle, benefits could be estimated based on the avoided cost of related or substitute public services. For example, the benefit of early intervention policies may include the avoided cost of policing, courts, incarceration or other related services for young offenders. Similarly, the benefits of preventative health measures could include avoided costs of acute medical services and care.	32
Apart from analysis of markets directly affected by a government action, other examples of marketbased valuation used to value benefits or costs include the analysis of prices and demand of goods or services that are substitutes or complements of each other. For example, the value of treating water to improve safety and quality may be inferred from the prices of marketed bottled water.	33

On the contrary, the Treasury Guideline does not refer to applying to a private project, such as Hume Coal.

Other recent projects

No other private project has been assessed under the NSW Treasury Guidelines and there is no legislative guideline, policy, or practice requiring mining projects to be assessed other than following the 2015 Mining Guidelines.

Therefore, any matters in the BISOE cost-benefit assessment, where the NSW Treasury CBA Guideline (2017) has inappropriately been applied, must be disregarded by the Department and the IPC. To give weight to BISOE's claim, that a private project needs to be assessed under a Government-only guideline, would compound an apparent bias directed at the Hume project, and it alone, amongst other mining projects assessed by the Department since 2015.

Departmental assessments of the Bylong, Wallarah 2, Tahmoor South, and Vickery coal mining projects required assessment against the Guideline for the Economic Assessment of Mining and Coal Seam Gas Proposals (Dec 2015) alone. The Department also specified the 2015 Guideline as appropriate, and reviewed by its peer reviewers, Centre for International Economics (CIE) for Bylong and Wallarah 2 and Marsden Jacobs for the Vickery Extension projects.

Indeed, other private coal mine projects, approved or rejected in recent times, had the Treasury Guidelines applied to them. Hume Coal considers that the insistence of the DPIE, BISOE and IPC (in its Recommendation 22) to apply the Treasury Guidelines, when no other private projects are subjected to the same treatment, is in breach of the no less favourable treatment test to the investments made by any other investors applying under free-trade agreements.

The BISOE 2017 report implies, on page 4 ,that the DPIE requested that the Treasury Guidelines be applied to the Hume Coal project:

> *"The Scope of Work issued by Department indicates that issues to be considered include:*
> *…*
> *consistency of the assessment with any relevant Government guidelines (e.g. NSW Treasury (2017) NSW Government guide to cost-benefit analysis and/or the NSW Government (2015) Guidelines for the economic assessment of mining and coal seam gas proposals)."*

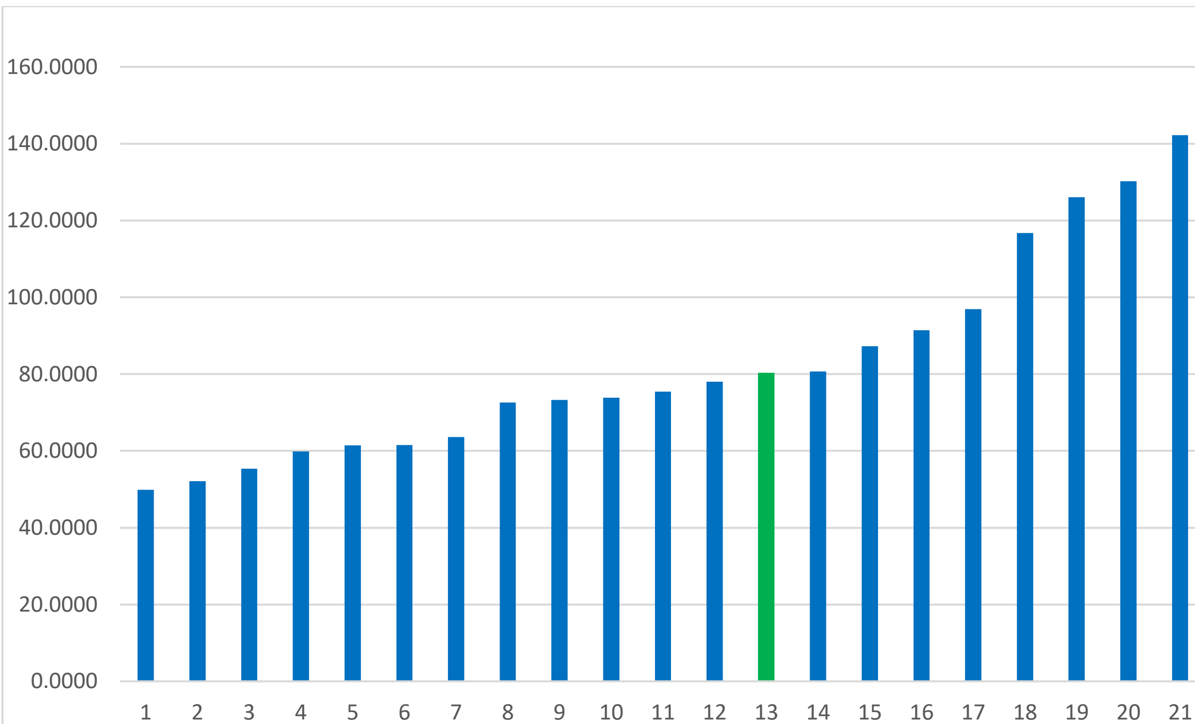
Hume Coal queries the actual wording of the Scope of Work, whether it specifically requested that the Treasury Guideline be applied, despite Hume Coal not being a Government initiative, and despite no other private projects being so treated.

2. Contingencies

As is the practice with all financial modelling, contingencies were included and reflected in the data provided for assessment of the economic assessment of the project by BAEconomics in all of the CBA assessments applied to the Hume projects (2017, 2018 and 2020). Also, sensitivity analysis to changes in various parameters were applied and the project assessed against various discount rates of 10, 7, and 4 percent.

Detailed operating costs of the Hume project is commercial-in-confidence and were prepared from a database of empirical costs assembled by Wood Mackenzie, a leading mine consultant, independent of Hume Coal and based on actual costs in the industry. These costs were updated and included in the 2020 CBA assessment by BAEconomics. It shows that Hume Coal's costs are reasonable, not optimistic as BISOE suggests, sitting about the mid-point in the NSW coal mines.

MINING: TOTAL CASH COST
($Au/tonne)



UNDERGROUND COAL MINES NSW: COMPARATIVE ANALYSIS

Source: Wood MacKenzie Confidential independent database on NSW industry mine costs. Hume Coal mine costs prepared by Palaris Consulting for inclusion in the 2020 BAEconomics EIA. All costs are in Australian dollars.

BISOE stated it had unresolved concerns about 'optimism bias', such as underestimating costs, being incorporated into the analysis.

Hume Coal submits that any potential for optimism bias in the modelling is more than offset by the following conservative assumptions:

- Real NPV, so inflation has been excluded. But the fact is, the Reserve Bank's target inflation is inflation of 2-3% per year.

- Hume Coal's real discount rate for the NPV is 7%, as required in the Guideline. This is very conservative since the NSW government-mandated nominal discount rate is 3.6% and the real discount rate is 1.3% for local governments[xx].

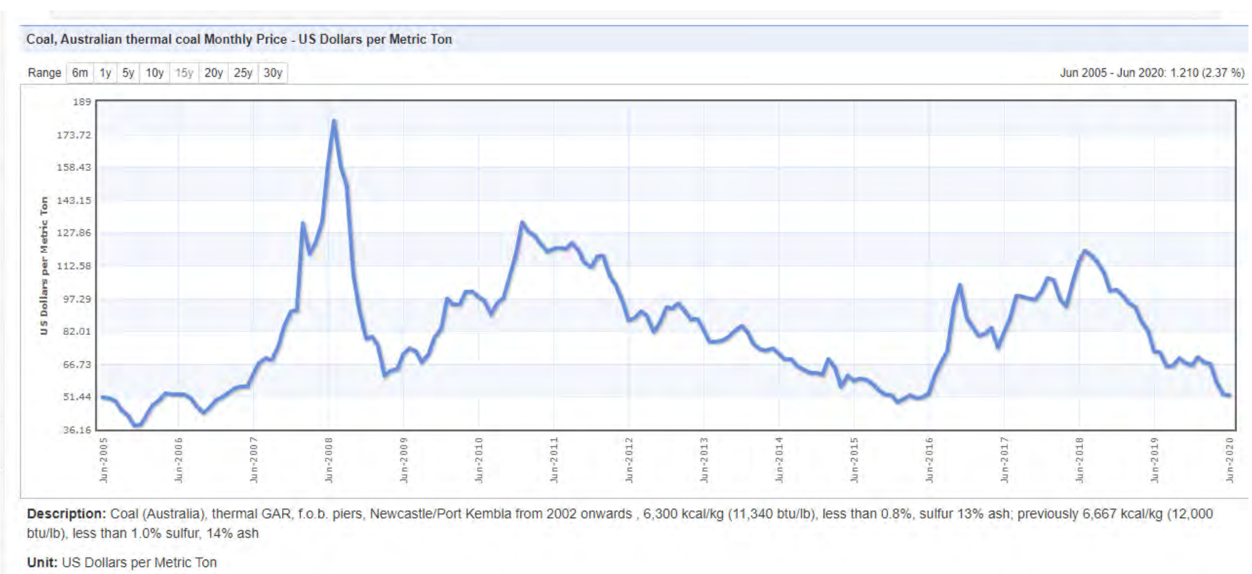
  Hume Coal notes how BISOE wants to have it both ways – to demand that Hume Coal be treated similarly to a Government Initiative, and apply the NSW Treasury Guidelines, but then does not permit Hume Coal to apply the lower discount rates that other Government bodies enjoy. Hume Coal is either a private project or a government project.

3. Price reduction risk

The BISOE report repeats, on four separate occasions, on pages 2, 3, and 11 that there is a caveat of coal price reductions in the future.

But prices can also go up. Given that it is elementary fact that coal price could change in the future in the free market, it is misleading to state only the downward risk and omit consideration of upside potential.

It is trite to repeat the risk of coal price reduction when BISOE should know that coal price is cyclical – it will go up and down into the future. The following chart[xxi] of Newcastle thermal coal price (as an example, not to show Hume Coal's historic coal price) over the past 15 years shows ups *and* downs, despite the global conflicts and other epidemics in the period such as Swine Flu (2009-2010) and MERS 2012.



It is noted that 'Regional NSW - Mining, Exploration & Geoscience' dated 4 June 2020 has concluded that the return to the State is adequate:

The proponent has planned a method of coal recovery that is designed to minimise surface subsidence which over a 20-year mine life is planned to recover 50 million tonnes of Run-of-Mine coal which would otherwise not be mined. MEG considers the return to the state is satisfactory given the constraints surrounding the project location.

4. Sensitivity test

Concerning BISOE's criticisms, on pp 12 & 29, that sensitivity tests for net environmental costs and net public infrastructure, Hume Coal notes that those costs are estimated to be $1m NPV, and net public infrastructure costs are estimated to be $0. On the other hand, the direct and indirect benefits to NSW is estimated to be $291m, NPV.

That is, the net environmental costs and net public infrastructure are only 0.3% of the total benefit.

5. Externalities

Externalities vs net producer surplus costs

BISOE queries at pages 2, 25, 28 and 37 that it is ambiguous how environmental mitigation costs of $13m NPV, to calculate the 'net producer surplus', reconciles to the environmental externalities of $1m NPV to calculate the 'net benefit to NSW' in a cost-benefit analysis (CBA):

> *"however, it is unclear, how (or if) the assessed externalities reconcile with the NPV of $13 million in environmental mitigation costs referred to on p.28 of the 2020 EIA."* (Page 2)
>
> "Total externalities (presumably equal to "environmental mitigation costs") are cited as $13 million in NPV terms in the 2020 EIA (p.28). Additional information on externalities is provided in Table 3-5 (predicted externality costs) and Table 3-6 (externality costs incurred to date) of the 2020 EIA. This is welcome. However, as discussed below, it remains unclear as to how (or if) the various items in these two tables combine to add to the $13 million (in NPV terms) allocated to environmental mitigation costs." (Page 25)

The environmental mitigation costs cited as $13m NPV on page 28 of the 2020 EIA, are *direct costs* for purposes of calculating the 'net producer surplus', which is a component of the CBA.

The environmental externalities in Table 3-5 and 3-6 are *indirect costs* to calculate the net benefit to NSW and is a separate component of the CBA.

These are different concepts and are not supposed to reconcile with each other. They are mutually exclusive categories by definition.

The 2015 Mining Guidelines state on page 11 that the environmental costs for the purposes of the net producer surplus calculation are "direct costs" only:

Task 3 Net Producer Surplus - Identify the direct costs and benefits to the producer

This approach estimates the net producer surplus attributable to the NSW community. Estimating net producer surplus requires information on the direct costs and benefits of the project. Table 3.5 outlines the direct benefits and costs of a mining or coal seam gas project that are typically considered.

The value of the direct benefits and costs will be estimated as part of the proponent's financial assessment of the project. The annual values of all direct benefits and costs estimated by the proponent should be entered into the Cost Benefit Analysis Workbook.

The costs entered by the proponent will reflect their expected expenditures.

On the other hand, 2015 Guidelines state on page 15 that the external costs are **"indirect costs" only**:

Task 7 Estimate indirect costs to NSW

The indirect impacts include the net environmental, social and transport costs, net public infrastructure costs and indirect costs to other industries.

Task 7.1 Net environmental, social and transport-related costs

Mining and coal seam gas projects can cause environmental impacts to air quality, ambient noise, biodiversity, greenhouse gas emissions, groundwater, non-Aboriginal heritage, Aboriginal heritage, surface water and visual amenity. Transport related impacts also occur such as increased traffic congestion. In general the total net environmental, social and transport costs will be attributable to NSW. The proponent should include the total net environmental, social and transport costs in the NSW CBA, unless there are cases where these costs are not entirely attributable to the NSW community.

That is, the environmental externalities for the CBA and the environmental costs to calculate the net producer surplus are mutually exclusive.

It is absurd for BISO to claim that ambiguities exist because two different, mutually exclusive amounts do not reconcile to each other. Indirect costs are not supposed to reconcile to direct costs.

To do as BISOE claims is to double count the environmental costs in the CBA calculation, once under the 'net environmental costs', and once again in the 'net producer surplus', leading to an incorrect CBA output.

Externalities and groundwater make good costs

BISOE states at pages 3, 25, 26, and 28 that groundwater make good costs are external costs:

> *"In terms of groundwater issues, it is particularly unclear how (or if) full "make good" commitments referred to in Hume Coal's Response to IPC are costed and indeed the amounts cited appear to represent a lower monetary commitment than in 2017. Given the community concerns over this issue, these matters should be clarified and the costing of externalities be made more transparent. It is highly unlikely that increased allowance for externalities alone*

would cause the project to record a zero NPV in economic terms. However, combined with less favourable price/demand conditions these factors could reduce project benefits materially." (page 3)

"Based on our experience, the most material issue relating to the HCP – and the one provoking the most intense debate - relates to groundwater usage. Table 3-6 (pp. 49-50) lists groundwater costs as totalling some $7.2 million to date and we estimate that future make good provisions detailed in Table 3-5 (pp.44-48) equate to $3.5 million in NPV terms (though see further comments below). If so then groundwater costs account for $10.6 million (rounded) of the assessed externality costs." (page 25)

As stated above, externalities are "indirect costs" only. Groundwater make good costs are direct costs that Hume Coal has to pay directly. The groundwater licence and monitoring costs referred to in table 3-6 are also *direct* costs. Therefore, it is incorrect to state that direct groundwater make good and licence purchase costs are the external, indirect costs.

Groundwater make good costs – IPC response

In response to BISOE's assertion on page 26 that uncertainties remain regarding the groundwater make good costs, Hume Coal confirms, that the response to IPC's recommendation in respect of groundwater, did not change any assumptions on estimating the groundwater make good costs. This is because the number and type of make good required did not change as a result of responding to the IPC recommendations.

This is because the DPIE chose not to request that Hume Coal do a revised groundwater model, and the additional independent peer reviewer confirmed that Hume Coal's existing groundwater model is fit for purpose, and the practicalities of make good process does not change the number and type of make good required.

6. Net public infrastructure cost

BISOE stated:

"A zero costing for net public infrastructure could be questioned given that there may be some use of public roads by mine-related traffic (though we likewise note that changes in levels of service to traffic are estimated to be negligible, see p.47)."p12

"Net public infrastructure costs - As noted previously, no serious consideration appears to be given to net public infrastructure costs. These may be more than negligible if there is substantial use of public roads during the course of the project." p28

Hume Response:

Task 7.2 of the 2015 Guidelines provides that the "net public infrastructure cost is the *difference* between the incremental cost of public infrastructure and the local contributions paid by the proponent" (emphasis added).

Net public infrastructure costs are expected to be nil because any incremental cost will not be greater than **$2m** NPV local contribution estimated to be paid. The assessment of net public infrastructure cost is below.

Net public infrastructure cost calculation

Item	Value ($m) NPV	Comment
Local contributions	**2**	As estimated in table 3-3 of the 2020 BAEconomics report.
Less: Incremental public infrastructure cost:		
Water	0	The properties on which the project will be built are not connected to the town water supply, and will not be connected in the future. As stated in EIS and RTS Water Balance Model, all water needs will be met on-site from the water gathered on premises, from a combination of: • net harvestable rainfall-runoff from all stormwater basins, mine water dams; • groundwater collected from the underground mine; and • water from groundwater bores. Accordingly, the cost to public water infrastructure is nil.
Sewerage	0	The properties on which the project will be built are not connected to the town sewage system, and will not be connected in the future. As stated in EIS and RTS Water Balance Model, sewage from the administration and workshop areas will be treated on site and reused on site. Black water will be subject to tertiary treatment and harvested for reuse in the CPP. Accordingly, the cost to public water infrastructure is nil.
Drainage	0	The properties on which the project will be built are not connected to the town drainage system, and will not be connected in the future. Accordingly, the cost to public water infrastructure is nil.

Power	0	As stated in the EIS, where Hume Coal proposes to use existing powerline, Hume Coal will upgrade it by replacing the old wires to new wires with a higher capacity, and replacing the old poles with new, taller poles. The benefit of these upgrade will be greater than any incremental cost of Hume Coal using the power that is in addition to the cost of the power that Hume Coal will pay, and therefore the cost is nil.
Communication expenditures	0	The cost to the communication infrastructure that is in addition to the internet and telephone cost that Hume Coal will pay to access those services will be negligible, since the cost of the service itself will factor in infrastructure usage as well as a profit margin.
Road damage	0	Hume Coal will use trains to transport its coal. Incremental road damage caused by employees' private vehicles will not be greater than voluntary planning NPV $2m
Subsidence damage	0	Not applicable because the mine will not cause any subsidence, due to the non-caving mining method.
Net public infrastructure cost	2-0=0	Incremental public infrastructure is nil, or negligible compared to $2m NPV local contributions.

It is implausible that there could be more than negligible net public infrastructure cost when any incremental public road usage cost would need to be greater than the local contributions to be made by Hume Coal, which BISOE knew to be approximately $2m NPV.

7. Worker benefits

BISOE recommends that *"benefits to workers be disregarded*" based on lack of evidence.

This is inconsistent with the approach taken by the Department with other mining projects. For example, the Department in its advice on the Wallarah 2 coal project accepted that mining projects have significant flow-on employment benefits:

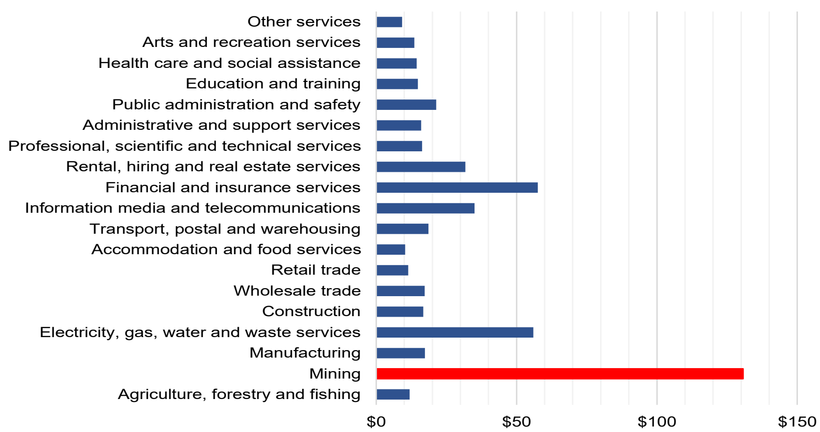
> *"However, overall the Department believes that mining projects have large flow-on effects for regional economies as they have large operating costs (some of which is spent on suppliers in the local region) as they pay higher than average wages (much of which is spent in the local region). The Department therefore maintains its general view that flow-on employment benefits are significant benefits from mining in NSW, which should be given weight in assessing the projects overall merits".*[xxii]

The simple economic reality is the wage premia paid to mine workers is high by wage levels for other workers in regional areas. The mean employee income for the Wingecarribee LGA is $45,527 or 37% of that paid to miners. This is a more accurate representation of the current labour market than ATO data, including superannuation income from the one-in-three people over 55 in the Wingecarribee LGA, distorting the actual income received by those employed as opposed to the retiree demographic.

Interestingly, mean employee income in Wingecarribee is 16% less than Wollondilly LGA to the north and 5% less than Goulburn Mulwaree LGA[xxiii] to the south, highlighting the predominance of lower-paid jobs in the accommodation, food services, and aged care sectors. These industries have been most impacted by the COVID-19 downturn

Further, to disregard the benefits of $925 million (undiscounted) in wages paid during operation, assuming Hume will wholly compete with full-time workers in other parts of the economy, ignores the impacts of the post-COVID economy where unemployment has dramatically increased, and productivity from every other employment sector is unable to compete with mining. The major industry sectors in the Southern Highlands have the lowest of all sectors in terms of labour productivity (Table 2).

LABOUR PRODUCTIVITY BY SECTOR (2019)[xxiv]



In turn, the predominance of lower-paid jobs in the main industry sectors in the Southern Highlands is compounded by the fact that those industry sectors are the most vulnerable to economic shock from the COVID-19 crisis.

Jobseeker and JobKeeper

In March and April alone, the rate of increase for Jobseeker in the Mittagong-Bowral Centrelink region was the second-highest regional increase in the nation, 92% and just trailing the Gold Coast at 93%[xxv]. An analysis of data from the JobSaver scheme (March-May 2020)[xxvi] further highlights the dramatic increase in JobSeekers claims in the local region, compared with neighbouring areas (Table 2).

JOBSAVER CLAIMS INCREASE (MARCH-MAY 2020)

JobSeeker Catchment	Percentage Increase
Southern Highlands	129
Robertson/Fitzroy Falls	110

Moss Vale/Berrima	119
Mittagong	157
Picton/Tahmoor	96
Goulburn	74

Also, the real state of the local labour market is masked by the fact that one-in-four businesses in the Southern Highlands are now the recipient of JobKeeper.

Whilst there may be an academic argument that labour benefits should be ignored in an economy with full employment and, particularly, in metropolitan areas, where labour is more fungible, this does not apply in the regions or the current economy. There is already a reservoir of labour seeking work with Hume Coal, as evidenced by expressions for employment made directly with the project, many of whom work more than one casual job, commute to Sydney, or have to leave the area after finishing school due to the lack of suitable employment.

The 2015 Mining Guidelines places strict limitations on the extent to which higher than average wages paid to the Hume workforce can be considered as a benefit in the cost-benefit analysis, but this does not apply to the Local Effects Analysis (LEA). The 2015 approach does not accord to standard economic thinking about the nature of 'wage premia' and, which is not consistent with the NSW Treasury Guideline (2017). For further discussion on wage premia and wage see BA Economics 2020 EIA[xxvii].

Expression of interest for employment from local residents

There is already a reservoir of labour seeking work with Hume Coal, as evidenced by 667 expressions for interest for employment received from residents, many of whom work more than one casual job, commute to Sydney or have to leave the area after finishing school, or had to take less paying jobs due to lack of careers in the local area.

In closing, the 2015 Mining Guidelines places strict limitations on the extent to which higher than average wages paid to the Hume workforce can be considered as a benefit in the cost-benefit analysis, but this does not apply to the Local Effects Analysis (LEA).

8. CGE modelling

BISOE states on page 3 that the state-wide CGE modelling results should be disregarded.

The reasons given for such drastic advice are responded as follows:

BISOE stated: CGE does not replace CBA – pp 3, 30, 31

> *"As noted by the Treasury Guidelines, CGE modelling does not replace CBA and as indicated in our First Review, the Guidelines do not call for state-wide analysis of flow-on effects. Citing such figures in support of the HCP could be misleading to policymakers who are not fully versed in the specifics of CGE modelling and the appropriate measure of project benefits."*

The 2020 EIA does not submit that CGE should replace CBA. BISOE itself recognised, on page 31, that the 2020 EIA, stated on page 83, that the CGE was "another lens", not a replacement to CBA. So, it is misleading for BISOE to state as a reason that 'CGE does not replace CBA' when no such thing was suggested.

Treasury Guidelines do not apply to private projects, as stated in the guide to the Treasury Guidelines.

BISOE stated: Rational for CGE model – p 30

> "… the rationale behind the use of a CGE model to measure benefits when these are already measured by a CBA is unclear."

To the contrary, other independent, economic experts have stated that CGE has benefits in addition to CBA.

The DPIE's independent, economic peer reviewer Marsden Jacob Associates, stated at page 11 to its November 2019 'Review of the Economics of the Vickery Extension Project', that CGE provides insights additional to the input-output analysis:

MARSDEN JACOB ASSOCIATES   Review of the economic assessment of the Vickery Extension Project   10

We also support the observation of AnalytEcon that estimating value added at a granular regional level is not meaningful where there is not sound knowledge of the basis of ownership of capital and how value added may or may not 'stick' in the region.

Nonetheless we are more optimistic than AnalytEcon that a CGE approach would provide some valuable insight over and above the input output analysis.

The CGE approach would also provide some insight into the underlying counterfactual that there would be no development in the absence of the mine. Under the non-development scenario current activities continue and the CGE approach could estimate the net effect of the any change. The CGE approach also addresses the underlying problem with a no change counterfactual which can imply there is no opportunity cost with proceeding with investments and capital and labour in the economy would be used elsewhere in NSW or the local economy. The CGE approach can also provide more insight into the temporal dimensions of flow on effects through different stages of mine development. In the short run the flow on effects to the local economy of construction may be significant relative to the longer-term steady state mine production.

HUMECOAL PROJECT

The DPIE's final assessment report on the Narrabri Gas project (June 2020) adopts the CGE modelling outcome at page 108 in its recommendation to approve the project, stating that the benefits are "very significant":

project.

Regional Economic and Socio-Economic Impacts

544. The macroeconomic assessment, using a computable general equilibrium model, indicates that the project would provide very significant direct and indirect socio-economic benefits for the locality, region and State, including:

- For the local Narrabri LGA economy:
  - up to 1,300 jobs at the project during construction, and 200 direct jobs at the project during operations;
  - 127 average full-time equivalent jobs in the LGA;

Narrabri Gas Project (SSD 6367) | Assessment Report 108

  - $3.6 billion ($2 billion net present value[12]) direct capital investment value for construction, and $5.5 billion ($1.6 net present value) operating costs over the life of the project;
  - $11 billion ($4.5 billion net present value) in real economic output; and
  - $526 million ($250 million net present value) in real income.
- For the wider regional economy[13]:
  - 162 average full-time equivalent jobs in the wider region;
  - $572 million ($348 million net present value) in real economic output; and
  - $690 million ($396 million net present value) in real income.
- For the State economy:
  - 224 average full-time equivalent jobs in the rest of NSW;
  - $384 million ($295 million net present value) in real economic output;
  - $4.8 billion ($2.1 billion net present value) in real income; and
  - $3.1 billion ($1.2 billion net present value) in royalties and tax revenue to the NSW Government.
- Total economic output:
  - 224 average full-time equivalent jobs in the rest of NSW;
  - $11.9 billion ($5.1 billion net present value) in real economic output; and
  - $6 billion ($2.8 billion net present value) in real income.

The Department has endorsed the use of CGE modelling in other projects. For example, in its assessment on the Bylong mine it said:

> *"The CGE modelling supports the conclusion that the project would provide a significant increase in regional employment opportunities during mining operations, with the lower bounds of the CGE modelling still showing significant benefits".*[xxviii]

The Department's report to the IPC also stated:

> *"This additional CGE modelling should provide further confidence to the Commission that the project as proposed would provide significant benefits to the regional and NSW economies"*[xxix]

It is absurd for BISOE to advise DPIE that CGE modelling output be disregarded when, as recently as June 2020, DPIE adopted the outputs from CGE to recommend that the Narrabri Gas project to be approved.

If the DPIE adopts BISOE's advice to disregard the outputs from CGE modelling when it used it other resource projects, Hume Coal submits that such treatment is treating Hume Coal less favourably than investments made in NSW by other investors.

Indeed, the 2015 Mining Guidelines state, at page 23, that there are different, acceptable ways of analysing flow-on effects, which include CGE:

Second round / flow-on effects

Second round effects can be extremely important for local communities and therefore considered as part of the LEA. A range of techniques are available for estimating second round or flow-on effects. These include CGE (computable general equilibrium)-modelling, Input-Output (I-O) or multiplier analysis. Most such techniques have limitations. For example, CGE modelling can be complex and expensive and lack transparency, while I-O analysis has been criticised for overstating impacts.

The LEA should include analysis of second round effects. However, the type and form of this analysis should be identified based on a case by case assessment of the most appropriate approach for each project. This may mean that, in some cases, a purely qualitative discussion is the best option. In other cases, CGE analysis may be most appropriate, particularly for larger projects. Regardless of the approach taken, any limitations should be noted. Careful consideration should be given to how quantitative results are presented to minimise the risk of them being misinterpreted.

It is bizarre for BISOE to recommend to the DPIE and the IPC that CGE be disregarded when the NSW government's very own guideline states that CGE is one of the acceptable methods.

Hume Coal submits that CGE modelling is a valuable tool for assessing economy-wide impacts of significant capital and labour expenditure associated with mining projects in general and coal mining projects in particular.

To be consistent with the Department's CGE position on other projects, it should not be disregarded, if the Department is to be consistent and, treat the Hume project with no less disadvantage than other mining projects assessed by the Department.

9. Local Effect Analysis

In response to BISOE's demand, at pages 36 and 37, for justification to back up the 30/70 local to non-local employee estimated ratio, Hume Coal notes that the 2015 Guidelines repeatedly recognises at pages 21 and 22 that the LEA local employment effects are estimates only:

> ***Estimating effects related to local employment***
>
> Employment effects are important as they feature in the State Environmental Planning Policies, are of importance to local residents, and are a major way in which mining projects contribute to the local economy.
>
> The estimation of employment effects should take into account the net benefits of the direct employment created by the project as well as the flow on employment that is created as these employees spend their increased income. In more detail, the flow of employment benefits through the economy can be summarised as:
>
> economy. This is a local economic benefit of the project.
>
> The approach to estimating employment effects therefore requires consideration of tota direct employment, the proportion of workers that are local residents, the net increase ir local workers' income and the flow on employment that local expenditure of increasec income will create.

In addition, Hume Coal notes that 667 local residentshave already sought to seek employment with Hume Coal once the coal mine goes ahead, which forms basis for the 30% local hire estimation.

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[i] Treasury Circular NSW TC11/17 16 December 2011 Determining the Present Value of a Provision
[ii] www.rba.gov.au/statistics/tables/#interest_rates
[iii] As at January 2020. https://www.ipart.nsw.gov.au/Home/Industries/Local-Government/Local-Infrastructure-Contributions-Plans/Local-Government-discount-rate
[iv] The Economics of Climate Change, Nicholas Stern, Cambridge University, March 2014
[v] WestConnex Updated Strategic Business Case (November 2015) page 41.
[vi] Department of Planning & Environment, Residual Issues Report SSD, Wallarah 2 Coal Project September 2017 page 22
[vii] ABS 1410.0 Data by Region 2012-2018
[viii] Labour productivity is estimated as gross value added (GVA) by sector per hour worked.
Source: ABS 2019, 5206.0 Australian National Accounts; Table 45. Gross Value Added by Industry, Current prices, June; Labour Account 2019, hours actually worked in all jobs.
[ix] Dept of Social Services, ABS, Demographics Group
[x] Analysis of JobSeeker by the Demographics Group reported in The Australian, June 27, 2020.
[xi] Bylong Coal Project SSD Department of Planning and Environment Final Assessment Report (SSD6367) page 18
[xii] Bylong Coal Project SSD Department of Planning and Environment Final Assessment Report (SSD6367) page 19
[xiii] Review of the Economic Assessment of the Vickery Extension Project NSW Department of Planning Marsdon Jacob page 10
[xiv] Review of the Economic Assessment of the Vickery Extension Project NSW Department of Planning Marsdon Jacob page 11

[xv] DPE Hume Preliminary Assessment Report (December 2017)
[xvi] Guidelines for the Economic Assessment of Mining and Coal Seam Gas Proposals (December 2015)
[xvii] Guidelines for the Economic Assessment of Mining and Coal Seam Gas Proposals (December 2015) page 1
[xviii] https://arp.nsw.gov.au/tpp17-03-nsw-government-guide-cost-benefit-analysis
[xix] Review of 2020 Economic Impact Assessment (Hume Coal and Berrima Rail Project), July 2020, page 6.
[xx] [xx] As at January 2020. https://www.ipart.nsw.gov.au/Home/Industries/Local-Government/Local-Infrastructure-Contributions-Plans/Local-Government-discount-rate
[xxi] https://www.indexmundi.com/commodities/?commodity=coal-australian&months=180 accessed on 28 July 2020
[xxii] Department of Planning & Environment, Residual Issues Report SSD, Wallarah 2 Coal Project September 2017 page 22
[xxiii] ABS 1410.0 Data by Region 2012-2018

[xxiv] Labour productivity is estimated as gross value added (GVA) by sector per hour worked.
Source: ABS 2019, 5206.0 Australian National Accounts; Table 45. Gross Value Added by Industry, Current prices, June; Labour Account 2019, hours actually worked in all jobs.
[xxv] Dept of Social Services, ABS, Demographics Group
[xxvi] Analysis of JobSeeker by the Demographics Group reported in The Australian, June 27, 2020.
[xxvii] BAEconomics 2020 EIA 3.6.1.1 to 3.6.3.5 pages 29-39 and Appendix D
[xxviii] Bylong Coal Project SSD Department of Planning and Environment Final Assessment Report (SSD6367) page 18
[xxix] Bylong Coal Project SSD Department of Planning and Environment Final Assessment Report (SSD6367) page 19

Appendix B9 – Applicant Response to Independent Expert advice (mining engineering) 1

HUMECOAL PROJECT

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

21 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS
RESPONSE TO AGENCY COMMENTS – GALVIN & CANBULET.

Dear Mandana,

Thank you for providing the Agency comments.

Please find attached the Response from Hume Coal and Prof. Bruce Hebblewhite for the commentary provided by both Prof's Galvin and Canbulet.

Regards,

Rod Doyle
Project Manager

Hume Coal Pty Limited

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21st August 2020

Attn: Mr Rod Doyle
Project Manager
Hume Coal Project

Report No. 2008/01.1

Review of Independent Review Reports by Professors Galvin and Canbulat (June/July 2020)

1. Scope

As requested by you in your email of 5 August 2020, I have prepared this report, No. 2008/01.1, as an independent review and response to two reports prepared by Galvin & Associates Pty Ltd *(GAPL)* and Dr Ismet Canbulat. The specific reports are as follows:

- GAPL Report No. 1716-12/3a dated 27 June 2020;
- Canbulat Report No. DPIE-HUME-2020-1 dated 24 July 2020.

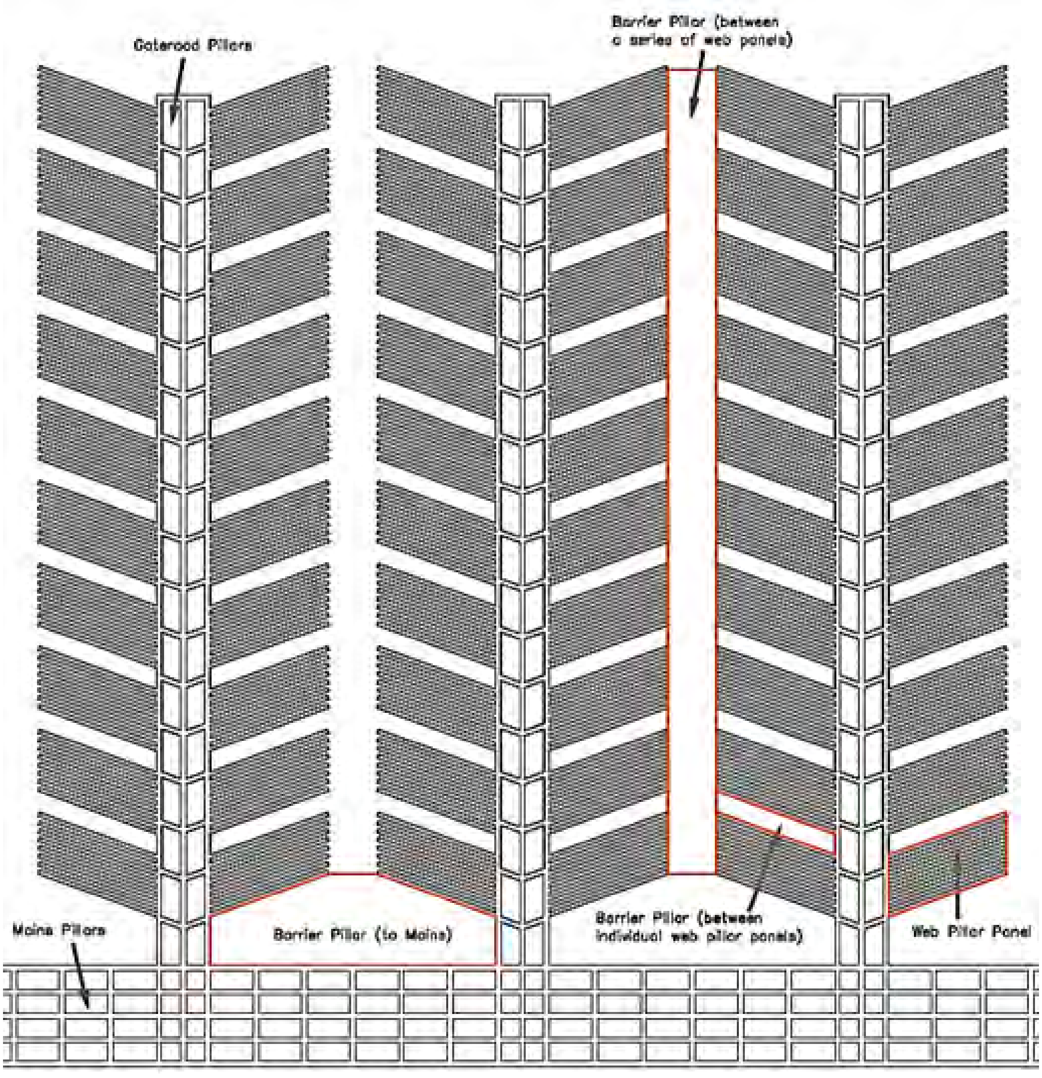
The above two reports were prepared for the NSW Department of Planning, Industry and Environment (DPIE). Professors Galvin and Canbulat had previously been retained by DPIE as subject-matter experts to advise on relevant technical (mining-safety) aspects of a project proposal submitted by Hume Coal to DPIE for approval. The author of this current report, Bruce

Hebblewhite, has been retained by Hume Coal as an independent reviewer for the Hume Coal Project *("the Project")*, in relation to mining/geotechnical issues of the project.

2. Background

The following paragraph and generic diagram of the proposed pine feather mining method are included here for background context only, including reference to the pillar system naming convention.

The proposed pine feather mining technique is a novel method, involving some innovative aspects of mine design and layout. It has been designed with the objective of minimising surface subsidence and impact on overlying groundwater aquifers within the overburden. The method has been designed to also provide underground wastewater storage capacity in mined-out areas.



For clarity, the various pillar types referred to by Hume Coal in the pine feather system include the following:

a) Web pillars – narrow pillars between adjacent parallel roadways within a production web pillar panel;
b) Intra-Panel Barriers or Barrier Pillars – between each successive web pillar panel;
c) Inter-Panel Barrier Pillars – solid pillars between each twin series of web pillar panels off a set of central gateroads;
d) Gateroad Pillars – development pillars between the central three development gateroads;
e) Mains Barrier Pillar – protective barrier between production panels and main development panel.

Some relevant indicative dates and steps in the review process up to this point, including the involvement and interaction with both Galvin and Canbulat, are as follows:

a) Dr Russell Frith (MineAdvice) engaged by Hume Coal to develop a suitable mine design – subsequently referred to as the "pine feather" mining system – 2014 and ongoing.
b) Participation by Bruce Hebblewhite as an independent reviewer appointed by Hume Coal in project review meetings, risk assessments and provision of various review reports on the Project – Sept 2014 to present.
c) Hume Coal appointed Prof. Keith Heasley, from West Virginia USA, to undertake 2D and 3D numerical modelling studies of the proposed mine design – late 2017. Preliminary results were presented to the March 2018 meeting (see below). A final report was issued by Heasley in June 2018.
d) DPIE appointed Professor Galvin to review the mining aspects of the project – 2017. Professor Canbulat was also engaged by DPIE as an independent expert reviewer. Both provided preliminary reports to DPIE in December 2017.
e) A meeting was convened in March 2018 between DPIE, Hume Coal, Hebblewhite, Galvin and Canbulat – chaired by Prof. Ted Brown – for the purposes of discussing the preliminary findings of each party, and seeking resolutions with respect to any outstanding mining/geotechnical issues.
f) All parties issued subsequent reports addressing issues and concerns raised.
g) DPIE issued a project Preliminary Assessment Report, incorporating further commentary from Galvin and Canbulat - Dec 2018.
h) Project referred to Independent Planning Commission (IPC).
i) Hume Coal submission and subsequent presentation to IPC – March 2019 (The documentation prepared by Hume Coal for this submission included Appendix C containing further reports by MineAdvice and B K Hebblewhite, in response to questions raised by IPC prior to hearing, and responding to DPIE December 2018 Assessment Report).
j) Summary of Hume Coal Project risk assessments by Palaris – March 2019 (subsequently formally reported to IPC in 2020).
k) IPC Assessment Report released – May 2019.
l) Russell Howarth report to Hume Coal on review of residual issues of disagreement – April 2020.

m) Hume Coal Response to IPC Assessment Report (submitted by EMM) – April 2020.
n) Reports by Galvin and Canbulat providing a review of reports (j), (l) and (m) in list above – June/July 2020.

Both the June/July 2020 GAPL and Canbulat reports were prepared in response to the 30 recommendations made by the Independent Planning Commission (IPC) in May 2019 and Hume Coal's response (report (m) above) to the IPC report. In relation to mining and related mine safety issues, the GAPL and Canbulat reports were focused on Recommendations R1 to R3, as listed below:

- *Recommendation R1.*
  Because the Applicant and Department remain a considerable distance apart regarding their positions on the safety of the pine feather method of mining, the Commission suggests that one of the Applicant or the Department, or both of them jointly, engage a new independent expert with experience in innovative coal mining technology with a view to resolving ongoing differences of opinion. This investigation would involve taking into account new information from the Resources Regulator.

- *Recommendation R2.*
  As a result of the outcomes of R1, the Applicant needs to advise if there are consequences that would arise in relation to mine design and economics (resource recovery).

- *Recommendation R3.*
  The Applicant should provide the Project Risk Assessment to the Department, and any other relevant Government agencies, if necessary, on a confidential basis, for consideration in any further Department or other Government assessment or response in the next stage of the assessment process.

3. Review and Response to GAPL Report

My comments below are provided in the order in which the matters occur within the June 2020 GAPL Report, with page numbers and section headings noted, where applicable. Comments are directed to the main body of the report rather than the Executive Summary, given there is greater level of discussion and information provided there.

1.0 Introduction

a) This confirms the scope assigned to GAPL by DPIE, being *"to review and verify Hume Coal's response to the Independent Planning Commission (IPC) Assessment Report dated 27 May 2019"*.

b) GAPL lists the three documents under review, as previously noted, being:
   - Hume Coal and Berrima Rail Project. Response to the Independent Planning Commission Assessment Report dated 27 May 2019 (EMM, 2020).
   - Independent Review of Residual Issues of Disagreement Between the Applicant and the Department of Planning Associated with the Hume Coal Project. Russell Howarth & Associates (RHAA, 2020) (Appendix A of EMM, 2020).
   - Pine Feather System – Risk Assessment Review. Palaris Report No. HUME5041-02. Commercial-In-Confidence (Palaris, 2020).

2.0 Contextual Background

a) GAPL confirms that a number of previously reported concerns have been resolved during the preparation of reports and the IPC process.

b) GAPL states that the *"main outstanding issue is the stability of very narrow and low width-to-height (web) coal pillars associated with the proposed mining method"*. GAPL notes that web pillar yielding and/or failure has potential consequences for safety, subsidence and hydrogeological response to mining. These unresolved concerns are expanded further, indicating concerns in relation to:
   - *The possibility that these pillars could fail in a sudden and uncontrolled manner while persons are exposed to the consequences of such failures.*
   - *The failure of these pillars in time to come as a result of factors such as roof falls, rib spalling, weathering and bearing capacity failure.*
   - *The limitations of all pillar stability design approaches (empirical, analytical and numerical) in assessing the stability of these pillars, particularly in regard to providing for permanent stability.*

c) GAPL then notes that previous concerns about storage of water up-dip from underground active mine workings have now been allayed, subject to the development and implementation of robust management plans.

d) GAPL also notes that previous concerns regarding noxious and flammable gas concentrations have also been allayed, except in the event of a sudden, uncontrolled failure of web pillars (see b) above).

e) The above concerns regarding web pillar yielding/failure are discussed later in this report.

3.0 IPC Report

a) GAPL provides background comment and references from the IPC Report, in particular noting the three recommendations (R1 to R3 – listed above in section 2).

b) A footnote on page 2 requires further clarification. GAPL notes that the IPC has used the term *"numerical geotechnical model"* and it is asserted that it should only be referred to as a numerical model, since it was not intended, and does not constitute a comprehensive geotechnical model. I believe there is confusion in the use of terminology here. It is correct to state that the numerical modelling work done by Heasley was never intended to be a comprehensive mine site geotechnical model encompassing all geotechnical parameters and factors, as stated by GAPL. However, the use of the term numerical geotechnical model by IPC (and by Hume in some documentation or discussion) was never intended to convey this. It was simply to make clear that the numerical modelling work under consideration by Heasley was modelling of a geotechnical nature, and not some other form of numerical modelling, such as numerical modelling of groundwater, for example.

4.0 Pine Feather System Risk Assessment

a) As an overall comment regarding the risk assessment *(RA)* documentation, I advise that I am not in a position to comment about the actual preparation of the documents, dates and version record control procedures. This is a matter for Hume Coal and their contractor, Palaris. Similarly, many detailed responses to actual risk assessment outcomes are outside my area of expertise and are a matter for Hume Coal/Palaris to respond to.

b) However, from a process perspective, I would like to offer some further generic comments regarding the RA processes and status. This issue was originally raised by a GAPL (2017) report which sought to be advised that Hume Coal had undertaken appropriate RA evaluation of the conceptual mining system under development. This advice was provided in the affirmative and re-confirmed to the IPC when the same question was raised. The Palaris report confirms that such risk assessment of the mining concept had taken place, thus removing any earlier doubts raised on this question.

c) It has previously been noted that in a project such as this, risk assessments are part of an ongoing and evolving process, with increasing level of detail, rigorous analysis and supporting documentation as the project proceeds through from concept design, to feasibility study, to detailed design and finally resulting in the development of a comprehensive set of risk-based operational management plans. The majority of these steps in the process occur after initial project approval is granted, not prior to. It is clear from the documentation that has been provided, to date, that Hume Coal has embarked on this ongoing process and is following normal industry practice in doing so.

d) P3, section 4.1 – GAPL acknowledges the intention of Hume to produce a detailed design RA associated with a bankable feasibility study.

e) P4, section 4.1 – It is correct to conclude that the 2015 date is correct for the original and main generic RA of the overall mining system (not 2017). This record should be amended. I can confirm that I was present at and participated in the 2015 RA.

f) P4, section 4.1 – GAPL states that the RA has not listed sudden or uncontrolled web pillar failure as a threat. However, it is then noted that the threat of *"web pillar failure results in long term catastrophic failure and subsidence"* is listed in the RA. This would appear to contradict the earlier GAPL statement. However, it is agreed that there is scope in future risk assessments to include greater clarity and expansion of such threats and the consequences they could pose to both environment and safety, albeit even if ranked at a low level.

g) Pp4-5, section 4.1 – Discussion is provided on the threat of *"web pillar failure due to long term creep results in subsidence"*. The documented control of ongoing monitoring of subsidence, underground pillars and confirmation of modelling work (Heasley) is endorsed by GAPL as an important control measure. The control has a further comment added, stating the *"3D modelling demonstrates significant factors of safety with respect to pillar collapse"*. This is a reasonable and appropriate comment, since a high factor of safety indicates loading well below maximum strength, and hence less likelihood of either imminent, or time-dependent *"creep"* failure. GAPL, however, is critical of this comment, implying that the 3D modelling conducted did not model creep behaviour. This is absolutely correct, and in fact there are very few numerical modelling packages available that can reliably model 3D creep behaviour on a large scale such as for this type of mine layout. However, the comment does not state that creep has been modelled. It is making a valid observation that higher values of Factor of Safety indicate a significantly reduced propensity for longer-term failure.

h) P5, section 4.1 – Further comments on the risks associated with flooding of old mine workings and hence pillar stability are reasonable for future consideration, although they are considered to be of minor impact (either beneficial or detrimental).

i) P5, section 4.2 – GAPL conclusions overall are a matter for Hume/Palaris to respond to.

5.0 <u>Russell Howarth & Associates Report</u>

a) The Russell Howarth & Associates (RHAA) Report was prepared as an independent review of the matters that were considered as matters of residual disagreement, of which there were eight (8) key issues. These were addressed in turn by RHAA and are considered by GPAL in the same manner. The report responds to IPC R1 and R2 and was prepared in January 2020, following the IPC report of May 2019.

b) The IPC R1 recommended engagement of an independent reviewer with experience in innovative coal mining technology. Russell Howarth is acknowledged as being a person of significant management, operations and technology experience and is widely respected across the mining industry. He clearly meets the IPC requirement – a point which is agreed by GAPL. GAPL does note that Mr Howarth does not possess specialist geotechnical expertise – something that was not required by IPC, nor is claimed by RHAA.

c) Section 5.2, Key Issue #1 – Development roadway stability after breakaway:
GAPL finds that *"provided the web pillar does not yield in an uncontrolled manner, I concur that local support systems could be designed and installed to manage this situation"*. The issue of web pillar yielding will be dealt with in later discussion.

d) Section 5.3, Key Issue #2 – Impacts of intra-panel pillar formation and unmined web pillars on subsidence:
GAPL is in general agreement with the findings of RHAA on this issue with a major qualification regarding the geotechnical modelling work, specifically the model calibration and the underlying constitutive law used by the model. An important conclusion by GAPL is that *"intra-panel stability should be able to be effectively controlled by modifying pillar widths at the time to maintain compliance"*. This is a significant recognition of one of the principal control measures that is present in the pine-feather system – a measure that has been previously acknowledged and is a feature of the flexibility of the system.

e) Section 5.4, Key Issue #3 – Goaf gas:
Detailed gas and ventilation issue are outside of the scope of my report. However, GAPL does return to the geotechnical issue created by the potential for web pillar failure resulting in multiple plunges causing gas emission. GAPL makes a valid point that local stability is different to regional stability, or instability. Discussion then moves to further consideration of web pillar instability but draws a final conclusion that *"provided web pillar instability does not develop rapidly in a panel prior to it being sealed …. I concur that gas content should be able to be managed safely. An effective control available if need be is to increase the width of the web pillars"*. This is effectively stating that there is no issue that cannot be managed or controlled in relation to goaf gas, given the available option, if required, for web pillar widths to be increased. Once again, this has always been acknowledged, albeit that the design is intended to provide for web pillar stability under normal circumstances. However, it is agreed that the flexibility of the mining system provides for this control option at the time, if required.

f) Section 5.5, Key Issue #4 – Strata failure of a web or plunge expels irrespirable atmosphere:
GAPL notes that these issues have largely been dealt with under Key Issue #3. However, the further issue of potential windblasts is discussed, with the risk of flying debris. RHAA has noted that this risk is fundamentally less than for conventional secondary extraction. GAPL

concurs, however noting that the pine feather method does not allow for multiple exit paths for windblast air to escape. This is correct, but to offset this, the potential areas of roof hang-up that might lead to air displacement and windblast in the pine-feather method are far smaller than most pillar extraction or other secondary extraction operations. Furthermore, with people already removed from the working place and so out of the direct "line of fire" of any potential windblast, there is then the opportunity through multiple development headings, for any windblast impacts to dissipate rapidly.

g) Section 5.6, Key Issue #5 – Alignment of plunges:
This issue appears to have been largely dealt with by RHAA without significant dissent from GAPL. Although GAPL does note that RHAA limited their conclusions by noting that they had not determined that suitable technology was in place for managing this issue. It is fair to say that RHAA did not actively seek out suitable technology, as this was not part of their brief. It is simply a statement of fact in terms of current awareness and a clear indication that ongoing technology developments are continuing in regard to alignment and control of mining equipment. It is agreed by all that appropriate management plans will need to be in place to make effective and reliable use of such technologies.

h) Section 5.7, Key Issue #6 – Flexibility of the pine-feather system:
DPIE experts had asserted previously that the method was less flexible than other proven systems of work. Noting now that the system is classified as secondary extraction, and that significant exploration has taken place and is ongoing, GAPL now agrees that *"the pine-feather mining technique as proposed has flexibility to mine the area and meet the objectives of the proposed plan".*

i) Section 5.8, Key Issue #7 – Ability of the mining system to store mining reject and excess water underground:
GAPL accepts the RHAA commentary on this issue.

j) Section 5.9, Key Issue #8 – Principal hazards common to underground mining:
Once again, GAPL accepts the overall generic discussion on the issue of principal hazard management provided by RHAA and accepts that the principal hazard of potential inrush and inundation can be adequately controlled.

In relation to strata-related hazards, GAPL returns to concern with regard to sudden or uncontrolled pillar failure (and possibly coal bursts) – which often do not provide sufficient precursors to enable an effective management plan response to be activated. GAPL makes the point that no pillar design system can guarantee, or "assure" permanent stability. This is clearly correct but is a comment that applies to all types of underground mining, not just this method. This would also include narrow fenders or pillar splits mined in pillar extraction operations, which often have narrow width-to-height ratios with personnel working directly adjacent to them, in contrast to the pine-feather system of remote mining. It is accepted that this issue must be considered as the mine design is further progressed, and additional risk assessments are carried out in preparation for the detailed operational management plans, such as the Strata Control Management Plan.

k) Section 5.10, RHAA Conclusions:

- Re: Principal Hazard Management – GAPL agrees that there is no principal hazard in inherent in the proposed system of work which is incapable of being managed and controlled …. *"provided that increasing pillar width is included as a control option"*. This is an appropriate response and is in line with what has been previously stated by Hume Coal.
- Re: favourable mining conditions – GAPL offers no opinion.
- Re: Hume Coal has conducted formal risk assessments – GAPL refers back to section 4 of their report (see earlier discussion).

l) Section 5.10, RHAA Executive Summary and 5.11, GAPL Review Conclusion:

Most of the points raised here have already been addressed. In relation to technology, it is important to clarify that GAPL notes that RHAA *"has not determined that some of the technology being relied upon…. is currently available"*. This is quite different from any inference that might be wrongly interpreted as stating that RHAA has determined that such technology is not available. This is clearly not the case.

It is understood from previous Hume investigations that suitable technologies are available, even if detailed integration with the appropriate types of mining equipment need to be implemented. The risk of failure to achieve such implementation is discussed and GAPL states that for other mining systems introduced to Australia there have been existing practices in place overseas. However, a further example where this is not the case is the lead taken in Australia with longwall automation technologies where Australia is a world-leader and has pioneered such technology integration worldwide. This technology has been largely developed through CSIRO who have also been the technology leaders with respect to remote plunge alignment technology development.

The main other concern by GAPL reverts to the geotechnical issues where RHAA did not claim to offer independent expertise. These issues are discussed further later in this report.

6.0 Hume Coal's Response to IPC Report

a) P14 – Re: DPIE Issue: Untested and unconventional mining method.

I will leave it to Hume Coal or others to respond regarding other examples of underground mining methods with similar layouts. I would, however, pick up on the point made by GAPL that the pine-feather method *"relies on the stability of narrow (web) coal pillars of small width-to-height ratio to provide internal support to the overburden"*. I believe that this description is inappropriate and/or misleading, in terms of the role of the web pillars. Whilst these pillars may be providing some support to the overburden, obviously, they are not the primary means of overburden support and the method is certainly not reliant on their ongoing stability.

The design is premised on the relatively massive and stiff units within the overburden spanning across the 60m panel width onto the intra-panel pillars, together with spanning in the perpendicular direction (<120m) between the gateroad pillars and the very substantial, solid inter-panel barrier pillars. It is for this reason that this method must be considered as a three-dimensional load-sharing problem. It needs a true 3D analysis to appreciate the fundamental regional stability of the system. By virtue of this 3D load-sharing design, the loading and hence performance of the individual web pillars is quite secondary to the overall system performance and long-term stability. It was for this reason that in 2017 Hume Coal agreed to commission Dr Keith Heasley to undertake the 3D numerical modelling of the system using the LaModel software – again, not for the purpose of a detailed analysis of web pillar behaviour, but to assess the regional stability with load-sharing in both directions relative to the plan view layout of the system. The scoping of the modelling study and the commissioning of Dr Heasley took place well before any similar recommendation (to undertake modelling) was provided by either GAPL or Canbulat. Further discussion of the modelling will be given later in this report.

b) P15 – Re: DPIE Issue: Uncertainty about the methodology underpinning the geotechnical model.
GAPL states that they are unaware of any response to the issues raised in GAPL (2018) and therefore those issues stand. Clearly there has been a communication failure between DPIE/IPC and DPIE's advising experts. Reports to Hume Coal from both MineAdvice and B K Hebblewhite, responding to the December 2018 reports of GAPL and Canbulat, and the DPIE Project Assessment, were provided as an appendix (Appendix C) to the submission to the IPC in March 2019.

It is then stated that attempts to calibrate the modelling using Berrima data were inconclusive. This view is challenged. The Berrima data provided very good calibration and was far superior to the level of calibration often available for many new project designs that are modelled.

Turning to pillar strength estimates used by Heasley, the Mark-Bieniawski empirical formula used is criticised as being 17% to 40% higher than "alternative mainstream formula". I would suggest that this is a skewed interpretation which assumes that so-called mainstream formulae are accurate and therefore all of the error lies in the formula used by Heasley. The true situation is that all such empirical formulae involve approximations and simplifications of a quite complex structural model of pillar behaviour. There is a clear error band associated with every formula used – probably at least ± 10% if not greater. So the reality is that the Mark-Bieniawski strength calculations are no more or less accurate than other empirical formulae in use.

Turning to the issue of the constitutive law used in the Heasley LaModel modelling work, it is clear that an elastic behaviour was modelled for all coal elements in the study undertaken. This may not be appropriate if the behaviour of web pillars under yielding conditions was to be investigated. If the web pillars under the applied loading regime did exceed the peak strength value assigned, it is correct that they would be flagged as having failed, with a factor of safety of 1.0 or less, but they would not redistribute load to adjacent coal under true yielding and load-shedding elastoplastic behaviour and the results would then be a mis-representation of reality.

However, scrutiny of the results produced by Heasley confirm that in all model studies conducted, the web pillars remained with FoS values in excess of 1, meaning that their loading was below the peak strength and therefore not prone to yielding, even if an elastoplastic constitutive model had been adopted. This is also the case, even in the most unlikely, but extreme model analysis where a full panel of web pillars was removed to simulate a fully yielded, zero-strength set of web pillars, yet there was still no failure or loading above peak strength in any of the surrounding pillar regions.

These points are clearly noted by Heasley (p17 of his final report). It would therefore not be of any value to repeat the modelling exercise using an elastoplastic constitutive behaviour, as it would not provide any significantly different results to the present outcomes.

In terms of using the modelling results to make categoric conclusions that *"pillar failure will not occur"*, it is correct to say that no design technique available provides this level of certainty. What the modelling does show is a very low to negligible likelihood of pillar failure.

GAPL makes further comments about the model used not explicitly modelling the lithology and geological and geotechnical factors. It is not clear what these geotechnical factors might be, but it is correct that lithology is not explicitly modelled. However, there are very few, if any, suitable 3D modelling systems capable of modelling both the mining geometry and the lithology in such a level of detail. By calibration of the model using Berrima data, where the geology/lithology is similar, it is reasonable to use the model for understanding the regional load distribution in a 3D sense. That was the purpose of this modelling exercise and it was extremely successful in doing this.

In relation to a number of the above issues, the following extracts are taken from the minutes of the March 2018 meeting chaired by Professor Ted Brown, all of which support the value and the suitability of the numerical modelling carried out:

- *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.*
- *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.*
- *The experts generally agree that the company's approach to the numerical modelling is appropriate and will assist the Department in its assessment process.*
- *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 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.*

- *The experts generally agree that the proposed mining method is flexible and could be modified throughout operations.*

On p16, GAPL returns to the issue of constitutive behaviour of numerical models and includes a quote attributed to myself, but taken from a different project. Firstly, the quote is accurate, and I stand by what was said in it. However, context is always important. The quote was used in discussing work on a different mining project which was discussing modelling of extensive rock failure and large-scale displacements above a longwall panel in goaf conditions. Clearly, if such extensive failure and large displacements are to be replicated by numerical modelling, then the model must be accurate with respect to failure criteria, which is a key part of constitutive behaviour.

Applying this to the Hume project – had the modelling been investigating conditions where web pillars were yielding/failing and potentially other regions also being stressed beyond elastic conditions, the quote would be absolutely valid and an appropriate elastoplastic model should have been used. BUT we are not in that position. The pillar coal has not been stressed beyond the elastic limit or above the pillar strength levels, and so representation of post-peak strength failure behaviour is not relevant.

c) P16, sections 6.2.1, 6.2.2 – these simply cross-reference to issues already dealt with.

d) P17, section 6.2.3 – A quote from the EMM (2020) response to IPC (p31) is questioned regarding reference to widening and support of roadways at breakaways being a safety improvement. I agree with GAPL that the widening of roadways is hardly a safety improvement, even if additional support clearly is. I suspect there is some confusion or error in the wording or form of expression used here and leave it to others to clarify/explain.

7.0 <u>GAPL's Overall Conclusions</u>

a) GAPL is critical of lack of technical support for outstanding issues, primarily of a geotechnical nature. As noted above, GAPL appears not to have received or reviewed all technical responses to their 2018 reports (including both MineAdvice and Hebblewhite reports) where these issues were canvassed. A number of such responses have been repeated again in this report for completeness.

b) GAPL claims that there is a need for *"refinements and reiterations to the numerical modelling if it is to be relied upon"*. This conclusion is challenged, for the reasons given above. The refinements suggested are expected to make no significant impact to the modelling results and would provide no further or new insights. The modelling conducted was appropriate for the purpose intended and does provide a useful understanding of the true 3D load distribution taking place in this particular mine layout.

c) Reference is made to a statement from the risk assessment that web pillars will not fail. Such a statement may have been made, however, I would assert that there is a possibility of isolated web pillar yielding, albeit that the design undertaken is robust and premised on avoiding web pillar failure due to the interaction with overburden strata stiffness and bridging characteristics. However, in the event of some localised yielding or failure of web pillars, the mine layout is sufficiently robust as to remain stable in the long-term – as was modelled by Heasley with the removal of a panel of web pillars as an extreme, but unlikely case.

d) GAPL states *"This is not to say that the mining method being proposed by Hume Coal cannot be safely and successfully implemented".* This is an encouraging conclusion, but further indicates that the current level of response to IPC does not adequately address the previous GAPL concerns. It is stated that due diligence requires further responses. It is hoped that if the previous documents that appear to have not been sighted by GAPL are assessed, together with these current reports, then a satisfactory level of due diligence has been followed and the remaining outstanding concerns can be resolved.

e) GAPL once again acknowledges that changes to either web pillar or intra-panel pillar dimensions offers an effective engineering control, in the event that such changes are needed on a local or as needed basis. There is nothing to warrant such changes being implemented as a fundamental or universal design change, but they are available at an operational management level, as and when needed.

4. Review and Response to Canbulat Report

As with the GAPL Report commentary, my comments below are provided in the order in which the matters occur within the July 2020 Canbulat Report, with page numbers noted, where applicable.

a) Many of the issues addressed by Canbulat have already been addressed in the review of the GAPL Report, and so are not repeated here at length.

b) Pp2,3 – Canbulat challenges the use of the Mark-Bieniawski pillar strength formula as being overly optimistic in estimating pillar strength. As discussed earlier, this is a relative comment, rather than absolute. It may be more optimistic than other empirical strength formulae, but they also may or do contain approximations which can lead to a degree of error. Whilst in a perfect world, it would be interesting to change the pillar strength formula used, there is no real justification for making such a change, other than for academic interest. It is also worth noting that Canbulat makes a comment about a hypothetical calculation using this formula for a width-to-height ratio of 0.1, which is simply unrealistic and inappropriate for use of any formula.

c) P3 – It is recommended that the modelling be re-run using strain-softening elements to represent the coal seam. As discussed previously, if the project was starting again, I would endorse this recommendation. However, based on the results obtained already, which clearly indicate that pillar coal has not exceeded peak strength, there is nothing to gain, and there would be no significant change to the results, even if the elements were modelled differently, as recommended.

d) P3 – Canbulat recommends that the Berrima back-analysis be expanded and that the input parameters were not presented. In fact, although the Berrima back analysis was not reported in detail in the Heasley report, it was presented to both Galvin and Canbulat at the March 2018 meeting with Professor Brown. Mr Alex Pauza made a presentation to the meeting and showed all of the calibration data including the single and multiple panel survey lines and subsidence data used for back-analysis.

e) P4 – The statement is made that *"there is a likelihood that the web pillars may fail in the active panel(s), which can pose a risk to mine workers at the face".* This statement does not define the likelihood. I would suggest that there is a likelihood under some localised conditions, but it is very low (not impossible, but very low). The statement then refers to risk to workers at the face. This statement does not acknowledge that workers will not be positioned at the face, but will be operating the mining system remotely, so there is a significant degree of protection afforded by positioning the workers well away from the active face adjacent to a web pillar.

f) P4 – It is not correct to state that the risk assessment did not consider the failure of web pillars – it was included as a risk under consideration.

g) P4 – Regarding the monitoring of pillars to confirm their strength – I accept that the strength is not directly confirmed, but monitoring will confirm their behaviour in terms of deformation and changes in applied load, from which useful inferences can be drawn regarding their stability (relative to strength) or otherwise.

h) P4 – Canbulat makes the closing statement that *"web pillars cannot be considered long-term stable and they will fail"*. My response to this comment is twofold.

Firstly, I note that the design of the layout has been carried out on the basis that under normal ground conditions, the web pillars will remain stable. However, I accept that there is a possibility that under some circumstances there is a possibility that they could fail or yield to a certain extent, even though continuing to carry some level of residual load. I believe the design is such that the surrounding barrier pillars are sufficiently robust to maintain regional stability, regardless of such localised behaviour. The 3D modelling results have reinforced this view.

Secondly, just as GAPL argued that it is not possible to guarantee pillar stability for ever using any design methodology, it is equally not possibly to categorically state that pillars will fail.

5. Final Summary Comments

The above reviews touch on a number of issues of a geotechnical nature, on which there is currently disagreement. It is hoped that the responses in this report go some way at least, to removing or minimising such disagreements. But I suspect some will remain and will not be readily resolved.

On these more difficult issues, I respectfully suggest that they are more of an academic or theoretical nature than matters that will make a significant difference to the current Hume Coal proposed mining system. I therefore conclude that in regard to geotechnical issues of substance, I do not believe that there is, or needs to be any considerable distance apart between the various opinions held.

I do believe that the proposed project has been subjected to rigorous analysis and review over a number of years and that appropriate engineering due diligence practices have been followed.

At this point in time, recognising the above, I put forward the following points seeking agreement, as a way forward, to avoid a further cycle(s) of reporting and review:

- It is accepted that all pillar design approaches involve approximations and will inherently contain some level of error. This includes both empirical and numerical techniques. No pillar design systems provide absolute certainty with regard to pillar stability (or otherwise).

- Making minor changes to empirical strength calculations within a regional stability modelling exercise is unlikely to result in significant changes that can be argued to be any more reliable than the current modelling approach.

- The proposed mine layout relies on load distributions across a range of barrier pillar systems that exist both across the width of the production web panels, and along the length of the panels. As such, it is clearly a 3D load sharing concept.

- LaModel is one of, if not the only suitable, currently available numerical modelling package to geotechnically model such a geometry with any degree of reliability.

- The 3D modelling conducted has provided clear indications of load distributions in both directions, as referred to above, with regional stability demonstrated, even in the extremely unlikely event of a complete removal of web pillars from a production panel.

- Whilst the original layout design is intended to achieve stability of all pillars in the layout, including the web pillars, under normal loading conditions, it is accepted that there is a possibility of some localised web pillar failure or yielding, albeit of a very low likelihood.

- The design does not rely on web pillars remaining stable indefinitely. The load-sharing across barrier pillar systems provides for situations where some localised web pillar yielding may occur, without any catastrophic outcomes.

- The mining system incorporates a high degree of flexibility, whereby, as the need arises, both web pillar widths and intra-panel pillar widths could be increased in localised conditions at the time, and/or plunges eliminated in order to provide effective control.

- Once the project proceeds to more detailed feasibility and design stages, further risk assessments will be conducted which can address geotechnical and other issues in greater detail, leading to the development of appropriate risk-based management plans in order to ensure adequate responses are in place to all perceived risk factors.

Bruce Hebblewhite
21st August 2020

Disclaimer

Bruce Hebblewhite is employed as a Professor within the School of Minerals & Energy Resources Engineering, at The University of New South Wales (UNSW). In accordance with policy regulations of UNSW regarding external private consulting, it is recorded that this report has been prepared by the author in his private capacity as an independent consultant, and not as an employee of UNSW. The report does not necessarily reflect the views of UNSW and has not relied upon any resources of UNSW.

Appendix B10 – Applicant Response to Independent Expert advice (mining engineering) 2

ATTENTION: Ms Mandana Mazaheri
Department of Planning, Industry and Environment
Locked Bag 5022
PARRAMATTA, NSW 2124

21 August 2020

RE: SSD-7171 & SSD-7172 THE HUME COAL MINE AND BERRIMA RAIL PROJECTS RESPONSE TO AGENCY COMMENTS – DPIE WATER.

Dear Mandana,

Thank you for providing the Agency comments.

Please find attached the response from Hume Coal / Dr Russell Frith for the commentary provided by Prof's Galvin and Canbulet.

Regards,

Rod Doyle
Project Manager

Hume Coal Pty Limited

MINE ADVICE
A.B.N. 15 152 928 222

HUME COAL PTY LTD
HUME COAL PROJECT

Responses to Various Review Reports Pertaining to the Hume Project EIS and Associated Mine Layout Design

AUGUST 2020

REPORT: HUME22/3

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REPORT TO :	Rod Doyle Project Manager Hume Coal Project
REPORT ON :	Responses to Various Review Reports Pertaining to the Hume Project EIS and Associated Mine Layout Design
REPORT NO :	HUME22/3
REFERENCE :	Your instructions to proceed
PREPARED BY :	Russell Frith
REVIEWED BY :	Client Representatives
DATE :	22nd August 2020

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Russell Frith
Senior Principal Geotechnical Engineer
FAusIMM(CP) RPEQ

Disclaimer

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EXECUTIVE SUMMARY

The assessment by NSW government of Hume Coal's EIS pertaining to proposed "pine-feather" mining layouts at the Hume Project, has now been in progress for 3.5 years. In addition to on-going technical discussions amongst the expert advisers to both parties, a major numerical modelling study has now been completed by a US mining and geotechnical expert, the results of which substantially support and confirm the suitability of the proposed general mining layouts in Hume Coal's original EIS submission.

Based on their most recent review reports, it is evident that the independent reviewers may have lost sight of the technical justification for the proposed mining layouts in the EIS in the first instance, and are now primarily focused on interrogating specific technical aspects of the numerical modelling, which in itself was only ever done to examine pillar load distribution variations in three-dimensions according to a realistic range of overburden conditions, the sole objective being to verify the suitability of the two-dimensional ARMPS-HWM design methodology upon which the proposed mining layouts were fundamentally based. The original layout design justifications must remain at the forefront of the discussion as the numerical modelling was never intended to replace them.

It is once again re-iterated that the most critical aspect of the proposed mining layout designs relating to the stability of the low width to height (w/h) web pillars that are an intrinsic part of the proposed mining method, is that the spans or distances between stable barrier pillars have been deliberately restricted in order to ensure that the overburden retains a high level of natural stability and so substantially contributes to the short and long-term stability of the web pillars and hence, the mine workings more generally. Overlooking this critical mine layout design aspect inevitably results in an incomplete appreciation of what is being proposed and importantly, why.

Unfortunately, the critical role of the overburden has consistently been overlooked or diminished as part of the review process, the debate becoming almost entirely focused on the stability of the low w/h web pillars with little or no regard for the stabilising contribution of the overburden. This has caused many of the on-going disagreements between the parties, which has consequently resulted in the EIS assessment process becoming far more convoluted and controversial than otherwise would, and indeed should, have been the case had the original layout design basis been considered as a system, rather than according to its individual parts which were never intended to function as or be reviewed as stand-alone controls.

The on-going debate and additional numerical modelling work during the 3.5 years since the EIS was submitted to NSW government, has not in any way discredited the technical design basis for the proposed mining layouts at Hume, in fact quite the contrary. Specifically, the stability of the proposed layouts has been shown to be relatively insensitive to both significantly varying overburden conditions, as well as the influence of significant reductions in web pillar strength and/or load-bearing ability. Therefore, the general suitability of the proposed mining layouts has been further justified in terms of both maintaining environmental impacts to acceptable levels and facilitating manageable mining conditions in terms of operational safety.

This report has provided what are considered to be final responses to the various concerns of DPI and E's independent reviewers, as well as a plea that the original design justifications for the mining layouts do not continue to be overlooked, particularly as their credibility is now greater than at the time of EIS submission in March 2017. Without full reference to the original mine layout design justifications, the Applicant cannot possibly receive reasonable treatment in the EIS assessment process, which is unfair to both them and persons that may ultimately be employed at an operating mine in the future.

1.0 INTRODUCTION

This report contains a series of definitive statements in response to three recent technical reviews pertaining to the EIS approval process for the Hume Project in NSW, namely:

- *Review Relating to Hume Coal's Response to Independent Planning Commission Report on Hume Coal Project and Berrima Rail Project,* Galvin and Associates (GAPL) 2020
- *Independent Review of Hume Coal's Response to the Independent Planning Commission Report – Mine and Berrima Rail Projects,* Canbulat 2020
- *Resources Regulator's Comments on Hume Coal Projects, Li 2020*

The GAPL and Canbulat reports are independent technical reviews of Hume Coal's EIS commissioned by NSW DPI and E, the third containing comments by the Principal Subsidence Engineer within the NSW Resources Regulator relating to mining subsidence and the protection of key surface infrastructure.

The reports represent the latest in a technical debate that has been on-going for 3.5 years between Hume Coal and their advisers, and NSW government and their advisers, having commenced with Hume Coal submitting their EIS to the NSW government for assessment in March 2017.

As a starting point it is of value to generally summarise the chronology of the technical reports that have been produced by the following entities:

(a) Mine Advice Pty Ltd, Professor Keith Heasley of West Virginia University, Palaris and Russell Howarth on behalf of Hume Coal,

(b) peer reviews of the same by Professor Bruce Hebblewhite and others on behalf of Hume Coal,

(c) independent reviews by Emeritus Professor Jim Galvin and Professor Ismet Canbulat of UNSW, commissioned by DPI and E at various junctures as part of assessing Hume Coal's EIS submission, and

(d) various inputs from the Resources Regulator.

Demonstrably, a significant amount of technical thought, risk-based mine design work, detailed technical peer review and subsequent debate has been undertaken in reaching the current point whereby once again, Hume Coal and its advisers are being asked to formally address a series of technical concerns relating to the overall suitability and justification of the proposed mine layout design. Several of these concerns have been previously addressed in detail, but nonetheless remain unresolved in the minds of DPI and E's independent reviewers based on their most recent reports.

For reference purposes, the relevant chronology of technical reports and interactions between Hume Coal and NSW Government, commencing with the EIS submission in March 2017, that directly relate to confirming the suitability of the proposed mine layout design, is as follows:

- *Mine Design Justification Report, Hume Project,* Mine Advice 2016a
- *Environmental Impact Statement Subsidence Assessment,* Mine Advice 2016b
- *Peer Review: Pillar Stability and Subsidence Assessment,* Hebblewhite 2016

- *Principal Subsidence Engineers Comments as a Result of an Inspection at Hume Coal on 13 September 2017,* Li 2017
- *Response to Questions Raised by Ismet Canbulat, Items IC3 and IC4 in Action Items,* Mine Advice 2017a
- *Response to Questions Raised by Jim Galvin, Items JG5 in Action Items,* Mine Advice 2017b
- *Independent Assessment, Hume Coal Project,* GAPL 2017
- *Review of the Mine Plan and the Subsidence Risks with the Proposed Mine Plan – Hume Coal,* Canbulat 2017
- *Preliminary Results of Hume Coal Numerical Modelling Study (as presented at the Experts Meeting on 28th March 2018),* Hume Coal 2018
- *Pillar Design Analysis Using LaModel for Hume Coal and Mine Advice,* Heasley 2018
- *Interpretation of the Numerical Modelling Study of the Proposed Hume Project EIS Mine Layout,* Mine Advice 2018
- *Independent Assessment, Hume Coal Project, Supplementary Report (included as part of DP and E Assessment Report),* GAPL 2018
- *Response to "responses to reviews of the Hume Coal Project by Galvin and Associates, and Professor Ismet Canbulat" (included as part of DP and E Assessment Report),* Canbulat 2018
- *Response to DP and E Assessment Report, Hume Project,* Mine Advice 2019
- *Assessment of Plunge Breakaway Roof Stability as a Function of Varying Heading Width,* Mine Advice 2020
- *Independent Review of Residual Issues Between the Applicant and the Department of Planning Associated with the Hume Coal Project,* Howarth and Associates 2020
- *Pine Feather System – Risk Assessment Review,* Palaris 2020
- *Review Relating to Hume Coal's Response to Independent Planning Commission Report on Hume Coal Project and Berrima Rail Project,* GAPL 2020
- *Independent Review of Hume Coal's Response to the Independent Planning Commission Report – Mine and Berrima Rail Projects,* Canbulat 2020
- *Resources Regulator's Comments on Hume Coal Projects, Li 2020*

This report will not attempt to describe in detail how the debate as to the suitability of the proposed mine layout designs have has developed since March 2017, but will simply summarise the outstanding technical issues as can be gleaned from GAPL 2020, Canbulat 2020 and Li 2020 and address them by reference to the previous work that has been done on behalf of Hume Coal and any further references that are deemed to be of relevance and significance.

2.0 SUMMARY OF OUTSTANDING ISSUES TO BE ADDRESSED

Having reviewed GAPL 2020, Canbulat 2020 and Li 2020, it is apparent that the following technical issues, in no priority order, need to be addressed herein:

1. the possibility that low w/h ratio web pillars could fail in a sudden and uncontrolled manner while persons are exposed to the consequences of such failures, has not been considered.

2. the potential impact of roof falls, rib spalling, weathering and bearing capacity failure on the stability of web pillars over time.

3. limitations of all pillar stability design approaches (empirical, analytical, and numerical) in assessing the stability of web pillars, particularly in providing for "*permanent*" stability.

4. whether the 3D numerical model used can model long-term pillar creep and so is able to assess the threat of web pillar failure due to long-term creep.

5. the statement that was published in 1996 some 24 years ago, that "*no respectable pillar design method can guarantee permanent pillar stability*".

6. that none of the pillar design procedures that have been used in this case "*assure*" permanent stability.

7. concern over similar mining layouts not being used at other underground operations.

8. at shallow cover depths, the proposed distances between intra-panel barriers are greater than would be used in total extraction to achieve negligible surface subsidence.

9. the proposed intra-panel barrier pillars are narrower than would be used for total extraction mining.

10. concern over the "reliance" being placed on web pillars to restrict surface subsidence at shallow depth.

11. the calibration of the numerical model to data from the adjacent Berrima Colliery was inconclusive.

12. the pillar strength equation(s) used in the numerical modelling are optimistic and over-predict coal pillar strength by a significant amount (17% to 40%) as compared to "*mainstream*" formulae.

13. that the constitutive elastic-plastic stress-strain model used to simulate coal pillar behaviour in the numerical model has somehow pre-determined the modelling outcome of pillar system stability by virtue of the fact that it does not allow coal pillar failure to be modelled.

14. the 3D numerical modelling did not adequately consider all geotechnical factors (e.g. presumably near-seam lithology, vertical jointing, clay bands, soft floor etc.) that can impact coal pillar strength, hence the model provides optimistic predictions.

15. the construct of the 3D numerical model was not available for critique by DPI and E's independent reviewers.

16. numerical modelling results more generally can be discredited and may be misleading based on the constitutive behavioural representations used for rock deformations and failure.

17. forming breakaways and therefore intersections as part of plunging is a safety threat and has not been adequately addressed.

18. reliance has been placed on the results of the 3D numerical modelling in assessing the stability of the remnant pillar system post-mining.

19. the use of an elastic-plastic coal pillar stress-strain constitutive model was justified on the basis that "*all web pillars are subjected to stresses lower than the peak strength*".

20. the use of the Mark-Bieniawski pillar strength equation is inappropriate as it over-predicts pillar strength at a pillar width to height (w/h) ratio of 0.1.

21. the 3D numerical modelling concluded that all web pillars will be "*perfectly stable*", such that any safety implications of web pillar failures have not been adequately addressed, either during active mining or longer-term.

22. details of the Berrima Colliery surface subsidence data were not made available to the independent reviewers.

23. the Berrima Colliery subsidence data used as part of calibrating the numerical model might be insufficient and so have caused the model to underestimate web pillar loads.

24. strain-softening coal pillar behaviour needs to be included in the numerical model, which needs to be re-run to "*estimate the subsidence magnitudes at varying depths*".

25. using strain-softening coal pillar behaviour in the numerical models, investigations need to be conducted to evaluate changing web pillar stability during the mining of individual plunges to confirm that it can be done safely.

26. the Berrima Colliery back-analysis may have been corrupted by the assumption of elastic-plastic coal pillar behaviour in the numerical model.

27. load-shifting between web pillars and intra-panel barriers due to high overburden stiffness may overload barrier pillars, impact their stability, and so increase subsidence.

28. project risk assessments only considered the impact of web pillar failure on subsidence rather than mine safety.

29. the numerical modelling does not include any impact of roof instability or rib spall.

30. the proposed web pillars "***will***" fail as they cannot be considered as long-term stable.

31. there is no record of geotechnical expert input into risk assessments undertaken after 2017.

32. the meaning of the word "*catastrophic*" is unclear as it applies to mine layout design for mine stability purposes.

33. high cover depth cannot be relied upon in this instance as an effective control against critical surface infrastructure being damaged by significant levels of surface subsidence due to mining, therefore other controls are required in this regard.

34. predicted surface subsidence levels due to mining are "*theoretical*" as there are no comparable mining layouts from which to draw meaningful comparisons.

35. validation of the effectiveness of the proposed mining layouts in relation to surface subsidence control should be assessed in areas unconstrained by critical surface infrastructure before mining occurs in the vicinity of such infrastructure.

36. critical surface infrastructure must be protected be fully protected by adequate coal protection barriers.

This is a long list of individual concerns and criticisms that have been raised in the three most recent review reports, many of which are interrelated. Therefore, in the interests of both brevity and technical clarity, commentary will be provided in the remainder of the report which attempts to address them more holistically as opposed to providing detailed point-by-point explanations in isolation.

3.0 COMMENTARY ON ISSUES AND CONCERNS RAISED

The 36 listed points of concern that have been extracted from the three recent technical reports, can be summarised in a series of 14 key objective statements related to the fitness for purpose of the EIS mining layout design, that this report needs to address as follows:

1. explain why project risk assessments focused on the link between web pillar stability and surface subsidence rather than mine safety and why no external geotechnical experts have been involved in risk assessments since 2017.

2. clarify the meaning of the word "*catastrophic*" as it applies to coal pillar stability and mine layout design.

3. justify the use of the Mark-Bieniawski coal pillar strength equation within the numerical modelling.

4. justify the use of elastic-plastic constitutive stress-strain coal pillar behaviour in the numerical modelling.

5. refute the suggestion that the input data and construct of the numerical modelling was not made available to DPI and E's two independent reviewers.

6. justify that the use of the Berrima Colliery subsidence data for calibrating the overburden in the numerical model has not resulted in an "*inconclusive*" outcome.

7. refute the suggestion that the numerical model may not have made an adequate allowance for load-shifting between web pillars and barrier pillars.

8. justify why the non-inclusion of long-term creep, roof instability, rib instability, weathering, bearing failure of the floor strata and general geological/geotechnical simplification within the numerical model does not render the modelling results, in terms of both pillar stability and surface subsidence predictions, as misleading.

9. reconcile the requirement for on-going stability of the remnant mine workings with the statement that is now being made, that no pillar design method can guarantee it.

10. refute the statement made by Canbulat 2020 that "*web pillars <u>will</u> fail*" (emphasis added by author).

11. provide a credible argument as to why the absence of comparable mining is not a constraint to approving the proposed layout designs at Hume.

12. clarify how critical surface infrastructure will be protected from mining subsidence effects.

13. confirm that roof stability and roof support for plunge breakaways and intersections, as discussed in Howarth and Associates 2020, is backed by credible geotechnical analyses.

14. overall, provide a credible and compelling set of arguments as to why the proposed web pillar designs will be short-term, long-term and "*permanently*" stable, and that <u>web pillars are in no way being relied upon in isolation</u> to ensure both adequate safety during mining and acceptable surface impacts due to mining subsidence.

Each of these statements will be addressed in the remainder of the report. However, it first needs to be stated that in generally reviewing both GAPL 2020 and Canbulat 2020, it is clearly evident that neither independent reviewer has considered Mine Advice's detailed response (Mine Advice 2019) to their earlier reviews of the 3D numerical modelling results (GAPL 2018 and Canbulat 2018 as included in DP and E 2018) as were contained in Heasley 2018 and Mine Advice 2018. This statement is based on:

(i) GAPL 2020 makes the statement on page iv that "*GAPL is unaware of any engineering-based response from the Applicant to the numerical modelling issues raised by GAPL in October 2018*", and

(ii) in both GAPL 2020 and Canbulat 2020, a number of the issues they raise have been previously addressed in significant detail in Mine Advice 2019.

How and why the two independent reviewers have not considered Mine Advice 2019 in their most recent reports is unclear.

It is recommended that both independent reviewers fully consider the entire contents of Mine Advice 2019 as the first step in considering the contents of this report, this then providing the mandatory pre-reading that underpins the comments made in response to each of the 14 objective statements listed previously. Mine Advice 2019 is included herein as Appendix A.

3.1 Project Risk Assessments

The reason that project risk assessments focused on the link between web pillar failure and surface subsidence was that these were all done at a time when the Applicant and their advisers were working on the reasonable assumption that this was the primary issue to address as part of an EIS submission, this being based on the SEARS provided to Hume Coal in NSW Planning and Environment 2015. The issue of safety during mining, including down to the level of slips and trips due to wet floor, was only raised in GAPL 2017 and subsequently confirmed as being relevant to DP and E's assessment of Hume Coal's EIS during the experts meeting on 28th March 2018.

Since the experts meeting, the primary geotechnical focus has been in undertaking the numerical modelling work as requested by the independent reviewers and responding to their substantial list of concerns as part of attempting to gain agreement on the fundamental basis of the mine layout design. During this period there has been no identified need to re-consider the mine layout design as part of a formal risk assessment, which provides the explanation as to why external geotechnical experts have not been involved in project risk assessments since 2017.

3.2 Use of the Word "Catastrophic"

GAPL 2020 is correct in that the word "*catastrophic*" is used with different meanings in different documents that are part of this entire engagement process. In the context of the mine layout design and associated risks, it is taken to mean the *en masse* failure and collapse of the coal pillar system, either in full or part, which could conceivably result in unacceptable surface and environmental impacts and/or significant mine safety risks including the potential for multiple fatalities.

From Mine Advice's perspective, this definition has been at the forefront of thinking in developing the generic mining layouts for EIS purposes, there being a need for both safe mining and acceptable mining impacts. This is demonstrated by the following quotation taken from Mine Advice 2016a:

> *The above-listed mandatory outcomes both during and after mining result in a mine design challenge if the overall mining outcome is to be one of (i) acceptable reserve recovery, (ii) acceptable production costs that allow the mine to be economic, (iii) acceptable environmental impacts both during and after mining is completed and (iv) safe mining operations.*

At no point during the development of the EIS mine layout design has the issue of mine safety been overlooked, accepting that developing effective operational controls in this regard is premature at the EIS stage.

3.3 Use of the Mark-Bieniawski Pillar Strength Equation

Whilst it may be an inconvenient truth, it is irrefutable that the empirically derived Mark-Bieniawski coal pillar strength equation is founded on a far more substantial database of coal pillar case histories than those of the UNSW PDP. It has also been evaluated and applied in a much wider range of coal pillar design and mine serviceability scenarios (e.g. first workings, pillar extraction, highwall mining, longwall chain pillars, multi-seam mining) than those of the UNSW PDP, which is limited to regular arrays of standing pillars in single-seam underground mining, some of which underwent core pillar failure.

Canbulat 2020 attempts to cast doubt over the usefulness of the Mark-Bieniawski pillar strength equation in this application, by arguing that for a pillar w/h of 0.1 it predicts a pillar strength in the order of 4 MPa, which cannot possibly be true. There is no argument with this statement, other than to the best of the authors knowledge, no coal pillar system has ever been formed-up using pillars with w/h values of only 0.1 and furthermore, there is no intent to do so at Hume, the absolute minimum w/h ratio being 1, which is an order of magnitude higher than 0.1. The Mark-Bieniawski pillar strength equation has not been and will not be applied at such a ridiculously low w/h value at Hume, therefore it should not be reviewed or criticised on such a fundamentally flawed basis.

The Mark-Bieniawski equation has its genesis in 692 case histories from 127 different coal mines covering all US coalfields and 67 different coal seams. In contrast, the UNSW PDP strength equations were based initially on 14 collapsed and 16 stable Australian cases, which was subsequently increased to 116 stable cases and 61 failed cases by including a number of South African case histories.

The general suitability of the Mark-Bieniawski pillar strength equation has been empirically evaluated by reference to the largest single coal pillar database in the world and found to provide meaningful design outcomes according to its developer, Dr. Chris Mark. It is accepted that it does not provide a link to a statistical Probability of Failure as per the UNSW PDP, however it is nonetheless associated with empirically-derived, risk-based, credible mine layout design principles in both underground mines (via the ARMPS method) and highwall mining (via the ARMPS-HWM method), most of which are not covered by the UNSW PDP.

It is noted that as part of applying the ARMPS-HWM method in developing the EIS mining layouts at Hume, Mine Advice 2016a used the pillar strength equations of the UNSW PDP to ensure that there were no major pillar stability discrepancies between the two sets of pillar strength equations requiring further consideration. None were identified in this regard.

3.4 Use of an Elastic-Plastic Coal Pillar Constitutive Stress-Strain Model

As stated in Heasley 2018:

> *Using the elastic, perfectly-plastic element in the coal wizard, also means that the pillar will maintain its peak strength throughout the post-failure range (see Figure 5). For thinner pillars that may be strain-softening after failure and for wider pillars that may be strain-hardening after failure, the elastic, perfectly-plastic behavior would be accurate through the elastic range up to the point of peak strength, but would then deviate from the expected strain-softening or strain-hardening behavior in the post-failure range (see Figure 5). Therefore, the elastic, perfectly-plastic pillar strength approach as used in these models is only accurate when used to model pillars with safety factors greater than 1. However, as long as the pillars in a model are below the peak strength, which means the pillars are within the elastic range and have safety factors > 1.0 (and are in the pre-failure range in Figure 5), the response of an elastic-plastic model is essentially identical to the response of a strain-softening or strain-hardening model.*

None of the analyses of web pillar stability at Hume using either the Mark-Bieniawski pillar strength equations or those of the UNSW PDP, have returned web pillar SF or FoS values under full cover depth loading down to 160 m depth of < 1. Therefore, the Heasley 2018 statement can be applied with confidence, the conclusion reached being that if both elastic-plastic and strain-softening coal pillar constitutive models give the same basic modelling outcome, there is no logical reason or value in running the latter as an adjunct to the former.

It is also noted that in terms of the back-analysis of the Berrima Colliery subsidence data, the use of an elastic-plastic constitutive pillar behavioural model is irrelevant as the worked areas between barriers consisted of total rather than partial extraction, this being discussed in more detail in Mine Advice 2019.

3.5 The Construct of the Numerical Model Was Not Made Available

Contrary to various recent statements, the independent reviewers were demonstrably provided with significant detail as to the construct of the LaModel numerical models used by Professor Keith Heasley in his analyses and Mine Advice's subsequent interpretation of same, based on the following:

- Heasley 2018 outlines in detail the fundamental basis of LaModel. Furthermore, Canbulat 2018 states as follows – "*I was an early user of the LaModel software, having used it since its advent in the 1990s. Since then, I have known Dr Keith Heasley, whose expertise is well-recognised internationally in the fields of numerical modelling and rock mechanics. LaModel has been used extensively to assess pillar stabilities and potential surface subsidence in most coal producing countries. I therefore fully endorse the use of 3D LaModel in assessing the Hume Coal project and Dr Keith Heasley's role in carrying out this assessment*". Therefore, there is no apparent argument that LaModel was not a suitable numerical method in this instance, and that at least one of the independent reviewers was both a past user and familiar with it.

- full details of the basis of the Berrima Colliery subsidence data used to calibrate overburden parameters was presented during the experts meeting on 28th March 2018 (see Appendix B which contains the specific Powerpoint slides that were used). Further details were included in Section 3.1.3.4 of Mine Advice 2018.

- the use of the Berrima Colliery subsidence data in calibrating the overburden was explained at the experts meeting of 28th March 2018 and further explained in Section 3.3 of Mine Advice 2018 as well as Sections 3.1.2.3 and 3.1.3.4 of Mine Advice 2019.

- the numerical modelling outcomes were presented in detail in Heasley 2018, the subsequent interpretations by Mine Advice being explained in Mine Advice 2018.

Whilst the independent reviewers might not necessarily understand or agree with the manner by which the overburden calibration and numerical modelling has been conducted, to state that full details have not been provided or that the results were somehow "*inconclusive*" is not borne out by the available documentation.

The author is unsure what else the independent reviewers would require in this regard, short of having direct oversight of and input into both the modelling work and subsequent interpretation analyses, thereby obviously losing their independent status in this matter.

3.6 Inadequate Allowance in the Numerical Model for Load-Shifting Between Web and Barrier Pillars

The suggestion has been made that an inadequate allowance for load-shifting from the web pillars to the overburden due to super-stiff overburden conditions, could result in a pillar system failure scenario that is not covered by the modelling results.

This is straightforward to dismiss when it is realised that irrespective of overburden stiffness, un-failed coal pillars cannot re-distribute the pre-mining vertical stresses acting upon them, only a proportion of any vertical stress increase due to mining. The reason for this is that to shed part or all of the *in situ* vertical stress, coal pillars would need to vertically expand, thereby requiring the overburden to lift upwards as a direct result, this being non-sensical.

On the basis of the above in combination with the relatively low overall reserve recoveries involved, it is judged that the coal pillar system failure scenario being envisaged is not credible in reality. Therefore, any numerical model inadequacies in this regard are irrelevant.

3.7 Non-Inclusion of a Range of Issues Renders the Modelling as Potentially Misleading

The independent reviewers have raised concerns about the numerical modelling by suggesting that it could produce misleading results if one or more of the following were not included:

- a long-term creep coal pillar behavioural model,
- roof instability in plunges,
- rib instability of web pillars,
- overburden weathering,
- bearing failure of the floor strata beneath pillars, and
- the general geological/geotechnical simplifications that are involved.

Taking each one individually, comments are now provided.

3.7.1 Long-Term Creep

The issue of web pillar failure due to long-term creep leading to additional subsidence, was included in a more recent project risk assessment review as reported by Palaris 2020 (see Figure 3.1). GAPL 2020 raise this as a concern, indicating that a listed "*additional control*" against this in the risk assessment was *the confirmation of modelling work (Professor Keith Heasley*, as is clearly stated in Figure 3.1.

System: 2. Design
Sub System: 2. Mining method and layout detail (that is all geometrical aspects) i.e. pillar design methodologies, roadway support design methodologies and hybrid mining system
Process: 2. Geotechnical design parameters

Risk Description	Design Controls	Control Effectiveness	Consequence Type	Current Risk			Additional Controls	Residual Risk			Comments/likely costs
				C	L	CR		C	L	Risk Ranking	
1. Web pillar failure due to long term creep results in subsidence	4. Intraweb pillars are designed to maintain stability in the event of web pillar failure	Strong	Natural Environment	2	1	Low	3. Include in operational procedures - ongoing monitoring of surface subsidence, underground pillars and confirmation of modelling work (Prof Keith Heasley).	2	1	Low	Ongoing modelling of subsidence and forward prediction of potential impacts. 3D Modelling demonstrated significant factors of safety with respect to pillar collapse. Total system design incorporates web pillars, intraweb pillars, barrier pillars and chain pillars
	5. Confinement due to paste fill or water	Weak									
	6. Supporting pillar design is conservative due to potential for web pillars to redistribute load (i.e. tributary load)	Strong									
	7. Pillar system design is fit for purpose for long term stability and includes a recognised and legislated 50m	Strong									

Risk Description	Design Controls	Control Effectiveness	Consequence Type	Current Risk			Additional Controls	Residual Risk			Comments/likely costs
				C	L	CR		C	L	Risk Ranking	
	barrier for inrush protection										
	46. Pillar stresses in sealed mine voids are relieved through hydraulic head	Weak									
	47. Protection pillars are planned beneath critical surface infrastructure	Strong									
	56. 3D numerical modelling demonstrates that catastrophic collapse is highly unlikely	Strong									

FIGURE 3.1. Extract from Palaris 2020

In the absence of a credible numerical model that allows long-term coal pillar creep analyses, mine design against long-term creep is best facilitated by undertaking "static" design analyses and ensuring that both the overburden and coal pillar system left in place are suitably stable and not prone to future instability.

In the opinion of the author, the review of the 3D numerical modelling results contained in Mine Advice 2019 is fully consistent with the review that is recommended by GAPL 2020 when referring to the statement made in the risk assessment that "*3D modelling demonstrated significant factors of safety with respect to pillar collapse*".

It would have also been useful to the reader had GAPL 2020 acknowledged both the range of listed existing "*design controls*" for this defined risk, as well as the fact that the "*additional controls*" being referred to, including the confirmation of the modelling work, were listed as "*operating procedures*" along with several other additional controls.

3.7.2 Roof Instability in Plunges

This issue has been addressed in several previous reports and will not be repeated herein. When it is remembered that the 3D numerical modelling was recommended so as to evaluate varying pillar load distributions as an adjunct to the initial ARMPS-HWM design work, rather than simulating actual pillar collapse, there is no obvious limitation of LaModel not incorporating this specific aspect.

It is also noted that roof instability in a plunge does nothing to change the stability contribution of the overburden in respect of web pillars, which is a significant component of the overall web pillar stability justification.

3.7.3 Rib Instability/Spalling in Plunges

As per roof instability, the issue of rib instability in plunges has been fully addressed in previous reports in detail and given the intent of the numerical modelling, its non-inclusion is not a material concern. Furthermore, the numerical modelling included analyses for both one and all web pillars in their entirety being fully removed, this being a wide-ranging parameter sensitivity assessment for web pillar strength variations, howsoever caused.

3.7.4 Overburden Weathering

The issue of overburden weathering in western areas of the proposed mining area was addressed in detail in Section 5 of Mine Advice 2018 and found to be minor in terms of the change on the overall structural competency of the HBSS. When combined with the fact that the primary design method, ARMPS-HWM, does not rely on the nature of the overburden lithology and the HBSS in the area affected by weathering is not a significant aquifer, it is concluded that the known weathering of the HBSS does not represent a significant threat to either the integrity of the remnant mine workings or the environmental impact due to the proposed mining.

With the above being the case and the use of a range of assumed overburden conditions within the numerical modelling, it is considered that the issue has been adequately addressed and does not require direct inclusion in the numerical modelling.

3.7.5 Floor Bearing Failure

This was addressed in detail in Section 5.3 of Mine Advice 2016b with the following findings:

> *To put the various values of bearing capacity for different strata types into their true perspective for Hume, the average pillar stress for the 6 m wide web pillars under full tributary area loading at 170 m depth is estimated to be 7 MPa. This returns a Factor of Safety against roof and floor failure in the coal material as 3.5 and 5.9 respectively. This is in excess of the overall coal pillar system FoS following mining and it is therefore concluded that the compression of the roof and floor coal material as well as the overlying and underlying sandstone units as a result of mining, will be confined to an elastic condition.*
>
> *As a final comment, the roof and floor material (be it coal or stone) was observed to show a limited tendency to deteriorate when exposed to moisture in the drill core trays. Based on these observations and experience of mining of the Wongawilli Seam in other parts of the Southern Coalfield, it is concluded that the potential for long-term degradation or weakening of the floor*

> *material due to moisture is negligible. Thus, there is also a negligible risk of such weakening causing increased levels of subsidence.*

As such, there is no obvious compelling reason to include floor failure due to either overstressing or moisture effects in the numerical model.

3.7.6 General Geological/Geotechnical Simplifications

Simplification is at the heart of engineering design, in all fields. Materials are characterised by what are commonly termed as "*mass*" properties which provide a reasonable approximation of their general properties on a simplified basis. This is why both parameter back-calibration to known outcomes and parameter sensitivity analyses are an important part of numerical modelling, both being part of the Hume 3D numerical modelling study.

Furthermore, the 3D numerical modelling study was no more than an adjunct to the original ARMPS-HWM layout design work, the aim being to examine varying pillar load distributions over and above the single, albeit conservative loading case used within ARMPS-HWM. As such, the modelling is not and has never been relied on for design purposes in isolation from ARMPS-HWM, hence any geological/geotechnical simplifications within the model are immaterial to the overall suitability of the proposed mining layout, which remains fundamentally justified by reference to the geotechnical assessment and associated empirical and analytical designs presented in Mine Advice 2016a and 2016b.

3.8 No Pillar Design Method Can "*Guarantee Permanent*" Pillar Stability

GAPL 2020 introduces this concept in direct response to a statement made in Howarth and Associates 2020 that "*there is a general geotechnical acceptance that the overall pine feather pillar system and incumbent strata will remain permanently stable*" (underline added by author). By Russell Howarth's own admission in his report, which was repeated several times in GAPL 2020, he is not a geotechnical expert. Therefore, it is doubtful that the term was knowingly and intentionally used in the coal pillar design context that has seemingly prompted GAPL 2020 to respond in such a manner.

GAPL 2020 credits the idea that no "*respectable*" pillar design method can assure permanent pillar stability to a 1996 UNSW research report (Salamon ***et al*** 1996) from some 24 years ago. Two comments are made in direct response:

(i) it appears to the author that the statement was made as a general caveat due to limitations in coal pillar design methods as they existed in 1996. Irrespective of its intent though, it does not logically follow that remnant coal pillars post-mining will never be permanently stable, which could easily and wrongly be inferred from the discussion in GAPL 2020.

(ii) it is fair to state that coal pillar design within mining layout design methods, has developed significantly since 1996 via the inclusion of the additional stabilising role of pillar w/h ratio and critically, the role of overburden stability which had been overlooked prior to 1996. The inclusion of pillar w/h ratio in terms of pillar behaviour rather than strength, and overburden stability considerations in both ARMPS 2010 and ARMPS-HWM from the US, was critical in the decision to utilise the latter for developing web and barrier pillar layouts at Hume, the UNSW PDP being consistent with the state-of-the-art in 1996 rather than 2016.

Galvin 2016 uses the term "*permanent*" when discussing the service life of different coal pillars, albeit with no clarification as to how it may differ from that of "*long-term*". Therefore, the difference between long-term and permanent is not definitive based on Galvin 2016, long-term being the terminology used previously in both GAPL 2017 and 2018.

In terms of a "*guarantee*" not being able to be provided (i.e. a design Probability of Stability of 1), this is fully consistent with risk-based design principles where there is always some level of residual risk that a proposed design will not function as intended. As Galvin 2016 states "*Every factor of safety is a heuristic because it does not guarantee an answer. Rather, it competes with other possible values and it depends on time and context for its choice. Nevertheless, it is used because it reduces the effort needed to obtain a satisfactory answer*".

To the best of the author's knowledge, the lack of an absolute design guarantee has never before been a barrier to mining approvals being granted (or the engineering design of structures more generally), which are typically based on acceptable levels of residual design risk and the ability to subsequently manage such residual risk.

Whilst the idea that no pillar design method can provide a guarantee or assurance of permanent (i.e. without reference to a time-scale) pillar stability endures, it is also demonstrable that current state-of-the-art pillar and layout design methods are significantly more reliable than those that existed in 1996 for reasons already outlined. Therefore, it must also be true that the prudent and appropriate use of state-of-the-art methods from 2016 inevitably provides for significantly higher confidence levels in the outcome than was the case in 1996.

3.9 The Statement That "*Web Pillars Will Fail*"

If no pillar design method can guarantee permanent pillar stability, then it surely logically follows that a guarantee of coal pillar failure cannot be provided. Therefore, it is considered that Canbulat 2020 is in error in making this absolute statement and should be requested to retract it unless a credible stand-alone technical justification can be provided in support of it.

Making such statements is likely to unnecessarily install fear into lay persons, even if unintentionally, and as such is inappropriate language for both a professional engineer and geotechnical expert with an absolute responsibility to the community more generally.

3.10 Lack of Comparable Mining to Refer To

It is not in dispute that what is being proposed at the Hume Project is novel, and the layout designs have needed to be developed by reference to highwall mining rather than underground mining layouts. Therefore whilst it is true to state that similar layouts are not known in underground mining, substantial highwall mining experience from the USA is being utilised, as was described in detail in Mine Advice 2016a and 2016b initially, and further summarised in Section 2 of Mine Advice 2019.

Specifically, Mark ***et al*** 1997 outline a suggested design strategy for a "*containment*" approach to the formation of small underground coal pillars with low w/h ratio, based on US experiences with low w/h ratio (as low as 1) pillar failures in underground mining, the strategy containing two stipulations:

(i) limiting the span above the area of small pillars to assist in stabilising the overburden.

(ii) limiting the area of small pillars to reduce the damage potential should a collapse occur.

Specifically, they recommend limiting spans to no more than 90 m and compartment areas of no more than 1.2 hectares (12,000 m^2). In this regard it is noted that the proposed individual web pillar compartments at Hume are in the order of only 60% of these two suggested upper limits, the maximum span between barriers being 56.5 m (at 80 m cover depth) and each compartment area being no more than 0.68 hectares.

Whilst it is true to state that the UNSW has not developed holistic design guidelines within the UNSW PDP for preventing the failure of low w/h ratio pillars in underground mines (despite comparable failed examples being included within the UNSW failed cases database), such design guidelines were developed in the US over 20 years ago. The layout design process at Hume has taken full cognisance of these guidelines and applied them in a conservative manner as part of developing suitably prudent and robust mining layouts.

3.11 Protection of Critical Surface Infrastructure

The need to adequately protect critical surface infrastructure from significant impacts due to mining subsidence was an integral part of the mine layout design developed for EIS purposes.

Li 2020 recommends that subsidence due to the proposed mining layouts be measured in initial mining panels well prior to mining in proximity to critical surface infrastructure, this then being an invaluable input into the design of adequate protection pillars for said infrastructure.

The mining schedule at Hume commences in the north-western part of the proposed mining area, which is remote from any of the defined critical surface infrastructure. Therefore, the recommendation of Li 2020 in this regard can be readily applied at Hume, this being a prudent approach to the design of actual surface protection pillars later in the life of the mine.

3.12 Confirmation of Geotechnical Analyses for Plunge Breakaway and Intersection Roof Stability

Appendix D contains a copy of Mine Advice's geotechnical analyses pertaining to roof stability and roof support for plunge breakaways and intersections, as discussed in Howarth and Associates 2020. This is simply to confirm that despite the report not making mention of or including the Mine Advice report, such advice was indeed provided to Russell Howarth during his review.

4.0 SUMMARY OF OVERALL MINING LAYOUT DESIGN ANALYSES

In addressing the overall concern of the independent reviewers in relation to future web pillar stability, which seems to be at the heart of the majority of the issues being raised in relation to both mine safety and surface subsidence levels, Section 4 of Mine Advice 2019 will be largely reproduced herein, as it provides the most comprehensive overall explanation in this regard.

As a starting point, it is assumed that there is no major disagreement between the various parties that the Ground Reaction Curve (GRC) concept is useful, hence GRC representations will be developed for both the 80 m and 160 m deep designs to assist in providing all parties with a similar understanding of likely remnant mine stability.

The GRC concept (Figure 4.1) was originally developed in the early 1960's to assist tunnellers ensure that permanent, and often, stiff permanent tunnel linings were not damaged by excessive ground strains. This has since been applied by others to coal mining problems, such as tailgate standing support design and longwall shield design.

The ground curve (ABCD in Figure 4.1) contains a section of negative slope (ABC) initially whereby the overburden strata is incrementally losing its natural stability as a direct result of increasing vertical movement, followed by a section of positive slope (CD) whereby natural overburden stability has effectively been lost, with self-weight or dead-loading of kinematically unstable material then dominating overburden behaviour. The support response curve (PQR) contains an initially elastic response followed by some form of post-peak response to R. System equilibrium is achieved at point Q where the required support pressure to a certain contain convergence level, is generated by the support at that particular convergence level.

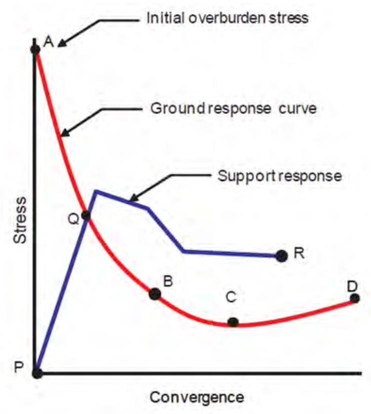

FIGURE 4.1. Generic Ground Reaction Curve (GRC) Representation

Figure 4.2 shows how a ground curve and pillar curve in this instance will be constructed from the available information; the following points of explanation being provided:

- Point A: tributary area stress on the centre web pillar.
- Point B: surface settlement in the centre of the web pillar compartment with all web pillars removed.
- Point C: *in situ* vertical stress acting on web pillars prior to mining

- Point D: overburden settlement required to drive the pillar to its peak strength (high stiffness roof and floor strata as assumed in LaModel)
- Point E: overburden settlement required to drive the pillar to its peak strength (low stiffness roof and floor strata consisting of defined thicknesses of coal)
- Points F and G: equilibrium conditions
- Line CD: stress-displacement response of a web pillar, pillar stiffness being based solely on an assumed E for coal of 2 GPa.
- Line CE: stress-displacement response of a web pillar, with pillar, roof and floor stiffness being based on an assumed E for coal of 2 GPa roof coal thickness of 3 m and floor coal thickness of 0.5 m, as per Mine Advice 2016b.
- Web pillar strengths have been assigned using the UNSW PDP Rectangular Power formula, as referred to by GAPL 2018 when raising the question as to web pillar probability of failure.
- The representation is for the centre web pillar only, the flanking web pillars inevitably being more stable than the centre pillar by virtue of being located closer to the adjacent intra-panel barriers within an otherwise sub-critical span.

It is noted that as system equilibrium is likely to occur before either the pillars or overburden exceed their elastic range, linear elastic parameters will be used, this assumption being further tested based on the analysis outcomes in terms of the indicated condition of both pillars and overburden at equilibrium.

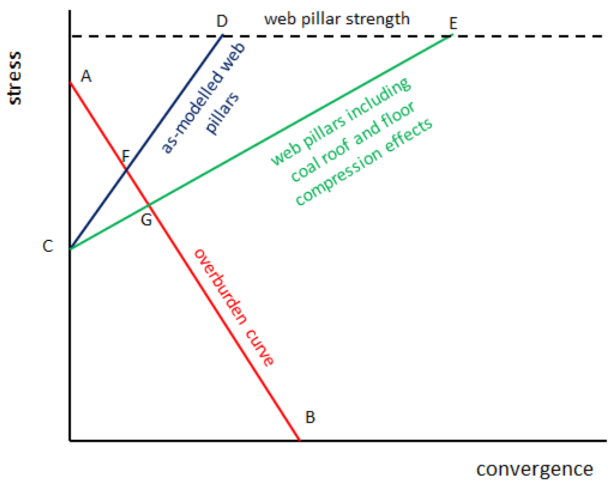

FIGURE 4.2. Schematic of GRC Representation Used

Most of the defined points within Figure 4.2 are self-explanatory and do not require explanation herein, however, Point B and the derivation of the Line C to E necessitate further discussion.

Point B is defined as the level of surface settlement that would occur if the vertical stress applied to the overburden by the web pillars is zero. Fortunately, LaModel was run for cover depths of 80 m and 160 m with all web pillars removed from the model, this being an exact simulation of this condition. Therefore, the returned values of S_{max} from each model will be used to fully define Point B.

Mine Advice 2016b provided details as to how surface settlements related to pillar, roof and floor compression were to be calculated, Mine Advice 2018 noting that it was only the coal pillar that was included in LaModel for the reason that the model could not include such detailed near-seam lithology. However in reality, it is actually beneficial to include the influence of lower stiffness (E) roof and floor strata in a GRC analysis, as it tends to reduce the stiffness response of the pillar to vertical compression, thereby resulting in system equilibrium being achieved at a lower level of pillar stress than with a stiffer pillar response, therefore returning a higher web pillar SF or FoS. The method for calculating roof, pillar and floor compression for any defined pillar stress level, will be as per that used in Mine Advice 2016b.

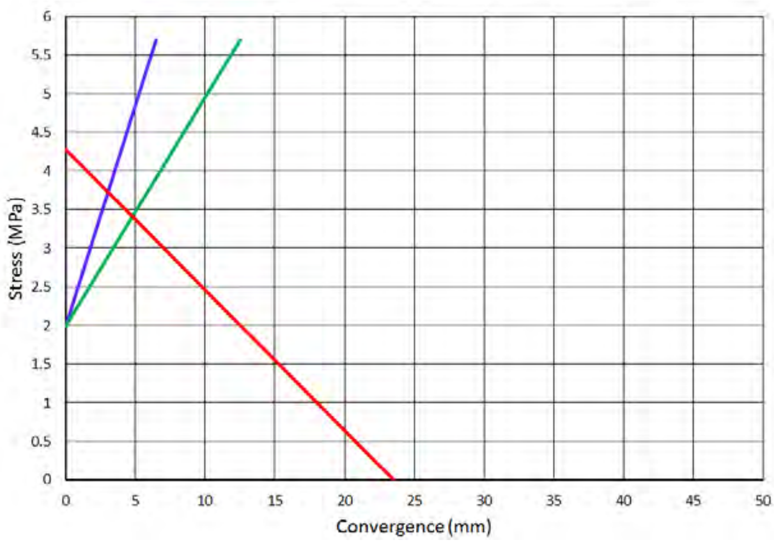

FIGURE 4.3. GRC Representation for 80 m Depth Layout Using UNSW PDP Strength Equation

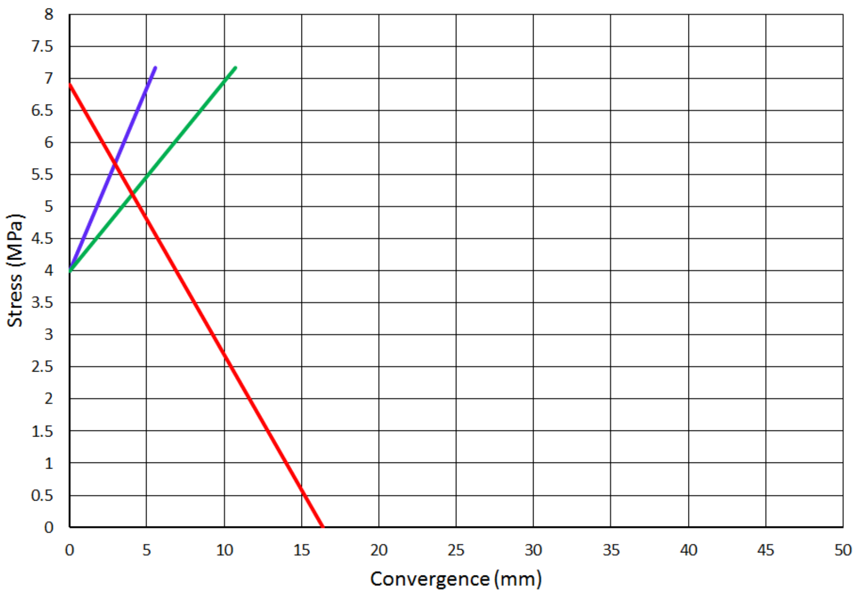

FIGURE 4.4. GRC Representation for 160 m Depth Layout Using UNSW PDP Strength Equation

Figure 4.3 shows the specific GRC curves for the 80 m depth layout based on the general representation of Figure 4.2. On the basis that the pillar curve that includes roof and floor compression effects (green line) is the most representative of actual conditions, it is found that at equilibrium (point G), surface settlement or overburden convergence is some 5 mm with the associated web pillar stress being 3.5 MPa, such web pillar loading being of lower magnitude than that indicated in the LaModel results due to the non-inclusion of coal roof and floor in those models.

It is noted that for the pillar only case, the equilibrium convergence is in the order of 3 mm whereas LaModel gave predictions in the range 2.1 mm to 2.4 mm, this variation relating to changing assumed overburden conditions.

With an equilibrium web pillar stress of 3.5 MPa and a web pillar strength of 5.69 MPa, the UNSW PDP FoS is found to be 1.63, this being exactly as per a PoF of 1 in 1000. However, when it is remembered that this only applies to the centre web pillar, it is self-evident that the PoF for the system of web pillars as a compartment between barriers, is less than 1 in 1000.

Figure 4.4 shows the specific GRC curves for the 160 m depth layout, again based on the general representation of Figure 4.2. It is found that at equilibrium (point G), surface settlement or overburden convergence is some 4 mm with the associated web pillar stress being 5.2 MPa, this again being of lower magnitude than that indicated in the LaModel results due to the non-inclusion of coal roof and floor in those models.

With an equilibrium web pillar stress of 5.2 MPa and a web pillar strength of 7.16 MPa, the UNSW PDP FoS is found to be 1.38, this having a PoF in the order of 2 in 100. Again, when it is remembered that this only applies to the centre web pillar, it is self-evident that the PoF for the system of web pillars within a compartment between barriers, is somewhat less than 2 in 100. Critically, as will be discussed later in this section of the report, in understanding the probability for web pillar failure the W/H ratio of the web pillar compartment also needs equal if not greater consideration, which at a depth of 160 m is only 0.32, this being a factor of 3 times less than the commonly used minimum W/H of 1 for the onset of FTA loading to surface.

With these GRC outcomes to-hand, a final overall summary can now be given justifying the credibility of the Applicants position in asserting that the proposed EIS mine layout designs are fit for purpose, in that they are suitably conservative and reliable in relation to both mitigating long-term environmental impacts following the completion of mining activities and safety risks during mining operations.

In summarising, the design outcomes and their implications in terms of the requirements of the EIS and associated peer review process that has been conducted by the two independent reviewers, it is firstly necessary to succinctly state the objectives and associated limitations of a mine layout design process at this stage of mine development, this context being critical when considering the suitability of the design outcomes.

All geotechnical design in underground coal mining, regardless of the risk being designed against, should cater for two distinct elements:

1. Pre-mining designs based on what may be termed as normal or typical geological/geotechnical conditions.

2. The operational management of those risks that cannot be quantified prior to mining, usually in the form of unknown or inadequately defined geotechnical conditions.

By definition, being able to successfully use element 2. during operations, requires that the manifestation of residual risks is sufficiently slow to allow operators to both identify and respond accordingly, this including both the occurrence of unexpected conditions associated with a fully formed-up design and the identification of significant geological anomalies that may render a proposed design as ineffective, the operational response being to then modify the design to be implemented, either in terms of the mine workings or artificial controls such as ground support. This process is known more generally as “strata management” and has been endemic to the Australian coal industry via a formalised system for around two decades.

With this in mind, it is stated that the mine layout designs proposed by Hume have been developed with these two distinct aspects in mind, including the inevitable sources of uncertainty involved in the design process, either related to geotechnical characterisation or implementation during subsequent mining operations, the primary focus at the EIS stage inevitably having been the layout design and associated environmental impacts under typical geological/geotechnical conditions.

The mine layout designs as being proposed by Hume have now been either initially designed or subsequently reviewed/tested by a range of methodologies, including:

- the ARMPS-HWM empirical method for the design of highwall mining layouts
- an assessment of individual coal pillars within the pillar system using the UNSW PDP strength equations
- 2D numerical modelling using LaModel
- 3D numerical modelling using LaModel
- a web pillar stability analysis under modified tributary area loading according to panel widths between intra-panel barriers using the UNSW PDP rectangular power strength formula
- a web pillar stability analysis using the Ground Reaction Curve method of analysis
- an assessment of post-mining overburden stability between barrier pillars using predicted overburden convergence against published case histories relating to measured surface conditions prior to known overburden collapses above standing mine workings.

The outcomes from each of the listed methods are summarised in Table 4.1, this then leading into a final holistic assessment of both remnant web pillar stability under assumed geological and geotechnical conditions, supplemented with operational management controls to effectively cater for residual risks that cannot be accounted for at the pre-mining design stage.

Stability Indicator	H = 80 m	H = 160 m
web pillar width (m)	3.5	5.5
web pillar w/h ratio	1	1.57
intra-panel barrier width (m)	14	20.9
barrier pillar w/h ratio	4	5.97
web pillar compartment span (m)	56.5	51.5
web pillar compartment W/H ratio	0.71	0.32
ARMPS-HWM SF web pillars under FTA Loading (design assumption)	1.68	1.31
ARMPS-HWM SF barrier pillars under FTA Loading plus Double Abutment Loading (design assumption)	2.69	2
ARMPS-HWM System SF	2.95	2.56
UNSW web pillar FoS under FTA Loading	1.33	1.04
UNSW barrier pillar FoS under FTA Loading	4.95	3.94
ARMPS SF web pillars under modified tributary area loading based on panel span	2.38	3.72
UNSW web pillar FoS under modified tributary area loading based on panel span	1.86	2.91
UNSW for web pillars at GRC Equilibrium Point	1.63	1.38
Overburden Convergence at GRC Equilibrium Point	5	4
Overburden Convergence Safety Factor (using an assumed critical convergence of no less than 100 mm)	20	25

Note: figures in red are linked to ARMPS-HWM, those in blue to UNSW strength equations considering pillars in isolation, those in green to modified tributary area loading of web pillars due to the span between barriers, and those in brown to the GRC analysis which includes certain numerical modelling outcomes.

TABLE 4.1. Summary of Relevant Web Pillar Stability Indicators, EIS Layout, Hume Project

The contents of Table 4.1 allow the following summary points to be made:

(i) the initial ARMPS-HWM designs (in red) were fully compliant with the requirements of this experience-based design method, and included several deliberately included or inevitable sources of design conservatism over and above the returned values of SF and w/h (e.g. setting minimum web pillar w/h = 1, setting minimum barrier pillar w/h = 4, limiting spans between barriers to 60 m, recognising that planned drive lengths were substantially < than in HWM, recognising the significant stabilising influence of the absence of an open cut highwall in the underground environment).

(ii) the application of the UNSW PDP strength equations to web pillars and intra-panel barriers individually (in blue), returned highly stable barrier pillars, but raised questions as to the likely stability of the web pillars due to the low FoS values returned under FTA loading to surface. In the absence of any ability to readily modify the loading of web pillars to account for the restricted spans between barrier pillars, this uncertainty drove the need to conduct more detailed modelling studies where the stabilising influence of both the overburden and the third-dimension could be brought into the stability analyses.

(iii) the numerical modelling studies were conducted by a world leading expert in the field and the main developer of the LaModel modelling package. This approach is judged to be fully consistent with world's best practice in terms of the use of numerical modelling in evaluating the stability of bord and pillar type mine layouts. The overburden characterisation used in the models was based on a back-analysis of known outcomes at the adjacent Berrima Mine, the modelling outcomes being fully consistent with the original ARMPS-HWM layout designs in terms of the overall interpretation of remnant mine stability. There was no identified need to modify the proposed mine layout to cater for any concerns over pillar loading distributions that emanated from the modelling runs.

(iv) an evaluation of web pillar stability in isolation from barrier pillars under modified tributary area loading according to the panel width between barriers and a W/H ratio of 1 defining the lower limit of super-critical or unstable overburden behaviour (in green), returned ARMPS SF values in excess of 2, thereby complying with the suggested "*prevention*" approach to massive pillar collapses outlined by Mark ***et al*** 1997, and web pillar FoS values in excess of 1.63, resulting in probabilities of failure under the UNSW PDP that are substantially < 1 in 1000.

(v) the stability assessment of centre web pillars using a Ground Reaction Curve approach (in brown), returned individual PoF values of 1 in 1000 at 80 m cover depth (FoS = 1.63) and 2 in 100 at 160 m depth (FoS = 1.38). When these outcomes for the centre web pillar are expanded to all of the web pillars within a web pillar compartment in order to generate a PoF for the web pillar "system", it is inevitable that the resultant PoF values are < 1 in 1000 given the substantial stabilising influence of intra-panel barriers on the remaining web pillars.

(vi) an overall system stability assessment using a Ground Reaction Curve approach (in brown), confirmed that at the point that equilibrium is achieved between the overburden and web pillars, the overburden between barriers is retained in a highly stable state, with SF values relating to predicted overburden movements as compared to critical overburden movements whereby overburden instability and collapse becomes likely, being in the range of 20 to 25.

The stability of the overburden above the web pillars, which is in fact the critical EIS and operational safety consideration, can be summarised from the GRC analysis as a combined function of (a) the stability of the overburden between the intra-panel barrier pillars and (b) the web pillars themselves. The two aspects are inter-related in that the web pillars act to reinforce and so stabilise the overburden via its own self-supporting ability, and the level of stability in the overburden acts to protect the web pillars from excessive vertical compression levels that could otherwise drive them to yield and eventual collapse. When the level of overburden stability is combined with web pillar system stability, it is inevitably concluded that the proposed layout designs meet the following design criterion:

> *"they are fit for purpose in that they are suitably conservative and reliable in relation to both mitigating environmental impacts and mine safety during operations"*

More to the point, the mine stability indicators that have been returned by these analyses are at least of the same order as would be applied to bord and pillar workings, albeit using a different pillar and roadway layout. This therefore addresses the need for previously worked areas of the mine to be accessed by persons for reasons of inspection and rejects emplacement.

With this outcome to hand, the final requirement is to provide high level commentary as to operational management processes.

Both the initial layout design process conducted as part of the EIS submission and subsequent review process, have highlighted a number of concerns that need to be included within the operational management process as part of ensuring that the intent of the mine layout design is always achieved in practice. Whilst it is inappropriate to develop an actual operational management plan and process at this stage of mine development due to the need to base it on a collaborative risk assessment process, key issues can at least be listed for completeness, as follows:

(a) ensuring that web pillar compartments are not directly influenced by major geological structures such as faults and dykes, this being due to the de-stabilising influence they can have on both coal pillars and in particular, the stability of the overburden.

(b) mapping of mine workings to identify such structures before the commencement of forming plunges in a given area, and potentially modifying the plunge layout to accommodate the presence of anomalous geological conditions.

(c) developing monitoring schemes that allow actual remnant mine stability to be tracked post-mining for both environmental impact and mine safety reasons. The current base-line surveys being conducted using GPS surveys is very encouraging in this regard.

(d) using best practice in terms of CM guidance during plunge formation, accepting that the major control of any impact of off-line drivage on stability, is limiting the number of drives between barriers so that irrespective of any off-line drivage, maximum coal recovery within any one web pillar compartment remains unchanged.

(e) the general requirements of operational strata management also apply, albeit that they are more focused on the safety of the mine workings in terms of changing conditions over time, which in itself may be used as a monitoring scheme for the stability of the overburden in already mined-out areas whilst ever access is available.

The final comment is a response to a statement made by Van Der Merwe 1999 when discussing the application of a Quadrant II mine design, as summarised in Figure 4.5:

> "*In Quadrant II the overburden is stable, although the pillars are unable to support the full weight of the overburden. This is potentially the most dangerous situation because there could be a false impression of stability when the OSR is not much greater than 1. The pillars will be stable for as long as the overburden remains intact; however the moment the overburden fails, the pillars will also fail. This may occur because of time-related strength decay of the stressed overburden, or when mining progresses into an area with an unfavourably oriented unseen joint set in the overburden. The closer the OSR is to 1, the more dangerous the situation".*

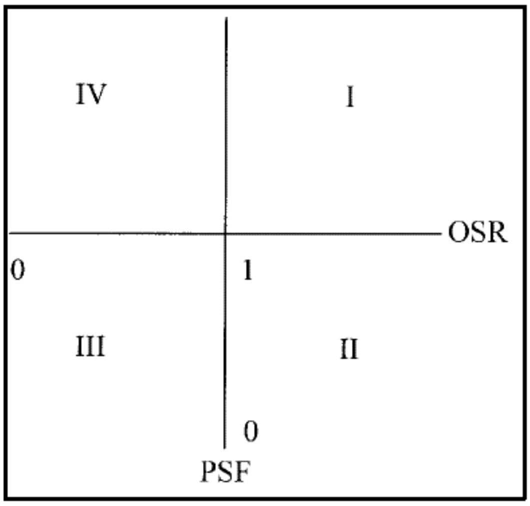

FIGURE 4.5. Plot of Overburden Stability Ratio (OSR) and Pillar Stability Factor (PSF) (NB values of <1 for either indicate imminent instability) – Van Der Merwe 1999

This statement by another of the world experts in the subject of pillar design and remnant mine stability, is fully encapsulated in both the understanding of the Applicant from the outset of the need to adopt a cautious approach to the design of the mine layout, and in particular the need to focus on stabilising the overburden by means other than the web pillars in isolation. The combined effect of the restricted spans between intra-panel barriers, the high stability of said barriers and the typical lithology of the overburden, is one of a highly stable overburden above web pillar compartments with a displacement-based Safety Factor against overburden instability in excess of 20. This is by far the most meaningful indication as to the level of design conservatism that is included within the proposed mine layouts at Hume, with the experts' technical debate in regards to web pillar stability in isolation being somewhat secondary in the overall scheme of things and certainly significantly out of context.

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APPENDIX A

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HUME COAL PTY LTD

Response to DP and E Assessment Report, Hume Project

FEBRUARY 2019

REPORT: HUME22/2

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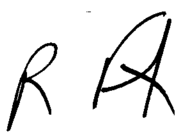
REPORT TO :	Alex Pauza Manager, Mine Planning Hume Project Hume Coal Pty Ltd
REPORT ON :	Response to DP and E Assessment Report, Hume Project
REPORT NO :	HUME22/2
REFERENCE :	Your Instructions to Proceed
PREPARED BY :	Russell Frith
REVIEWED BY :	Guy Reed and client's representative
DATE :	23rd February 2019



....
Russell Frith
Senior Principal Geotechnical Engineer

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EXECUTIVE SUMMARY

This report contains a series of technical responses to queries and questions raised in relation to the proposed mine layout design at Hume by NSW DP and E's two independent experts, Emeritus Professor Jim Galvin and Dr. Ismet Canbulat. Each have been addressed in detail and none are considered to be of sufficient significance to detract from the integrity and suitability of the mine layout design that was proposed by Hume Coal in its 2017 EIS submission. In fact, it would be fairer to state that having been required to address those concerns, the level of confidence in the proposed mine layout design being fit for purpose, has increased. Therefore, it is clear that the independent review process has been of significant value.

Unfortunately, this does not appear to manifest in DP and E's project assessment report whereby in Section 6.3 they conclude that:

> *"Notwithstanding the Department's considerable efforts to resolve disagreements between experts, there is a substantial degree of residual uncertainty about the mine design and the geotechnical model. In that context, the Department must adopt a precautionary approach to its assessment".*

This has undoubtedly arisen as many of those residual mine design and geotechnical model uncertainties relate to the 3D numerical modelling work undertaken by Emeritus Professor Keith Heasley, the specifics of which the proponent and Mine Advice only became aware of upon publication of the DP and E assessment report, neither having had the opportunity to address those concerns, either formally or informally, prior to this time. In this sense, it is without question that DP and E's conclusion in this regard is premature, as it is fundamental to any peer review process that a proponent is given the opportunity to address issues raised before a final determination. That this hasn't occurred is extremely concerning.

Details of the author's responses to the "core" issues raised in the most recent independent expert review reports are contained herein and so will not be repeated in this summary. However most were either academic arguments about detailed technical issues, or mis-understandings on the part of the independent experts that have now been considered and clarified. Nothing raised has resulted in Mine Advice modifying its position on the proposed mine layout design, which as a professional consulting company maintaining substantial professional indemnity insurance, it would be required to do if it became aware that there were fatal flaws in what it was proposing. The original layout design as contained in the EIS submission, has now fully withstood two independent reviews commissioned by DP and E and a substantial 3D numerical modelling exercise conducted by an overseas expert. Therefore, Mine Advice remains fully resolved that the proposed layout design is fit for purpose and that the geotechnical model that supports it is as robust as can be achieved in practical terms at the pre-mining stage.

The author accepts and has always maintained that there are a number of management issues to be addressed and implemented in operations, in order to ensure that any significant deviations from the assumed conditions under which the general mine layout was developed, are identified and the mining layout and/or process modified to suit. This general process is endemic to all underground coal operations in NSW and Australia, where geological and geotechnical uncertainty cannot be eliminated at the pre-mining design stage, irrespective of how much exploration data and design work is conducted. No residual risk issue can be identified at Hume that is not amenable to this type of operational management process, which ensures that the as-formed mine layout design is fully fit for purpose in terms of both short to medium term requirements during mining operations, and the long-term requirements of on-going remnant mine stability for environmental reasons. The fact that the required detailed risk assessments and associated management plans have not yet been developed, should not be seen as a shortcoming in the EIS submission, and is certainly not a valid reason to deny an approval to proceed to mining operations, albeit with associated approval conditions.

1.0 INTRODUCTION

This report contains the various responses to the NSW Department of Planning and Environment's (DP and E) assessment report relating to the Hume Project (DP and E 2018), the focus of this assessment being the contents of the two independent expert reports that were appended to that report by Galvin and Associates (GAPL 2018) and Dr. Ismet Canbulat (Canbulat 2018). It is noted that both independent experts submitted previous reports in response to Hume Coal's EIS submission (GAPL 2017 and Canbulat 2017), following which Hume Coal submitted a formal response back to DP and E (Hume Coal 2018) which included the results of a numerical modelling study examining the proposed mine layouts in more details (Heasley 2018) and interpretations thereof (Mine Advice 2018).

The purpose of this response is to address:

(i) The technical basis of the mine layout design, in particular all of the aspects that in combination act to maintain the stability of the mine workings, in particular the low w/h web pillars and so mitigate unacceptable environmental impacts.

(ii) To provide comment on each of the issues, raised by the two independent experts in their most recent reports, as they relate to the integrity and reliability of the proposed mine layout design.

(iii) Using (i) and (ii), to present an updated summary of the reasoning that supports the proponents contention that the proposed mine layout design is fit for purpose in that it is suitably conservative and reliable in relation to both mitigating environmental impacts and mine safety during operations.

Each of these will be described in detail as part of formulating a formal response to the most recent independent expert review reports.

2.0 TECHNICAL BASIS OF THE HUME MINE LAYOUT DESIGN

Over and above main headings and three heading production panel developments, the Hume mine layout consists of web pillar "compartments" containing what are termed as "plunges" or "drives" separated by narrow web pillars, with each compartment being separated by what are termed as "intra-panel" barrier pillars – Figure 2.1. It is the stability of the low width to height ratio (w/h) web pillars that has been the primary concern of the independent experts, hence it is the technical basis of their design and justification that is the subject of this section of the report.

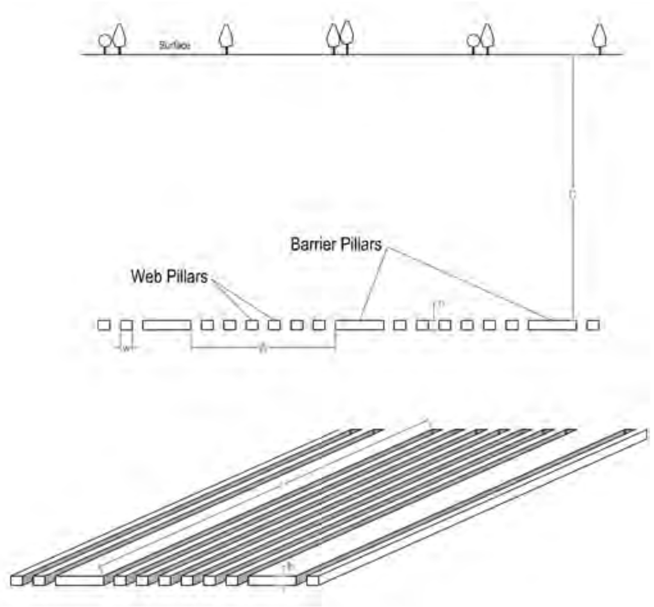

FIGURE 2.1. General Panel Features and Layout (Mine Advice 2016a)

It is accepted that for each compartment of web pillars to be considered individually, the various barrier pillars surrounding them need to be suitably stable. For demonstration purposes herein, this will be assumed to be the case, particularly as neither expert has raised major concerns in regards to barrier pillar stability.

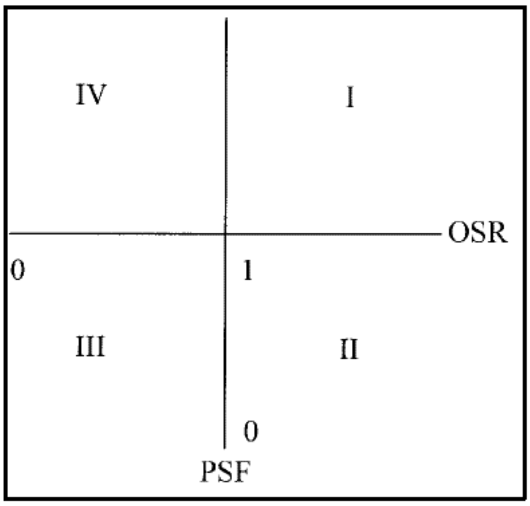

FIGURE 2.2. Plot of Overburden Stability Ratio (OSR) and Pillar Stability Factor (PSF) (NB values of <1 for either indicate imminent instability) – Van Der Merwe 1999

The design basis for the web pillars at Hume is one that includes the stabilising contribution of both the pillars themselves and most importantly, the overburden. This is not a new or novel layout design principle, the use of sub-critical spans between barriers in order to justify reduced pillar loadings and increased pillar stability between barriers having been previously recognised and addressed in both South Africa and the United States as part of other pillar design methods, as is now summarised.

Van Der Merwe 1999 presented a classification scheme (see Figure 2.2) to define the varying contribution to mine stability of both coal pillars and the overburden, the following descriptions being directly taken from that paper:

> *Quadrant I: both the overburden and the pillars are stable. This is the ideal situation for mains development.*
>
> *Quadrant II: the overburden is stable, although the pillars are unable to support the full weight of the overburden.*
>
> *Quadrant III: indicates a situation where both the pillars and the overburden will fail. This is the ideal situation for the snooks in pillar extraction. One wants both to fail in this situation.*
>
> *Quadrant IV: indicates that the pillars are able to support the overburden, even though the overburden may fail. This is also a safe situation, although gradual failure may occur over a long period as the pillars lose strength.*

This is a useful classification scheme as it outlines the four possible scenarios relating to remnant mine stability and the relative contributions of both coal pillars and the overburden. For example, empirically-based coal pillar strength determinations have been exclusively founded using case histories related to Quadrant IV, the idea being that by eliminating the self-supporting ability of the overburden, coal pillar loading at failure can be approximated by full tributary area (FTA) loading to surface, this then taken to be an indication of coal pillar strength in each case. The pillar strength equations of the University of New South Wales Pillar Design Procedure (UNSW PDP) are good examples of the outcome from such a process.

In contrast, the design of web pillars at Hume is consistent with either Quadrant 1 or Quadrant 2, which requires that the stabilising contribution of both the overburden and remnant web pillars be combined when determining a representative design Stability Factor (SF). The UNSW PDP does not provide any specific guidance in this regard, albeit that the various pillar strength equations can be applied under less than FTA even though FTA was the assumption used in their derivation. As stated by GAPL 2018:

> *"Once having derived the relationship between the 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 be equated to a probability of failure".*

The stability of the overburden and the consequent reduction in pillar loading was also brought into pillar design in the US (Mark 2010), based on the realisation that for deep cover, coal pillars within what was termed as the Active Mining Zone or AMZ (see Figure 2.3 from Mark ***et al*** 2011), this being the area of production pillars between barriers, were commonly over-designed under FTA loading to surface. Based on the analysis of stable and failed cases at higher cover depths, it was identified that quite a number of stable cases contained SF values under FTA loading conditions < 1 (see Figure 2.4). As a direct result, the width to depth ratio (W/H) of the AMZ was included in the pillar design process, with pillar loading under sub-critical AMZ conditions being reduced to less than FTA (see Figure 2.5).

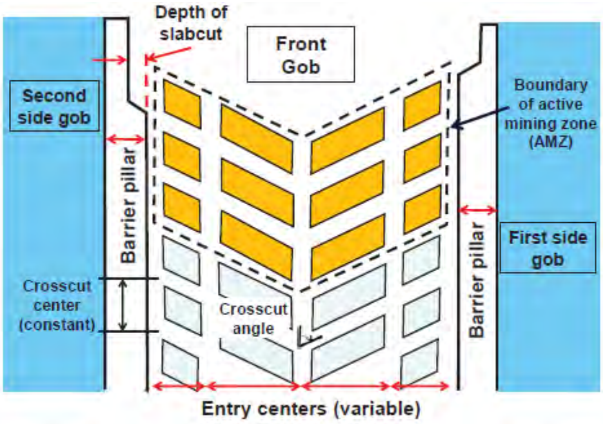

FIGURE 2.3. Geometry of Typical Retreat Mining Panel Showing the ARMPS Input Parameters (Mark *et al* 2011)

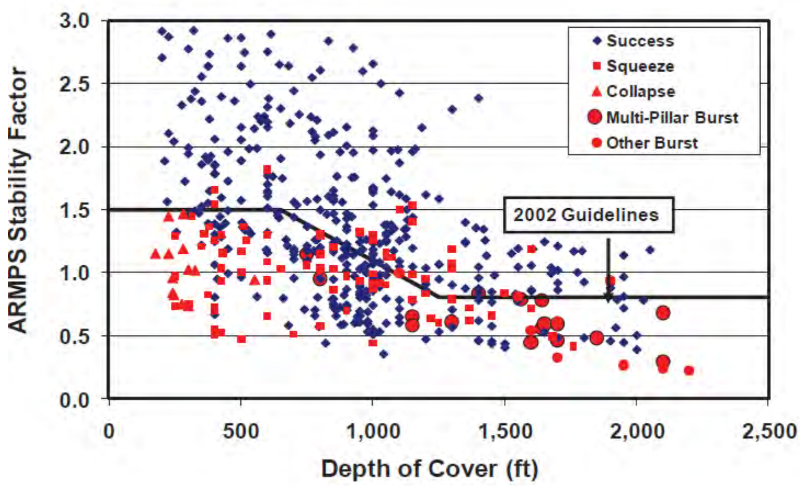

FIGURE 2.4. The 2010 ARMPS Deep Cover Data Base, Showing the Recommended ARMPS Production Pillar SF from the 2002 Deep Cover Study (Mark 2010)

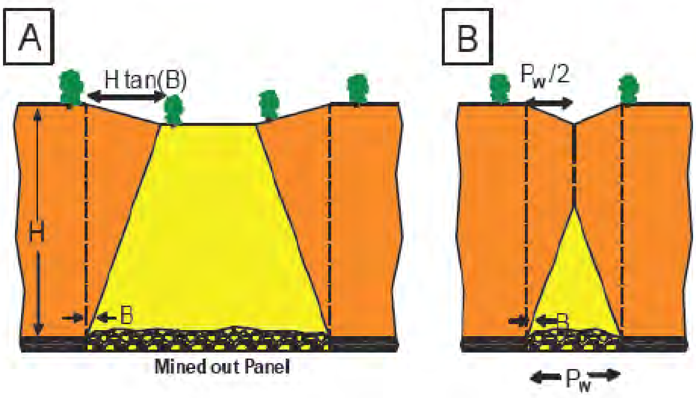

FIGURE 2.5. The "Abutment Angle" Concept Used to Estimate Loads in ARMPS (A) Supercritical Panel (B) Subcritical Panel (Mark *et al* 2011)

By including W/H as a pillar design consideration within the AMZ, the stabilising influence of the overburden was brought into the ARMPS design method and therefore used in combination with the stabilising influence of the coal pillars within the AMZ. This turned ARMPS from a Quadrant IV design method under the Van Der Merwe 1999 classification, to one that aimed to work within Quadrants 1 or 2.

This modification to ARMPS led to the realisation that for sub-critical AMZ conditions, the stability of production pillars within the AMZ and that of the adjacent barriers, became inextricably linked in that the production pillars could not collapse without the barriers also collapsing. This meant that the role of the barrier pillars was not simply to truncate a collapse of production pillars (this being the long-held definition of the role of barrier pillars), but to assist in preventing such a collapse in the first instance. This led to the development of a "system stability" design approach whereby the individual stabilising influence of both AMZ pillars and barrier pillars was combined, this approach being an integral part of the ARMPS-HWM method, as used to develop panel layouts for EIS purposes at Hume.

This concept was taken further by Frith and Reed 2017 and 2018, whereby based on both a conceptual model for the stability of the overburden as well as reference to published failed cases, a justification was presented for the coal pillar design problem being one where the coal pillars acted to reinforce rather than suspend the overburden (in the same way that the roof of mine roadways is reinforced by the action of roof bolts and long tendons). This is again consistent with the Van der Merwe 1999 classification, the suspension problem being Quadrant IV and the reinforcement problem being Quadrants I or II.

Frith and Reed 2018 outlined a general equation for the reinforcement of a mine roadway roof (based on that included in UNSW 2010) (Equation 1), as follows:

$$FoS = f\,(P_{roof}, P_{support})/\text{applied load} \qquad [1]$$

where:

FoS = a measure of stability

P_{roof} = contribution to stability from the roof strata itself (e.g. Coal Mine Roof Rating)

$P_{support}$ = contribution to stability from installed roof support (e.g. PRSUP)

applied load = horizontal stress in the case of roadway roof reinforcement

This basic equation manifests in the statistically significant empirical relationships published by Colwell and Frith 2009 and 2012 relating to primary roof support design in normal width and wider coal mine roadways respectively. It is also the foundation of the AMCRR Method as published by Colwell and Frith 2010.

Equation 1 can be modified for general coal pillar design as follows:

$$FoS = f\,(P_{overburden}, P_{pillar})/\text{applied load} \qquad [2]$$

where:

FoS = a measure of stability

$P_{overburden}$ = stability contribution from the overburden (linked to both the structural competence of the overburden and horizontal stresses acting as described in detail in Frith and Reed 2017)

P_{pillar} = stability contribution from coal pillars left in place

applied load = either horizontal stress or vertical stress based on the problem being reinforcement or suspension respectively (NB $P_{overburden}$ = zero represents the special case of full-tributary area loading to surface with the overburden being critically unstable, as per a Quadrant IV design problem).

There is little doubt that the general stability of mine workings within an AMZ (as previously defined) is a combined function of the stabilising influence of both the overburden between suitably designed and stable barrier pillars, and any remnant pillars that are left in place between such barriers. It has been recognised as such in South Africa, the United States and Australia for in the order of 20 years.

This approach was applied to the design of the low w/h web pillars and a suitable spacing between the intra-panel barrier pillars at Hume, both aspects being part of the ARMPS-HWM empirical design method (NIOSH 2012), which along with the general similarity between HWM layouts and those being proposed at Hume, is why ARMPS-HWM was selected as the primary EIS layout design methodology (Mine Advice 2016b). It also dictated the need to calibrate and include the geotechnical nature of the overburden within LaModel as part of the 2D and 3D numerical modelling exercises that further examined the stability of the proposed remnant mine workings (Heasley 2018).

With the overall design strategy for the low w/h web pillars being defined, it leads to the following three statements that need to be kept in mind when considering comments made by the independent experts and the associated responses herein, namely that:

(i) The stability of web pillars in isolation from barrier pillars, MUST be evaluated by considering the relative contributions of both the web pillars and the overburden within the span between barriers.

(ii) If the stabilising influence of the overburden is ignored in the mine stability assessment, then the stability of the low w/h web pillars MUST be combined with that of the adjacent barrier pillars as part of a pillar "system" stability approach.

(iii) Only if it can be demonstrated that the overburden between intra-panel barriers is likely to be critically unstable to surface (i.e. fully super-critical), as per the approach used by UNSW when selecting failed cases so that FTA loading to surface could be reasonably assumed, should the stability of the low w/h web pillars be considered in isolation from any other stabilising influence (i.e. the adjacent barrier pillars or the overburden).

This then provides the necessary background context to allow the reader to better understand (a) the reasoning for the various responses to concerns raised by the independent experts in their most recent reports (Section 3), and (b) the further explanation as to why the proponent believes that the proposed layout designs are generally fit for purpose in terms of reducing the risks associated with environmental impacts and mine safety during operations, to acceptably low levels (Section 4).

3.0 RESPONSES TO CONCERNS RAISED BY THE INDEPENDENT EXPERTS

Both of the independent expert reports have been reviewed and responses are provided herein on a point by point basis for clarity purposes. The two reports will be addressed separately noting that as GAPL 2018 is addressed first, some of the associated responses also address concerns raised in Canbulat 2018.

3.1 Galvin and Associates

3.1.1 Core Issue #1 – Numerical Modelling

3.1.1.1 Extreme Ranges of Pillar Sizes and Shapes

"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".

This has always been understood and so is accepted. It is for this reason that the design studies have included ranges of pillars loads in order to better understand the sensitivity of mine stability to such variations. The EIS layout design report (Mine Advice 2016b) considered two extreme pillar loading conditions, and the more recent numerical modelling studies included sensitivity analyses related to varying overburden stiffness for exactly the same reason. A primary control of pillar loading distribution is the stability and stiffness of the overburden between barrier pillars, the layout being deliberately designed to ensure that low w/h ratio web pillars are loaded by a reasonably stable and stiff rather than unstable and relatively soft overburden system. In this way, the stability of the web pillars is far less sensitive to pillar loading variations than might otherwise be the case.

3.1.1.2 Web Pillars Going into Yield

"*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*".

This statement seems to suggest that it may not be possible to satisfy this statutory requirement (taken from the NSW Regulations rather than the Act) for the low w/h web pillars by virtue of the reviewer's on-going stated concern that said web pillars may yield. It is noted that the "role" of the web pillars has been repeatedly defined as being part of a larger pillar system, hence it would logically be argued that the probability of instability of any web pillar is inextricably linked to that of the broader pillar and overburden system. Therefore, there is no obvious inevitable impediment that can be identified that would prevent Hume Coal from meeting this statutory requirement during mining operations.

3.1.1.3 Operational Safety

"*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*".

A statement made in GAPL 2017 provides a suitable summary of the proponents position on this issue, namely that "*…on this occasion and as advocated in the EIS, the restricted web panel spans associated with the Hume Coal Project might remove the risk of uncontrolled collapse of web pillars that comply with as-designed dimensions. Consideration still needs to be given for the potential for uncontrolled failure of undersize web pillars and pillars adversely affected by geological structure*". The issue of both the inadvertent formation of undersized web pillars and the de-stabilising influence of geological structures (on both coal pillars and the overburden) will be commented on later in the report. Suffice to state that both threats were recognised from the outset and are related to operational management, rather than the process of justifying a general mine layout under what may be termed as "normal" or "typical" geological conditions.

3.1.1.4 Imbedded Uncertainty in the Mark-Bieniawski formula

Four queries were raised under this heading, as follows (the numbering being as per the review report):

> *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?*

The reason for this series of queries is not clear nor is its relevance, as the Hume layout design does not ever rely upon the Bieniawski formula, nor the SF recommendations associated with its use as recommended by Bieniawski and quoted by the reviewer. It would appear that the reviewer is primarily interested in the knowledge of the author as to the specific statistical differences between the two stated pillar strength formulae. The author is not aware that such detailed knowledge of the historical development of coal pillar strength formulae is a mandatory pre-requisite for the use of such formulae for design purposes as part of a formal and published design process such as ARMPS-HWM. However, the basis of the queries will be addressed generally as follows.

The Mark-Bieniawski formula as a credible pillar strength formula for use within an empirically-based design methodology is presumably not being questioned by the reviewer. The formula is intrinsic to both the ARMPS-HWM and ARMPS pillar design methods, the latter of which is based on the back-analysis of some 692 case histories from 127 different coal mines covering all US coalfields and 67 different coal seams - see Figure 2.4 (Mark 2010). In contrast, the development of pillar strength equations by the UNSW was initially based on 14 collapsed and 16 stable cases, with the combined Australian and South African database as also analysed by UNSW, consisting of 116 stable cases and 61 failed cases (Galvin ***et al*** 1999). In other words, the general suitability of the Mark-Bieniawski formula has been empirically evaluated by reference to the largest single coal pillar database in the world and found to provide meaningful design outcomes according to its developer, Dr Chris Mark.

The UNSW pillar strength equations (based on 14 'collapsed case' data points) are relied upon by both Galvin and Associates and Dr. Canbulat in arriving at various conclusions in their reviews. However in his second report, Dr. Canbulat argues in relation to laboratory test data for Hawkesbury Sandstone at Hume, that a set of some 25 data points is "*insufficient for making accurate conclusions and decisions for the entire mine*". Since the introduction of the UNSW pillar strength equations two decades ago, to the best of the authors knowledge no comprehensive study has ever been undertaken to confirm or update the Probabilities of Failure associated with these formulae by analysing design vs actual outcomes, yet in the United States such a process has been on-going.

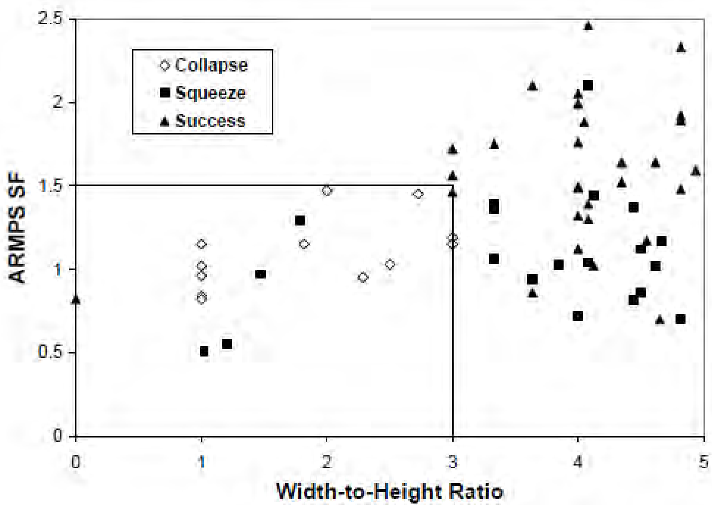

FIGURE 3.1. Pillar Collapse Case Histories from the US: ARMPS SF and width-to-height Ratio (Mark 2006)

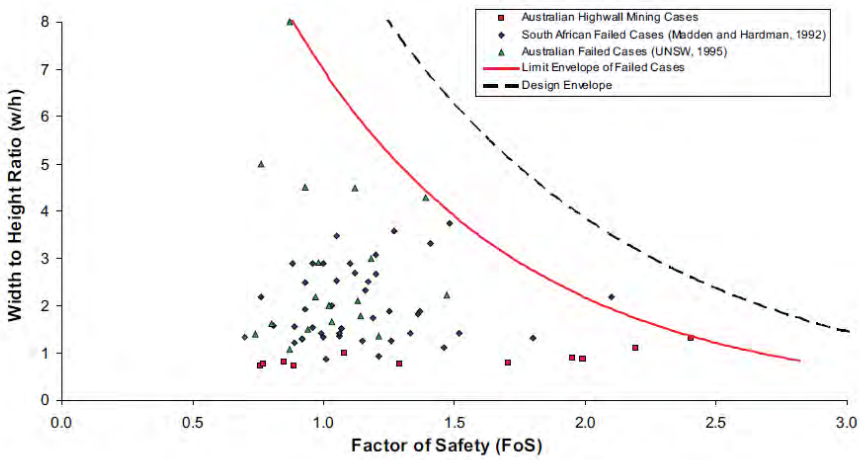

FIGURE 3.2 Database of Pillar Collapses – Width to Height Ratio v FoS (Hill 2005)

More generally, uncertainty in the accuracy of any pillar strength formula is addressed by the use of case history databases in determining suitable design recommendations and if possible, associated levels of design uncertainty. As both the pillar strength formula and the supporting databases vary from method to method, design recommendations in terms of SF and uncertainty levels cannot and should not be transferred between methods. This was understood from the outset when developing the Hume layout design guidelines.

It is also understood that the Mark-Bieniawski formula is typically used in conjunction with the w/h ratio of the pillar when designing against pillar collapses. As illustrated in Figure 3.1 and discussed by Mark 2006, all massive pillar collapses in the US can be characterised as having an ARMPS SF < 1.5 and a w/h < 3. He also notes that pillar collapses in South Africa all had w/h values < 4, which is generally true of the Australian cases as outlined by Hill 2005. Therefore, if pillars were to be designed with an ARMPS SF > 1.5 and w/h > 3, it could be reliably stated that there was no precedent for a massive pillar collapse for pillars designed to these two conditions within the ARMPS database consisting of > 600 case histories. A broadly similar statement can be made in relation to both the South African and Australian databases as presented in Figure 3.2, whereby it is clearly evident that the use of FoS and w/h ratio as a combined design criterion, provides for far more reliable design against pillar collapse, than FoS in isolation.

In answering the key question posed as to whether any uncertainty should be carried over, the answer given is “yes”, but on the strict proviso that pillar design also includes due consideration of pillar w/h ratio and overburden stiffness (as outlined in Section 2), rather than solely relying on calculated pillar stability in isolation.

The reviewer’s disagreement with combining pillar SF (or FoS) and w/h ratio into a broader-based pillar stability design criterion is known, and duly acknowledged (based on Galvin 2006). However Mine Advice’s position on this issue is fully consistent with that of Dr Chris Mark as the primary developer of ARMPS and ARMPS-HWM, as explained in more detail via the technical arguments outlined in Reed ***et al*** 2016.

3.1.1.5 Strength of a Low w/h Ratio Pillar Based on the Mark-Bieniawski Formula

Three queries were raised under this heading, as follows (the numbering being as per the review report):

> *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)?*

The basis of the queries is assumed to relate to how to apply the various pillar strength equations according to the numerical modelling outcomes and also the inclusion of pillar length in the Mark-Bieniawski pillar strength equation as outlined in Table 2 of GAPL 2018 and the associated commentary (re-produced herein).

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 %

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.

The first point to make in addressing these queries is that pillar length was introduced into pillar strength equations due to the recognition that the early strength equations such as those from Salamon and Munro 1967 and Bieniawski 1983, were either founded on databases of predominantly non-rectangular pillars, or the *in situ* testing of predominantly non-rectangular sections of coal. This was judged to result in such equations under-estimating the true strength of distinctly rectangular coal pillars, which resulted in both the UNSW and Chris Mark independently including pillar length in new strength formulations, as is evident in Table 2 from GAPL 2018. In other words, it should clearly be the case that a long rectangular pillar is stronger by some amount than a square pillar of the same w/h ratio. It is assumed that this general concept is not in dispute.

The manner by which pillar length was incorporated into their pillar strength equation(s) by Salamon and Mark-Bieniawski, varied. As stated by the reviewer, "*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)*". To the best of the author's knowledge, this judgement on the part of Salamon has never been independently proven, but simply incorporated without question by UNSW into their rectangular pillar strength equations.

Mark and Bieniawski adopted a different technical approach, but again did not independently verify the accuracy of their method in the real world, other than by incorporating the resultant pillar strength equation into ARMPS and later ARMPS-HWM and reporting the outcomes of the database analyses, which included design recommendations in terms of SF etc.

It is therefore surely a matter of academic argument as to whether the judgements of Salamon or Mark/Bieniawski result in the more realistic incorporation of pillar length into pillar strength equations, such debate being well outside the domain of an EIS application and associated peer review process.

In terms of the specific queries, the following responses are provided:

> Query 4: the short answer is "no" as even though the numerical modelling study returned lower web pillar loading values than assumed by ARMPS-HWM for design purposes (which was based on the application of FTA Loading), all of the web pillar SF design outcomes from ARMPS-HWM are 1.3 or greater, as described in Mine Advice 2016b, a web pillar SF of 1.3 under FTA being the minimum design value under this method for the specific condition of the distance between intra-panel barriers being 60 m or less. Even when applying the UNSW Rectangular Power formula as was included in Mine Advice 2016b, the FoS of web pillars never falls below 1 under FTA loading.
>
> Query 5: as stated previously, the Bieniawski recommended design values have never been incorporated into the Hume layout design process. ARMPS-HWM provides specific SF design values for the web pillars, barrier pillars and overall pillar system stability that are based on the back-analysis of the US HWM database. Therefore, the query is unfounded and indeed makes no sense, as it would be totally inappropriate to modify design SF values related to the Bieniawski strength equation in this way due to the use of a different, albeit related pillar strength equation, particularly given that a HWM mining layout is fundamentally different to a bord and pillar layout, this being the assumed basis for the reviewers selection of an SF of 1.5 as the base value.
>
> Query 6: the first point to make is that it is assumed that the reviewer means probability of "instability" or failure rather than probability of "stability" in the query. Secondly, the source of an FoS of 1.55 corresponding to a minimum probability of <u>instability</u> of 1 in 1000 is not obvious to the author. Galvin 2016 provides data tables that state that for a PoF of 1 in 1000, the associated UNSW FoS is 1.85 for their linear formula and 1.63 for their power formula. In terms of there being a "*common standard*" for coal pillar failure probability in NSW, the author is unaware of any such standard or even guideline. It is assumed that the reviewer is actually referring to a probability of failure of 3 in 1000, which as stated in Galvin 2006, "*it is general practice in South Africa and Australia to design panels to have a minimum probability of failure of around 3 in 1000, which typically equates to a power law safety factor of 1.6*". "General practice" does not constitute a "standard" and there is no such stipulation in either the NSW Regulations, the NSW Strata Control Code of Practice or any other industry publication to the best of the author's knowledge. However, it is accepted that this may be a common informal criterion applied by the NSW inspectorate when reviewing pillar design applications based on the use of the UNSW PDP.

In more general terms, as the design basis of the Hume Coal layout was a combined function of pillar stability and overburden stability between barriers, this resulting in a "pillar system design approach" as was generally agreed by all experts at the meeting held on 28th March 2018, any application submitted to the NSW inspectorate relating to the formation of web pillars at Hume would inevitably not be based on the FoS or SF of said web pillars in isolation. Moreover web pillars would be included as one component of a larger pillar and overburden system whereby both the stability of barrier pillars and that of the overburden above web pillars was also included, this allowing their true probability of failure to be assigned a substantially higher value than that based on the application of the UNSW PDP to the design of web pillars in isolation, as being assumed in the query.

Nonetheless, an updated analysis of web pillar stability using the results of the numerical modelling and the UNSW PDP strength equations will be detailed in Section 4 of this report, in order to provide the most up to date numerical modelling interpretation.

3.1.1.6 Pillar Constitutive Law

A single query was raised under this heading, as follows (the numbering being as per the review report):

> 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?*

This query by the reviewer again invokes the idea that the stability of web pillars needs to be evaluated individually, whereas as was stated as part of the EIS submission and subsequent responses by the proponent to earlier independent expert reviews, the design of the web pillars is as part of a larger pillar system which includes the stabilising contribution of both the overburden and adjacent barrier pillars. Therefore, the basis of the query is generally rejected by the author as it is inconsistent with the fundamental basis of the layout design strategy being applied.

Furthermore, the reason that 3D numerical modelling was undertaken by the proponent was to allow a better appreciation of the likely load distribution between the various pillars in the pillar system, this being an adjunct to, rather than alternative to the use of the 2D ARMPS-HWM as the primary layout design methodology. It also allowed the inclusion of the stiffness of the overburden based on geomechanical properties, whereas ARMPS-HWM was restricted to limiting the distance between intra-panel barriers in order to stabilise the overburden without consideration of the overburden type and its contribution to web pillar stability.

This query also leads to the issue of average pillar stress vs pillar stress distributions when evaluating coal pillar stability, which is a fundamental difference between empirical design methods and the associated pillar strength equations (which work to average pillar stress), and numerical modelling (which due to the need to discretise the pillar into elements, both vertically and horizontally, means that the model will develop vertical stress distributions within each pillar, this adding an additional level of analysis complexity, over and above the use of empirical methods).

The Mark-Bieniawski pillar strength formula has been incorporated into LaModel by Emeritus Professor Heasley with full knowledge of this difference in pillar loading approach. In his report he explains the logic by which the transition from a pillar strength equation based on average pillar stress, to a numerical model that generates vertical stress distributions within each pillar, was formulated and justified.

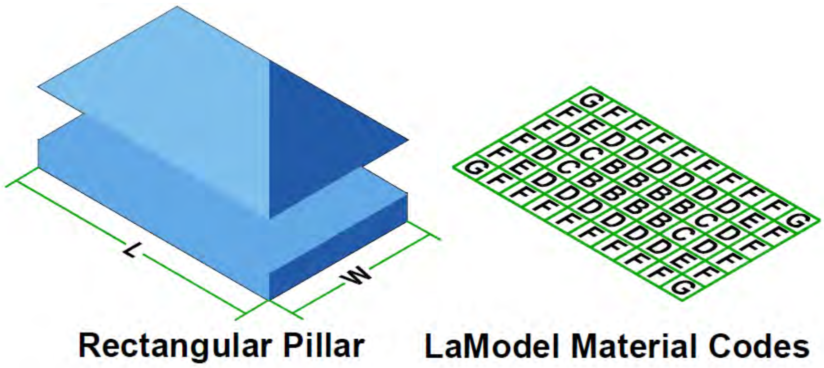

FIGURE 3.3. Schematic of Pillar Load and LaModel Element Mapping (Heasley 2018)

The reason for the inclusion of an elastic-plastic constitutive law for coal pillar behaviour in LaModel, was not to eliminate coal pillar yielding, but to allow the full peak-loading profile of each pillar to be generated at the point that peak pillar strength is achieved (see Figure 3.3), as also used in the derivation of the Mark-Bieniawski strength equation. As the outer elements of a pillar have lower defined peak loading levels than those within the inner section of the pillar (see Figure 3.3), a modelling mechanism is required to allow all elements of the pillar to attain their peak loading values at the same juncture, this then defining the pillar reaching its peak strength or maximum possible loading condition. The use of a strain-softening constitutive law for the behaviour of coal pillars in LaModel would prevent this from being simulated in the model and so act to substantially reduce the peak strength of each pillar, thereby rendering the model unable to apply the Mark-Bieniawski pillar strength equation and generate meaningful pillar SF values.

In terms of ensuring that the modelling was not in any way influenced by the lack of a strain-softening constitutive law for the web pillars, a review of individual SF values was conducted, this being to demonstrate that the SF values returned were sufficiently high so that web pillars remained well within the initial elastic portion of the stress/strain curve overall. The 3D models showed that at a cover depth of 80 m where the W/H ratio of the panel between barriers is at a maximum (0.7), the average web pillar SF is in the order of 1.8 to 1.9. For a cover depth of 160 m where the W/H value is at its lowest level (0.32), the average web pillar SF is lower at 1.43 to 1.46, all clearly remaining within the elastic portion of the pillar stress/strain curve.

Overall, the entire premise of the query is judged to be flawed in that (a) the use of an elastic-plastic constitutive law is specifically required for LaModel to produce outcomes that are consistent with the Mark-Bieniawski strength formula at peak pillar loading prior to any onset of yield or failure, and (b) as a result of (a) LaModel cannot evaluate post-peak pillar behaviour in a meaningful manner without corrupting the simulation of the peak strength condition of the pillar. Furthermore, the stated web pillar design basis remains that they must be treated as part of a larger pillar system, with the stability of the adjacent barrier pillars, which are acting to stabilise the web pillars by virtue of the restricted span between barriers, being well beyond any legitimate concern in regards to pillar yield.

In terms of the final comment made by the reviewer in that the numerical models may need to be re-run for the reasons stated, a response to this will be deferred until Section 4.

3.1.2 Core Issue #2 – The Pillar System

The section of GAPL 2018 discussing "the pillar system", raises three general "residual" issues that the reviewer has requested be addressed:

(i) Whether stability/instability of the web pillars poses any significant threat to the safety in the mine workings during operations or not?

(ii) The potential for safety threats associated with (i) to manifest either as a rapid pillar collapse, and/or (ii) a more gradual yielding in a controlled and non-violent manner.

(iii) Concern over uncertainty in the ability of the overburden to span between intra-panel barriers based on geological variations.

Each will be addressed in detail

3.1.2.1 Threat of Web Pillar Instability to Operational Safety

There is no doubt that the occurrence of a rapid and uncontrolled pillar collapse in an underground mine represents a significant safety threat to persons via either being trapped/directly impacted by the collapse or via any associated windblasts that propagate through the mine. This is far more so than the planned collapse of the overburden in a total extraction longwall panel for example due to the large plan areas of collapse that are commonly involved with pillar collapses.

Table 1.—Massive pillar collapses in coal mines

Case history	State	Depth, m (ft)	Pillar size, m (ft)	ARMPS SF	w/h ratio	Collapsed area, ha (acres)	Collapse size, m (ft)	Damage from airblast
A	WV	84 (275)	3 by 12 (10 by 40)	0.86	1.05	2.3 (5.7)	150 by 150 (500 by 500)	26 stoppings, 1 injury.
B1	WV	73 (240)	3 by 12 (10 by 40) 3 by 18 (10 by 60)	0.96 1.10	1.00 1.00	–	–	32 stoppings, fan wall out.
B2	WV	75 (245)	3 by 12 (10 by 40)	0.94	1.00	1.7 (4.1)	100 by 150 (350 by 500)	40 stoppings.
B3	WV	85 (280)	9 by 9 (30 by 30) 6 by 12 (20 by 40)	1.46 1.47	3.00 2.00	2.8 (6.8)	180 by 180 (600 by 600)	70 stoppings.
C1	WV	60 (195)	3 by 12 (10 by 40)	1.19	1.00	2.1 (5.2)	140 by 150 (450 by 500)	103 stoppings.
C2	WV	99 (325)	9 by 9 (30 by 30)	1.15	3.00	1.9 (4.8)	100 by 180 (350 by 600)	Minimal.
D	WV	69 (225)	6 by 6 (20 by 20) 9 by 9 (30 by 30)	1.15 1.42	1.82 2.73	1.7 (4.3)	100 by 160 (350 by 540)	37 stoppings.
E1	WV	91 (300)	3 by 12 (10 by 40)	0.79	1.42	7.4 (18.2)	240 by 290 (800 by 950)	Major damage.
E2	WV	91 (300)	3 by 12 (10 by 40)	0.71	1.11	6.7 (16.6)	220 by 275 (720 by 900)	Major damage.
F	OH	76 (250)	2 by 12 (7 by 39)	0.66	2.12	2.0 (4.9)	90 by 215 (300 by 700)	Minimal.
G	UT	168 (550)	12 by 12 (40 by 40)	0.95	2.29	7.9 (19.4)	150 by 490 (480 by 1,620)	Major damage, 1 injury.
O	WV	–	–	1.03	2.50	1.8 (4.5)	120 by 150 (400 by 500)	–
R	CO	120 (400)	4 by 24 (12 by 80)	0.57	1.71	2.8 (6.8)	180 by 150 (600 by 500)	Minor damage.

NOTE.–Dash indicates no data available.

TABLE 3.1. Massive Pillar Collapses in Coal Mines (Mark *et al* 1997)

Mark ***et al*** 1997 summarise a number of pillar collapses from the US, including the plan area that was involved (see Table 3.1), the range being 1.7 to 7.4 hectares or 17,000 m^2 to 74,000 m^2, all of which are substantially lesser in area than the infamous pillar collapse at Coalbrook in 1960, the major collapse covering an area of some 324 hectares or 3,240,000 m^2. The Mark ***et al*** 1997 paper provides summary descriptions of several "smaller" (in the order of 2 hectares) events in the US whereby whilst no-one was killed, persons were injured from being blown over and there were significant disruptions to mine ventilation.

There is no debate as to whether a rapid and uncontrolled pillar collapse in any underground coal mine is a tolerable safety threat, the layout design requirement being that the likelihood of one occurring must be reduced to the lowest practical level (ALARP).

In terms of gradual or controlled web pillar yield, which might also be termed as a “creep” or “squeeze”, there are a number of known examples in both Australian mines and overseas that can be referred to in terms of assessing the resultant safety threats. To the best of the author’s knowledge, whilst pillar creeps have rendered certain areas of mines as inaccessible and unsafe, no person has ever been significantly injured or killed as a direct consequence, the primary associated risks being either loss of coal reserves or loss of equipment.

In essence, the safety threats associated with a pillar creep or squeeze are highly amenable to being effectively managed through the formal operational management process, whereas it is far less certain when the pillar failure mode is rapid and uncontrolled, the latter therefore being the primary safety focus.

3.1.2.2 Impact of the Rate of Pillar Instability on the Safety Threat

The GAPL review appears to be accepting that the proposed Hume layout design generally meets the requirements of mitigating the impact of mining at surface to acceptable levels, the focus of their review shifting to workplace safety, which was not described in the EIS, the purpose of an EIS being an environmental assessment rather than a mine safety assessment. It is judged to be logical that if a mine has been designed to be long-term stable, the safety threat posed by a pillar collapse during mining operations should already be effectively catered for. Nonetheless, the concern will be addressed in further detail herein.

The question in relation to safety in the workplace rather than surface impacts, is whether the web pillars, in isolation from barrier pillars, can undergo a rapid and uncontrolled collapse or not, either during or subsequent to mining operations in any given production panel. There is no argument that with w/h ratios in the range of 1 to 1.57, web pillars are of sufficiently low w/h to allow such an event <u>should the necessary pillar loading conditions eventuate</u>.

Mark ***et al*** 1997 provide details of a number of such events within US underground coal mines associated with the formation of comparable w/h ratio remnant pillars, as summarised in Table 3.1.They also provide a summary description of those collapsed cases as follows:

- The ARMPS SF was < 1.5 in every case and less than 1.2 in 81% of the cases (it is assumed that this relates to FTA loading of the collapsed pillars)
- Pillar w/h values < 3
- Overburden judged to be “strong” in every case
- The minimum dimension of a collapsed panel suffering major damage was 110 m, with the minimum collapsed area being 1.6 ha.

In addition, the author notes that the minimum dimension of any collapsed case was 90 m at a cover depth of 76 m, with the general W/H ratio of collapsed areas being between 1 and 2.64, albeit ignoring the case from Mine G, which as described in the paper was influenced by overlying workings which are not relevant to Hume.

Mark ***et al*** 1997 outline a suggested design strategy for a "*containment*" approach to the formation of small pillars with low w/h ratio, which is based around two stipulations:

(i) Limiting the span above the area of small pillars to assist in stabilising the overburden.

(ii) Limiting the area of small pillars to reduce the damage potential should a collapse occur.

Specifically, they recommend limiting spans to no more than 90 m and compartment areas of no more than 1.2 hectares (12,000 m^2). In this regard it is noted that individual web pillar compartments at Hume are significantly less than both of these suggested limits, the maximum span between barriers being 56.5 m (at 80 m cover depth) and each compartment area being no more than 0.68 hectares.

In terms of assessing the likelihood of a web pillar collapse occurring in the first instance, two independent criteria need to be met:

(i) A portion of the overburden must be critically unstable so that the web pillars are being directly loaded by kinematically unstable material with zero inherent stiffness.

(ii) The web pillars become overloaded by that amount of overburden, so that both web pillars and the unstable overburden section can collapse in tandem.

The use of sub-critical spans between intra-panel barriers is designed to prevent (i) occurring for the overburden as a whole, the reliability of which increases with increasing cover depth as the W/H between barriers consequently reduces. Therefore, the only scenario by which (i) can come about is for a portion of the overburden to become critically unstable above a web pillar compartment, which in turn reduces the tributary area load influencing the web pillars, and so acts against such a collapse occurring.

As stated by GAPL 2018:

> *"Once having derived the relationship between the 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 be equated to a probability of failure".*

Therefore, in order to further evaluate the potential for a web pillar collapse in operations by reference to the UNSW PDP, web pillar loading needs to be modified using the proportion of the overburden that might become unstable within the spans between intra-panel barrier pillars, as is now detailed.

With the maximum span between barriers being limited to 56.5 m, applying a W/H ratio of 1 returns an effective maximum depth of 56.5 m above the web pillars whereby the overburden might become critically unstable. At a maximum effective cover depth of 56.5 m, the following web pillar ARMPS SF and UNSW FoS values are found for the two extreme design cases at depths of 80 m and 160 m:

- H = 80 m: ARMPS SF = 2.38, UNSW FoS = 1.86
- H = 160 m: ARMPS SF = 3.72, UNSW FoS = 2.91

It is worth noting that as the ARMPS SF values are in excess of 2, this complies with the suggested "*prevention*" approach to massive pillar collapses outlined by Mark ***et al*** 1997, and with the web pillar

FoS values being in excess of 1.63, significantly so in the case of 160 m depth, the associated probabilities of failure under the UNSW PDP are now substantially < 1 in 1000.

With this analyses to hand, it is assessed that the threat to the safety of the mine workings from web pillar instability is reduced to the lowest practicable level, any residual threat able to be transferred to the operational management process.

3.1.2.3 Overburden Spanning Between Intra-Panel Barriers

Hume Coal made the following statement in their response to the independent experts reports, as quoted by GAPL 2018:

> "*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*"

In response to this, GAPL 2018 made the following statement:

> *"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, v. This is reflected in t', E and v 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".*

Hume Coal made the statement to address comments made by the reviewer in GAPL 2017, whereby it was suggested that significant reliance or confidence was being placed on the spanning ability of the overburden lithology or geology between intra-panel barriers as part of protecting web pillars from FTA loading and a soft overburden loading system that could cause an uncontrolled collapse of said pillars. The proponent is well aware of the basis of the concern that is being raised by the reviewer, which is why the design of sub-critical spans between barriers was based on using panel GEOMETRY and restricting said spans to sub-critical levels without any consideration of or reliance upon the overburden lithology. This is in fact part of the ARMPS-HWM design process as was clearly outlined in Mine Advice 2016b and has been intrinsic to the layout designs since they were first developed.

It would be fair to state that Hume Coal has taken a "cautious" approach to the issue of layout geometry since the commencement of the layout design process, hence it is not necessary for reviewers to advise caution in this manner as it could perhaps suggest that the proponent was not doing so in the first instance.

3.1.3 Core Issue #3 – The Role of Web Pillars

A number of technical issues were discussed by the reviewer under this heading, including:

(i) The assumption of FTA loading in calculating web pillar probabilities of failure, as was included in GAPL 2017.

(ii) The potential influence of rib spall and roof falls within the UNSW pillar database.

(iii) The potential impact of localised geological structures on web pillar strength

(iv) The potential influence of small remnant pillars (termed “stooks”) within the areas of full extraction at Berrima Colliery from which surface subsidence data was used for LaModel calibration purposes.

(v) The reliance being placed by Hume Coal on the spanning ability of massive strata protecting the integrity of web pillars.

A further point (point 6.) in GAPL 2018 was retracted by the reviewer as being a misrepresentation on his part, and will therefore not be considered further herein.

Each issue will now be addressed in detail.

3.1.3.1 Use of FTA Loading in Determining Web Pillar PoF Values

Hume Coal were quoted by the reviewer as follows:

> “*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”*

In response, the reviewer made the following statement:

> “*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*”.

The author does not disagree with any of the comments made by the reviewer in this regard. However the reality is that the reviewer demonstrably included web pillar PoF values under the assumption of FTA loading in his initial review report (GAPL 2017). The quoted response was part of the proponent objecting to the inclusion of these figures in his review report specifically for Hume, on the basis that the assumed web pillar loading conditions were inconsistent with the intent of the proposed panel layout design, not that it would be inappropriate to reduce web pillar loading to less than FTA if it could be justified.

Clearly, the reviewer has mis-understood the reasoning for the proponents statement, hence his response requires no further comment.

3.1.3.2 The Potential Influence of Rib Spall and Roof Falls within the UNSW Pillar Database

Hume Coal were quoted by the reviewer as follows:

> *"Another key reason 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…"*

It is important to understand the context behind Hume Coal making this statement, which has been omitted by the reviewer in his second review report. Specifically, it was made in response to the reviewer's analysis of web pillar stability based on 0.2 m increments of rib spall and roof spall for varying depths of cover (see page 35 of GAPL 2017, included herein as Table 3.2), in particular that pillar geometry variations of such a low magnitude would inevitably be unresolved within the UNSW pillar database. Therefore the proponent was arguing that such sensitivity analysis was an inappropriate application of the UNSW PDP, the result of which could be seen as being detrimental to the proponent.

Table 5: Analysis of sensitivity of web pillar stability to 0.2m of spall.

Depth (m)	Situation	Tributary Area Loading	
		UNSW PDP Factor of Safety	Probability of Failure
80	As-designed	1.30	8%
	0.2 m rib spall	1.19	20%
	0.2 m roof fall	1.24	12%
	0.2 m rib & 0.2 m roof spall	1.13	28%
160	As-designed	1.01	50%
	0.2 m rib spall	0.96	61%
	0.2 m roof fall	0.97	63%
	0.2 m rib & 0.2 m roof spall	0.91	70%

TABLE 3.2. Analysis of Sensitivity of Web Pillar Stability to 0.2 m of Spall (GAPL 2017)

It is noted that to the best of the author's knowledge, the original publications of the UNSW PDP did not raise the spectre of the need to undertake such rib spall sensitivity analyses as part of its use, this only having become a stated concern by custodians of the UNSW PDP more recently, including Canbulat 2010 which presented a detailed discussion on the topic of time-dependent pillar deterioration due to rib spall, concluding that:

"A similar study was also conducted for the Australian pillar collapse database in this paper. The results revelated that the collapsed cases included in the Australian database of Salamon et al 1996, were due to low nominal safety factors and there is no indication that these pillars collapsed due to a high level of spalling.

This would seem to indicate that in spite of South African studies that attempted to link unexplained pillar collapses in the Vaal Basin to time-dependent rib spall, no such de-stabilising influence could be found in the small number of Australian collapsed cases.

It is accepted that it would be relevant to evaluate the de-stabilising impact of rib spall in conditions whereby significant rib spall was likely to occur, the main common driver for rib spall being cover depths > 200 m. However, this is judged not to be the case at Hume.

Contrary to the context of the Hume Coal statement quoted by the reviewer, he has seemingly taken it out of its intended context and provided a long commentary on the potential impact of rib spall and roof falls on pillar stability IN REALITY, rather than addressing the stated concern in regards to the analyses he undertook in GAPL 2017. The proponent stands by their original assertion that the reviewers analysis as contained in Table 3.2 is inappropriate, and not as per their understanding of the intended use of the UNSW PDP.

3.1.3.3 The Potential Impact of Localised Geological Structures on Web Pillar Strength

Hume Coal were quoted by the reviewer as follows:

"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….."

In response, the reviewer stated that:

"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".

Given that all parties recognise that anomalous geological structures have the potential to modify web pillar strength and therefore, need to be managed in operations (as outlined by the proponent in Hume Coal 2018), it would have been more useful for the reviewer to provide comment on (a) whether they believe that the associated risk to mine stability can indeed by effectively managed during mining operations, (b) provide an outline of key considerations that need to be incorporated into future operational management processes, and (c) as a minimum conduct a review of what has been proposed by the proponent, even if only at a high level in terms of general principles.

3.1.3.4 The Influence of Small Remnant Pillars on Surface Subsidence at Berrima Colliery

Hume Coal were quoted by the reviewer as follows:

"……..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".

"*Importantly, the panels at Berrima contain no substantial remnant pillars…..*"

The quotations relate to the use of surface subsidence data from the adjacent Berrima Colliery in determining, by back-analysis, the geotechnical characteristics of the overburden at Hume for subsequent use in the numerical modelling study undertaken by Emeritus Professor Heasley. Essentially, the reviewer is questioning whether Hume's assumption in regards to (i) a lack of substantial remnant pillars in the various extracted areas at Berrima, is consistent with the measured surface subsidence of < 10 mm S_{max}, and (ii) whether any errors in this assumption have a significant impact on the numerical modelling results. Given the reliance that has been placed by the proponent on the numerical modelling outcomes in further justifying its case, resolving this concern is an important aspect of this response.

Based on the reviewers own stated experience in pillar extraction operations, including having statutory oversight, he has advised it to be "*unwise*" to apply the Berrima Colliery case study without more robustly validating the data and also carefully assessing if the associated mining circumstances apply to the Hume Coal Project if the data proves reliable. Therefore, this is exactly what has been done in response as now detailed.

The question posed by the reviewer is founded on the question as to whether the remnant coal left in place within areas of total extraction at Berrima, was sufficient to substantially modify the manifestation of surface subsidence, this data being the primary basis for calibrating the overburden in LaModel by Emeritus Professor Heasley. In addressing this question, there are only two possibilities, both of which will be addressed in detail:

(i) Remnant coal had no substantial influence on surface subsidence.

(ii) Remnant coal did have a substantial influence on surface subsidence.

If it can be shown that the manner by which the numerical models were set-up caters for both scenarios, then any concern or uncertainty related to this issue can logically be dismissed as being irrelevant.

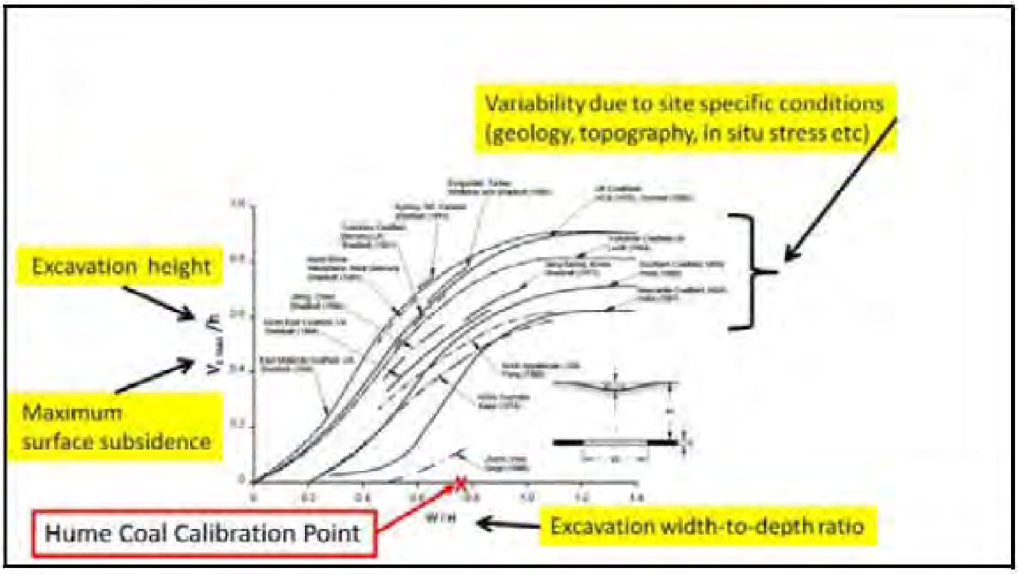

FIGURE 3.4. Illustration of the Extreme Nature of the Numerical Model Calibration Point by Reference to International Subsidence Behaviour (GAPL 2018)

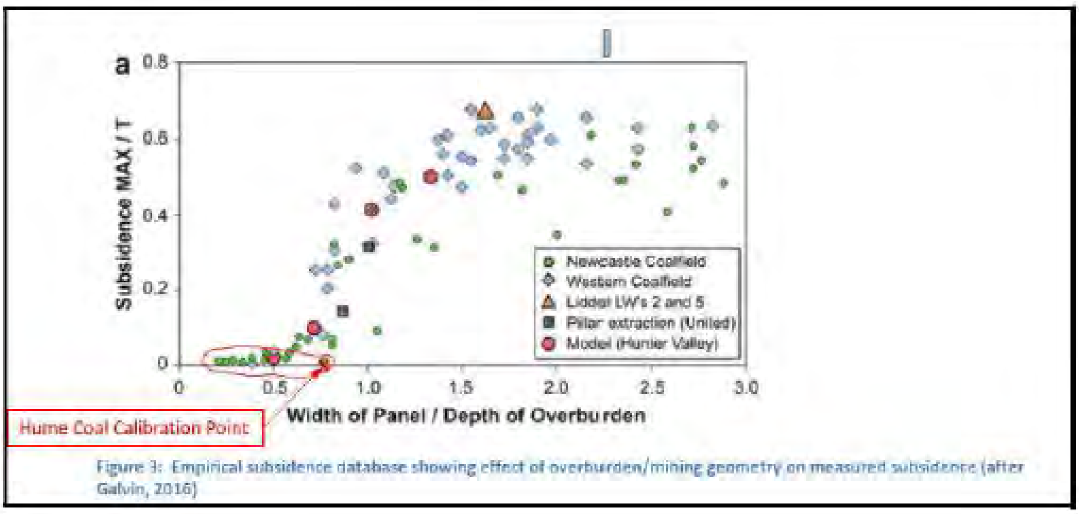

Figure 3.5. Illustration of Extreme Nature of the Numerical Model Calibration Point by Reference to Subsidence Outcomes in NSW Coalfields (GAPL 2018)

GAPL 2018 refers to two figures (reproduced herein as Figures 3.4 and 3.5) in explaining the basis of the concern raised. These will be referred to as required in formulating this response.

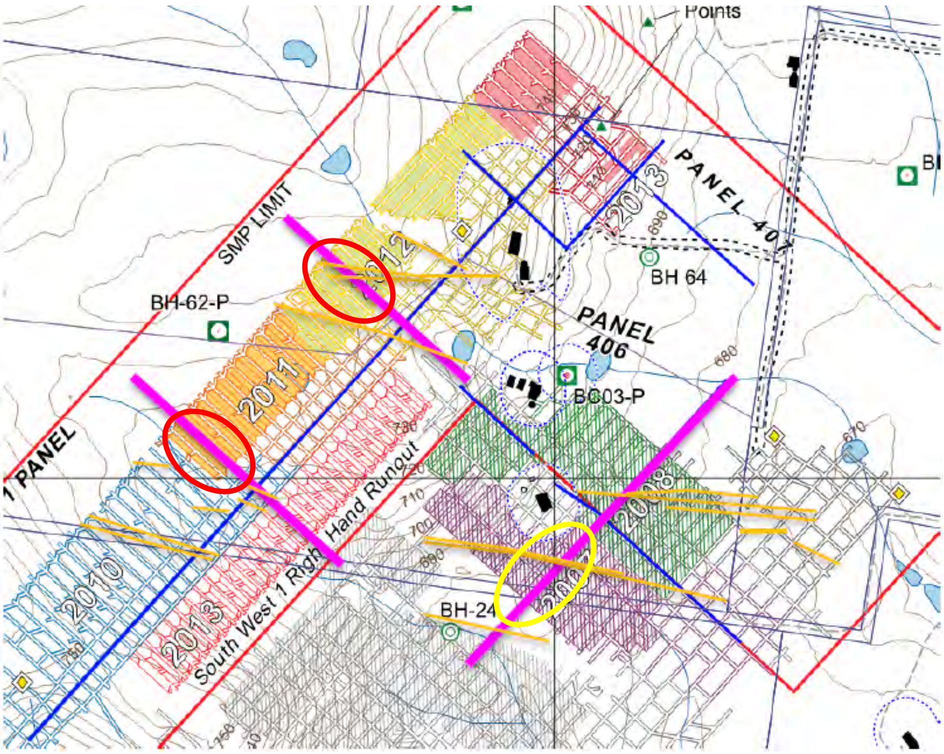

FIGURE 3.6. Berrima Colliery Workings and Subsidence Cross-Lines Above 404 and SW1 Panels

The first point to make is that the S_{max} magnitude that was used in calibrating the overburden in LaModel, was based on three measurements rather than one, such that any subsidence modifying influence at work must have presumably been of similar magnitude in all cases. The three subsidence cross-lines and the underlying mine workings from Berrima are shown in Figure 3.6 and the following comments are made:

(i) The specific areas from where surface subsidence data was taken from for use at Hume, are indicated as ellipses, the two from SW1 being in red and that from 404 in yellow.

(ii) As stated in DGS 2010, their surface subsidence predictions at Berrima were based on the assumption of 85% recovery within total extraction panels.

(iii) Examining the pillar layout in 404 Panel, due to the number of headings, cut-throughs and pillars within the area extracted in 2007, it is fully accepted that a significant number of small stooks would have inevitably been left in place during lifting operations, if for no other reason than to protect the stability of intersections (termed as Stook X in industry terminology). Therefore, the reviewers suggestion that measured surface subsidence might have been directly influenced by their presence, potentially has merit in 404 panel.

(iv) In contrast to 404, SW1 panel, which was the origin of two of the three subsidence measurements relied upon by Hume, contains a series of single headings driven across the full 120 m width of the panel. Therefore practical mining experience would logically suggest that the SW1 panel would be far less influenced by the planned leaving of remnant stooks than 404, yet the measured surface subsidence is broadly the same.

Consideration of the specific roadway and pillar layouts leads to the conclusion that there likely is a varying influence of remnant coal pillars on surface subsidence development at Berrima, with surface subsidence from above SW1 panel being far less likely to be directly influenced as compared to 404 panel.

If it is accepted for the sake of argument that surface subsidence above SW1 panel is not being significantly influenced by remnant coal in areas of attempted full extraction, the question then remains as to whether there are other reasons as to why the magnitude of S_{max} being < 10 mm is extremely low, as compared to comparable extraction panels, this being clearly indicated by the reviewer based on Figures 3.4 and 3.5.

In response to this question, the following points are noted:

(i) Whilst it is accepted that measured surface subsidence of < 10 mm for a panel W/H ratio in the order of 0.75 is very low in general terms, it is not so extreme to be substantially remote from other measured data, as can be gleaned from both Figures 3.4 and 3.5. Had the W/H ratio been 1.5 and S_{max} only 10 mm for example, that would have undoubtedly been a major departure from measured behaviour.

(ii) There is no argument that the measured surface subsidence as a function of W/H being 0.75 is significantly below the more typical behaviour for the major NSW coalfields – the Western and Newcastle Coalfields being shown in Figure 3.5 and single panel sag subsidence for three NSW coalfields, including the Southern Coalfield (which is where Berrima and Hume are located) being shown in Figure 3.7. The question therefore is whether there are any substantial differences between relevant subsidence controls at Berrima, as compared to these other NSW Coalfields more generally, that could explain the apparent "extreme" measured behaviour from Berrima?

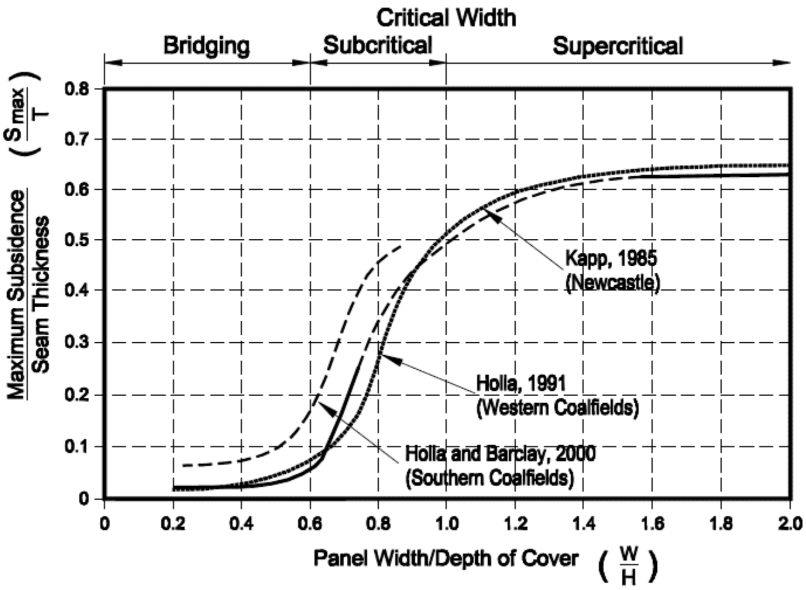

FIGURE 3.7. Sag Subsidence Over Single Panels (Mills *et al* 2009)

There are three relevant geotechnical considerations that could explain this difference in measured surface subsidence at Berrima for a W/H ratio of 0.75, according to known characteristics of the Berrima site as compared to other NSW coalfields more generally, and the NSW Southern Coalfield more specifically:

(a) The level of tectonic horizontal stress is substantially lower at Berrima and Hume, as was outlined in more detail in Mine Advice 2016a and summarised herein in Table 3.3.

(b) The overburden above the Wongawilli Seam locally is dominated by the Hawkesbury Sandstone (see Figure 3.7), whereas the overburden above most other mines in the NSW Southern Coalfield contains a range of different strata units in addition to the Hawkesbury Sandstone.

(c) As compared to the majority of the longwall panels in the NSW Southern Coalfield, Berrima is relatively shallow (< 200 m as compared to 400 to 500 m more typically), with S_{max} being known to increase for any given W/H ratio as cover depth increases (Ditton and Frith 2003).

The point being made is that there are at least three relevant geotechnical differences between the overburden above the Wongawilli Seam at Berrima and overburdens more generally in NSW, that could logically explain the apparent discrepancy between measured surface subsidence at Berrima as compared to that predicted by GAPL 2018 from more generic NSW coalfield-based empirical curves.

This general suggestion also fits with measured subsidence data from extraction panels with higher W/H ratios at Berrima (as reported by DGS 2010), with known super-critical total extraction panels whereby full overburden collapse to surface should occur returning S_{max}/T values well below the generally expected value in the order of 60% (the measured data points being included in Figure 3.9 to provide improved context). It is judged to be far less credible to suggest that small amounts of remnant coal in total extraction panels could substantially reduce surface subsidence in super-critical extraction panels, as compared to sub-critical panels such as SW1 and 404, the measurement data also being included in Figure 3.9 for reference purposes.

Location	Major Tectonic Stress Factor Range (average)	Major to Minor Conversion Factor Range (average)
NSW Southern Coalfield	0.7-1.4 (1.04)	0.46 – 0.82 (0.68)
NSW Newcastle Coalfield	0.84-0.84 (0.84)	0.65-0.69 (0.67)
NSW Western Coalfield	0.75-0.94 (0.81)	0.6-0.75 (0.67)
QLD German Creek/Lilyvale Seam	0.47-0.7 (0.6)	0.47-0.58 (0.54)
QLD Rangles Measures	0.46-0.56 (0.51)	0.48-0.55 (0.52)
QLD Moranbah Measures	0.64-0.66 (0.65)	0.54 (0.54)
HUME COAL - HU0040	0.44	0.73

TABLE 3.3. *In Situ* Horizontal Stress Parameters for Various Coalfields Compared with HU0040 (Mine Advice 2016a)

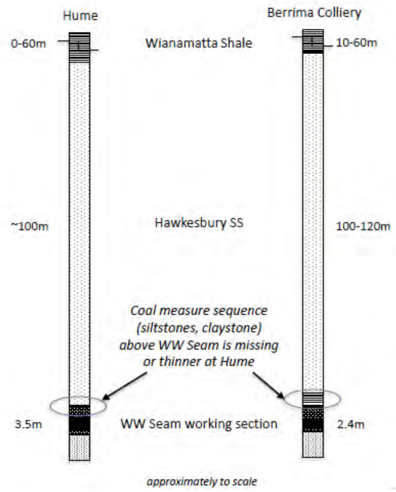

FIGURE 3.8. Comparison of Generic Overburden Lithology, Wongawilli Seam

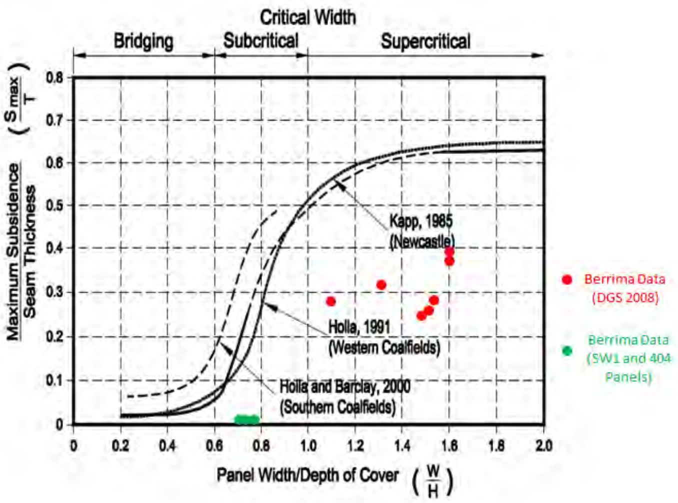

FIGURE 3.9. Sag Subsidence Over Single Panels (Mills *et al* 2009) and Measured Subsidence Data from Berrima

If it is assumed, based on the preceding discussion, that the measured subsidence data from Berrima was not substantially influenced by remnant coal within total extraction panels, then the conservative nature of the selected numerical modelling values for E and t for the overburden, cannot be argued. If however, it is the case that remnant coal did substantially reduce subsidence at surface and that this may have then resulted in an optimistic characterisation of the overburden in LaModel, then as stated by GAPL 2018 this would require said models to be re-run.

However, it first needs to be remembered that the overburden in LaModel was characterised by thickness or t values that were substantially less than those returned by the modelling back-analysis using the assumption that S_{max} = 10 mm at Berrima. The results of that back-analysis were reported in Mine Advice 2018 and are re-produced herein as Table 3.4. Of most interest is that the table contains the predicted S_{max} at Berrima for the chosen mid-range E (16.5 GPa) and t (30 m) combination for use at Hume, the value being 93.1 m, this being almost an order of magnitude higher than the measured value from Berrima of 10 mm.

GAPL 2018 contains the following statement referring to measured surface subsidence at Berrima:

> "*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*".

When it is also considered that the E and t combinations used in the numerical modelling extended to as low as E = 8.2 GPa and t = 20 m, it is evident that the LaModel predictions of S_{max} for Berrima are of a similar magnitude to those predicted by GAPL 2018. In other words, the cautious manner by which E and t values were selected for use at Hume based on the Berrima back-analysis, are not inconsistent with those that would be inferred using LaModel if the GAPL 2018 prediction of S_{max} without the influence of remnant coal were taken as being fully representative.

The conclusion from the analyses and discussion presented in this section of the report, is that whilst the concern raised by the reviewer that remnant coal in total extraction panels at Berrima may have blighted both the back-analysis to determine overburden characteristics for use at Hume, and hence the entire numerical modelling study, a more detailed consideration reveals that this uncertainty has no discernible impact due to the conservative manner by which the overburden was characterised and incorporated into LaModel in the first instance.

One final point is worth stating, and that relates to GAPL 2018 even suggesting that small amounts of remnant coal within total extraction panels might have the ability to reduce surface subsidence by more than an order of magnitude (i.e. 130 mm to < 10 mm). If this is correct, it actually represents an absolute proof of concept for Hume as it confirms that the leaving of low w/h coal pillars that are unable to fully support the overburden to surface within sub-critical spans between barriers, has the ability to stabilise the full overburden without undergoing any form of pillar failure. This is particularly encouraging when it is considered that:

(a) The extraction panels at Berrima were 120 m wide whereas the web pillar compartments at Hume are limited to no more than 60 m width.

(b) Reserve recovery in web pillar compartments at Hume is planned to be no more than 57%, whereas total extraction is commonly taken to achieve around 85% in-panel recovery.

The measured value of S_{max} at Berrima as used in the LaModel back-analysis, could only be achieved if the overburden between barriers at Berrima were also highly stable without the influence of remnant coal in the first instance, this also being a significant aspect of long-term remnant mine stability design at Hume.

3.1.3.5 Reliance on the Spanning of Massive Strata to Protect Web Pillars

Technical considerations relating to this issue were addressed in Section 3.1.2.3 and do not need to be re-stated herein.

3.2 Dr. Ismet Canbulat

The second review report of Dr. Ismet Canbulat (Canbulat 2018) is quite different to that of GAPL 2018 in that it is heavily focused on details pertaining to the numerical modelling undertaken by Emeritus Professor Keith Heasley and also providing a strong defence of the proponents criticism of the numerical modelling included in his first review report, Canbulat 2017.

The comments made herein will be largely restricted to those criticisms that are judged to be related to the confidence levels that can be placed in the currently proposed mine layout design, this being a function of the layout design work that has been conducted to-date and the level of design conservatism that has been applied. The comments made are in no priority order.

- The report continues to assert that the stability of the overburden between intra-panel barriers is strongly linked to the bridging capabilities of the Hawkesbury Sandstone. This is incorrect as has been stated several times by the proponent. The bridging or spanning of all or at least part of the overburden between barriers is a combined function of the both the W/H ratio and the lithology of the overburden. The initial layout design using ARMPS-HWM did not consider the nature of the overburden, only the magnitude of the span between barrier pillars. If the Hawkesbury Sandstone is less competent than assumed in the numerical modelling for example, the general geometry of the web pillar compartments remain sub-critical to surface, this becoming ever more so as cover depth increases, due to the span between barriers being limited independent of cover depth. This issue is also addressed in Section 3.1.2.3 in response to comments made in GAPL 2018.

- The report also raises the issue of the constitutive law used to define web pillar behaviour, namely the assumption of elastic-plastic behaviour. This was discussed and addressed in detail in Section 3.1.1.6 and does not need to be repeated.

- The statement that "*removing all web-pillars in all panels may not be representative of realistic conditions. Using strain-softening elements in all pillars, including at the edges of barrier pillars, may have represented a more realistic approach*" is technically correct, but fails to acknowledge the point of removing all of the web pillars in one of the numerical modelling scenarios. This was done, not to be realistic, but to demonstrate that even if all of the web pillars failed (without suggesting that this is a credible scenario), the barrier pillars would remain stable and surface subsidence effects would remain at low levels. It was also intended to usurp the various technical concerns that were introduced by the reviewers in regards to web pillar loading magnitudes and constitutive behaviour laws, both of which have been raised again in response to the numerical modelling that was undertaken by Emeritus Professor Heasley.

- The comment that the back-analysis conducted by Emeritus Professor Heasley as to the nature of the overburden at Berrima was "a very simple back analysis" as quoted in Canbulat 2018, cannot be found via a word search of Heasley 2018. The entire issue of the back-analysis of measured surface subsidence data from Berrima and what both reviewers consider to be anomalously low values of S_{max}, has been addressed in detail in Section 3.1.3.4 and needs no further comment herein.

- Canbulat 2018 states that "*Further to the above, no details of the Berrima Colliery back analysis were presented in Dr Heasley's report. The findings presented consisted solely of three lamination thicknesses and elastic modulus. If elastic, perfectly-plastic coal material properties were also assumed in the back analysis, this assumption may not be true for the total extraction panel(s). In addition, super-stiff overburden strata may indicate low subsidence magnitudes for an isolated panel. However, high stiffness overburden may result in increased load transfers onto the barrier pillars (as evidenced by reported LaModel results for Hume Coal), which may, in turn, impact their stability. These details should have been included in the report to review*".

  Firstly it is unclear as to why an assumption about coal constitutive behaviour has any link to the back-analysis of surface subsidence above an area of total extraction (i.e. assumed to contain no substantial remnant pillars) that is surrounded by highly stable pillars or solid coal. Nonetheless, the issue and significance of anomalously low S_{max} values at Berrima has been dealt with in Section 3.1.3.4 and requires no further comment.

- Issues relating to mine safety during forming of the unsupported drives were also raised in GAPL 2018. This has been considered and addressed in Section 3.1.2.2 using modified tributary area loading based on the width of web pillar compartments between intra-panel barriers and a W/H value of 1. The proponent does not believe there is any need or value in addressing this issue with further numerical modelling studies.

- The most substantial section (Core Issue #6) of Canbulat 2017 is a detailed response to the various criticisms raised by the proponent as to the relevance and interpretation of the numerical modelling outcomes contained in Canbulat 2017. As is stated in Canbulat 2018, this modelling "*sought to highlight some critical design considerations*" and so presumably was not intended for layout design purposes. Therefore, it is considered by the proponent that the numerical modelling outlined in Canbulat 2017 is substantially less credible than that conducted and reported by Emeritus Professor Heasley. As such, it has no bearing on the on-going mine assessment process and so requires no further comment herein.

- The statement is made on page 10 that "*Years to centuries may elapse before spalling is able to trigger a pillar failure. Van der Merwe and Madden (2010) comment in this regard; "Given sufficient time, any act of removing material from underneath the surface of the Earth will result in subsidence". The magnitude of subsidence will be determined by the amount of spalling, the size of the core of a pillar, and the overburden stiffness between the barrier pillars. I accept that the rate of spalling in the Wongawilli Seam may be very slow and it may take centuries for the pillars to fail but it will eventually happen, even if the pillars are not loaded at the levels of* *tributary area load. In my opinion, the crux of Hume Coal's assessment should be to demonstrate the potential consequences of failure rather than ascertaining whether the pillars will fail or not*". This statement does require a specific response.

The "scenario" numerical models reported in Heasley 2018 and interpreted in Mine Advice 2018 whereby all of the web pillars were removed, which by any standard is a grossly conservative if not unrealistically conservative modelling assumption, addresses the statement about demonstrating the consequences of web pillar failure, presumably at some indeterminate point in time in the very long-term. As well as surface subsidence effects being shown to be minimal should web pillar failure occur, the mine will inevitably be abandoned at that time hence there are no safety concerns to address, and on the basis that the mine is flooded and sealed, any associated overburden fracturing would have a negligible if not zero effect on sub-surface groundwater levels.

- The suitability of Young's Modulus testing results that were used in the numerical modelling has been questioned by the reviewer, stating that "*More test results from all parts of the mine will provide better understanding of the overburden modulus*". This is undoubtedly true, but the unstated inference that such an understanding is of real significance to the review and approval process at the current time requires a response.

  The numerical modelling study deliberately utilised the complete range of known E values from the available laboratory testing in order to determine the extent by which variations in E were of significance to the modelling predictions. By any standard it was clear-cut that pillar load distributions, which was the objective of conducting said modelling, did not materially change as a result of an E variation from 8.2 GPa to 23.2 GPa. Certainly, the overall interpretation of mine stability with an assumed E value of 8.2 GPa was not different to that at 23.2 GPa. This is not a surprising outcome when it is remembered that the spans between intra-panel barrier pillars were established from ARMPS-HWM, which gave no consideration to the nature of the overburden. In other words, the nature of the overburden was secondary to restricting the span between barriers, the numerical modelling results clearly bearing this out.

  In order to provide further justification for the range of E values used in the modelling, reference is made to the 109 UCS tests reported in Mine Advice 2016a and published relationships between E and UCS for Hawkesbury Sandstone (Pells 2004). The reported UCS values range from 9.4 MPa to 101 MPa with an average value of 43 MPa. Applying the average UCS value to Figure 3.10 returns an E range of just below 9 GPa to just above 20 GPa, which is entirely consistent with the numerical modelling assumptions used.

  A final point that needs to be made is that as discussed in Mine Advice 2018, E and t for the overburden are to some degree interchangeable, in that "*the influence of overburden properties E and t on overburden stiffness is multiplicative. This means that a model using E = 10 GPa and t = 20 m will return the exact same results as a model using E = 5 GPa and t = 40 m*". Therefore, if the assumed E values used in the Berrima back-analysis were significantly in error, the back-analysed value of t would directly compensate for this.

  Based on the above arguments, the proponent sees no need or benefit from collecting further borecore for Young's Modulus testing and conducting further numerical modelling runs on the basis of concern that the values used to-date are insufficiently comprehensive for EIS purposes.

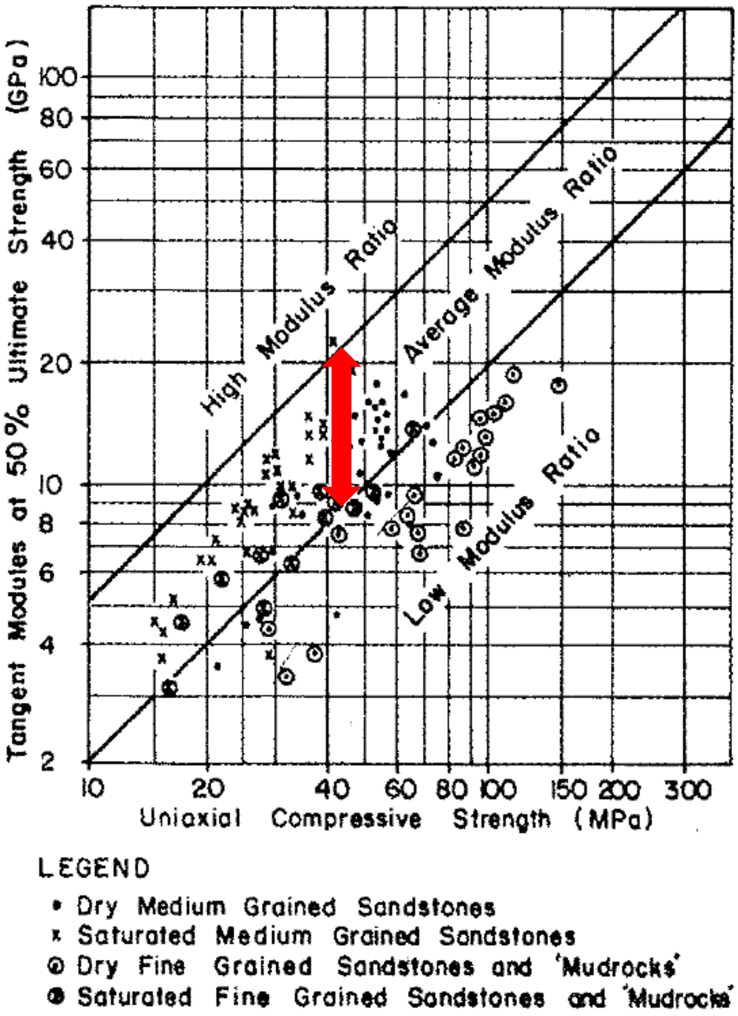

FIGURE 3.10. Data from Robson 1978, as Reported by Pells 2004.

The final section of Canbulat 2018 provides comments and questions relating to the contents of Mine Advice 2018, which are now addressed where a specific concern has been raised that has not been addressed elsewhere in the report.

- Uncertainty as to the Berrima back-analysis has been raised on the basis of the potential presence of vertical joints in the overburden, to the point that "*In my opinion, significant vertical discontinuities present uncertainty and are residual risks and their existence should therefore be considered in any given layout. It is unknown if the Berrima panel(s) contained any significant vertical discontinuities. Thus, the appropriateness of the back analysis is unknown regarding the vertical discontinuities*".

  This entire issue was addressed in detail in Mine Advice 2018 on the basis that vertical joints were omni-present within the overburden, the controlling influence on vertical joint stability and hence overburden stability, being horizontal stress. Furthermore, it was also confirmed that due to the very low predicted levels of overburden settlement due to mining, the impact on horizontal stress magnitudes would inevitably be minimal (which also directly impacts vertical conductivity of the overburden), such that joint condition should not materially change. It would have been far more instructive had the reviewer outlined any technical flaws in the arguments presented in Mine Advice 2018 than simply state the presence of unresolved uncertainty in terms of the influence of vertical joints and in doing so, bring the Berrima back-analysis into apparent question.

- Any concern over the use of ARMPS-HWM-defined web pillar SF values for long-term stability will be addressed in the Section 4 of this report, where a further detailed technical summary of the various empirical and numerical modelling outcomes will be provided, outlining ALL of the design parameters that are relevant to remnant mine stability, rather than continuing to focus on web pillar SF or FoS values in isolation.

- The following statement is made by the reviewer:

  "*P30 Smax=23.5mm in the panel failure case: I agree fully with the statement that the surface subsidence of 20mm or 23.5mm will not be substantial. However, it needs to be appreciated that if the web-pillars in one panel fail, there is a high likelihood that the web-pillars in adjacent panels will also fail. This will result in more loads on barrier pillars, which will result in more surface subsidence than 23.5mm*".

  As stated previously, the scenario models that the reviewer refers to were not intended to be credible predictions of the likely outcomes should web pillars fail, as by removing all of the web pillars, no coal was left in place. As discussed by GAPL 2018, such remnant broken coal will remain in place and so act in some way to mitigate the consequences of pillar failure. The primary reason for conducting these scenario models was to demonstrate that detailed technical arguments as to pillar constitutive laws and design SF values for web pillars were largely irrelevant and meaningless, as the overall layout design relied far more on the stability of barrier pillars than web pillars for surface protection.

- The following statement is made by the reviewer:

  "*Section 4 Displacement-based stability criteria: I agree with Dr Hebblewhite's view that this section presents a detailed technical discussion. I also believe that it exceeds Professor Brown's anticipated response, which he envisaged at the experts meeting. A detailed review of this section will take a significant amount time and resources, requiring detailed data from every single panel referenced in this section. I am not confident if it will add any benefit to the Hume Coal design*".

  The author did not pre-empt what Emeritus Professor Brown's anticipated response might be, other than picking-up on his stated view as raised by Emeritus Professor Galvin, that displacement-based rather than load-based stability criteria may be of benefit in evaluating mine stability supported with coal pillars. It is accepted that a detailed review may take significant time and resources if there is a need to obtain detailed data from every single panel referenced in the section. In effect the reviewer is suggesting that there is a need to review in great detail all of the case histories in the supporting databases for such empirical methods as the UNSW PDP, ARMPS-HWM, ARMPS and a host of others as well, before they can be used with confidence. Unfortunately detailed case histories that were used to formulate the UNSW PDP are unavailable.

The analysis presented by Mine Advice 2018 simply demonstrates based on published measurement data from a wide range of sources, that the predicted post-mining overburden settlements at Hume are a fraction of those that are known to be required before mass instability of the overburden commences at surface. In the context of the role of overburden stiffness and stability being an integral part of web pillar design (which has caused so much concern to be raised by the two independent experts), demonstrating the typical level of post-mining overburden stability between barriers should logically be of great assistance to the reviewers. For the reviewer to offer no opinion on this aspect as to its technical merits, but seemingly have sufficient knowledge to be prepared to dismiss its likely value, would appear to be contradictory.

4.0 UPDATED SUMMARY FOLLOWING REVIEW OF THE EXPERT REPORTS

Having reviewed both independent expert reports that were included in DP and E 2018, there are no issues identified that cause Mine Advice to change its view that the proposed mine layout design guidelines are fit for purpose, in that they are suitably conservative and reliable in relation to both mitigating long-term environmental impacts and mine safety during operations. This final section of the report will present the various reasons and arguments as to why Mine Advice still believe this to be the case.

On the basis that both reviewers appear to remain unconvinced as to the likely stability of web pillars post-mining due to their low w/h ratio and the associated FoS values under FTA loading, a further analysis will now be conducted aimed at demonstrating that the likely *in situ* values are substantially higher than those either quoted in Mine Advice 2016b under the design assumption at that time of FTA loading, or as part of analyses conducted by the reviewers. The aim of this is to demonstrate that the concern expressed by both reviewers as to whether the web pillars may yield or not, is substantially less significant than inferred by a FTA loading assessment.

There appears to be good agreement between the various parties that the Ground Reaction Curve (GRC) concept is useful, hence GRC representations will be developed for both the 80 m and 160 m deep designs to assist in providing all parties with a similar understanding of likely remnant mine stability.

The GRC concept (Figure 4.1) was originally developed in the early 1960’s to assist tunnellers ensure that permanent, and often, stiff permanent tunnel linings were not damaged by excessive ground strains. This has since been applied by others to coal mining problems, such as tailgate standing support design and longwall shield design.

The ground curve (ABCD in Figure 4.1) contains a section of negative slope (ABC) initially whereby the overburden strata is incrementally losing its natural stability as a direct result of increasing vertical movement, followed by a section of positive slope (CD) whereby natural overburden stability has effectively been lost, with self-weight or dead-loading of kinematically unstable material then dominating overburden behaviour. The support response curve (PQR) contains an initially elastic response followed by some form of post-peak response to R. System equilibrium is achieved at point Q where the required support pressure to a certain contain convergence level, is generated by the support at that particular convergence level.

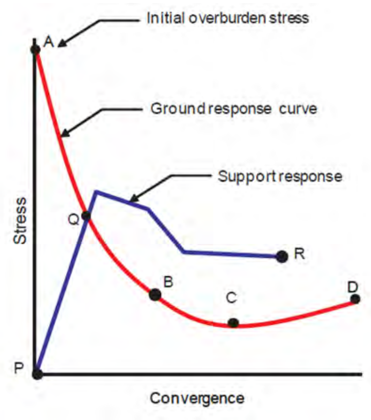

FIGURE 4.1. Generic Ground Reaction Curve (GRC) Representation

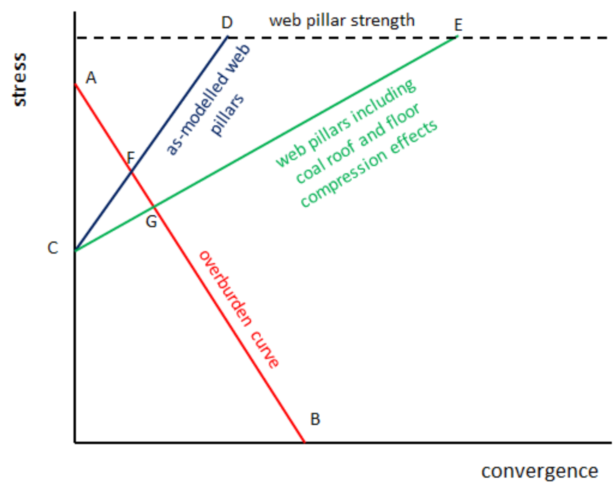

FIGURE 4.2. Schematic of GRC Representation Used

Figure 4.2 shows how a ground curve and pillar curve in this instance will be constructed from the available information, the following points of explanation being provided:

- Point A: tributary area stress on the centre web pillar.
- Point B: surface settlement in the centre of the web pillar compartment with all web pillars removed.
- Point C: *in situ* vertical stress acting on web pillars prior to mining
- Point D: overburden settlement required to drive the pillar to its peak strength (high stiffness roof and floor strata as assumed in LaModel)
- Point E: overburden settlement required to drive the pillar to its peak strength (low stiffness roof and floor strata consisting of defined thicknesses of coal)
- Points F and G: equilibrium conditions
- Line CD: stress-displacement response of a web pillar, pillar stiffness being based solely on an assumed E for coal of 2 GPa.
- Line CE: stress-displacement response of a web pillar, with pillar, roof and floor stiffness being based on an assumed E for coal of 2 GPa roof coal thickness of 3 m and floor coal thickness of 0.5 m, as per Mine Advice 2016a.
- Web pillar strengths have been assigned using the UNSW PDP Rectangular Power formula, as referred to by GAPL 2018 when raising the question as to web pillar probability of failure.
- The representation is for the centre web pillar only, the flanking web pillars inevitably being more stable than the centre pillar by virtue of being located closer to the adjacent intra-panel barriers within an otherwise sub-critical span.

It is noted that as system equilibrium is likely to occur before either the pillars or overburden exceed their elastic range, linear elastic parameters will be used, this assumption being further tested based on the analysis outcomes in terms of the indicated condition of both pillars and overburden at equilibrium.

Most of the defined points within Figure 4.2 are self-explanatory and do not require explanation herein, however Point B and the derivation of the Line C to E necessitate further discussion.

Point B is defined as the level of surface settlement that will occur if the vertical stress applied to the overburden by the web pillars is zero. Fortunately, LaModel was run for cover depths of 80 m and 160 m with all web pillars removed from the model, this being an exact simulation of this condition. Therefore the returned values of S_{max} from each model will be used to fully define Point B.

Mine Advice 2016a provided details as to how surface settlements related to pillar, roof and floor compression were to be calculated, Mine Advice 2018 noting that it was only the coal pillar that was included in LaModel for the reason that the model could not include such detailed near-seam lithology. However in reality, it is actually beneficial to include the influence of lower stiffness (E) roof and floor strata in a GRC analysis, as it tends to reduce the stiffness response of the pillar to vertical compression, thereby resulting in system equilibrium being achieved at a lower level of pillar stress than with a stiffer pillar response. The same method of calculating roof, pillar and floor compression for any defined pillar stress level will be used herein, as that outlined in Mine Advice 2016a.

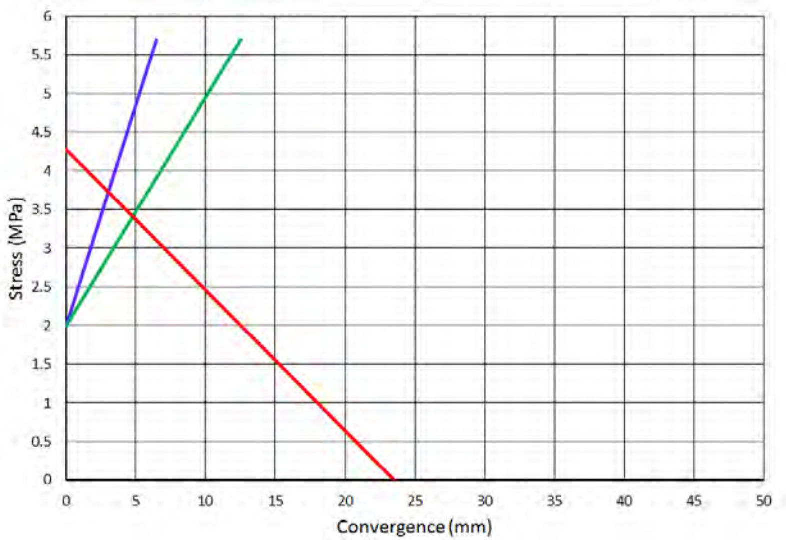

FIGURE 4.3. GRC Representation for 80 m Depth Layout Using UNSW PDP Strength Equation

Figure 4.3 shows the specific GRC curves for the 80 m depth layout based on the general representation of Figure 4.2. On the basis that the pillar curve that includes roof and floor compression effects (green line) is the most representative of actual conditions, it is found that at equilibrium (point G), surface settlement or overburden convergence is some 5 mm with the associated web pillar stress being 3.5 MPa, such web pillar loading being of lower magnitude than that indicated in the LaModel results due to the non-inclusion of coal roof and floor in those models.

It is noted that for the pillar only case, the equilibrium convergence is in the order of 3 mm whereas LaModel gave predictions in the range 2.1 mm to 2.4 mm, this variation relating to changing assumed overburden conditions.

With an equilibrium web pillar stress of 3.5 MPa and a web pillar strength of 5.69 MPa, the UNSW PDP FoS is found to be 1.63, this being exactly as per a PoF of 1 in 1000. However, when it is remembered that this only applies to the centre web pillar, it is self-evident that the PoF for the system of web pillars as a compartment between barriers, is less than 1 in 1000.

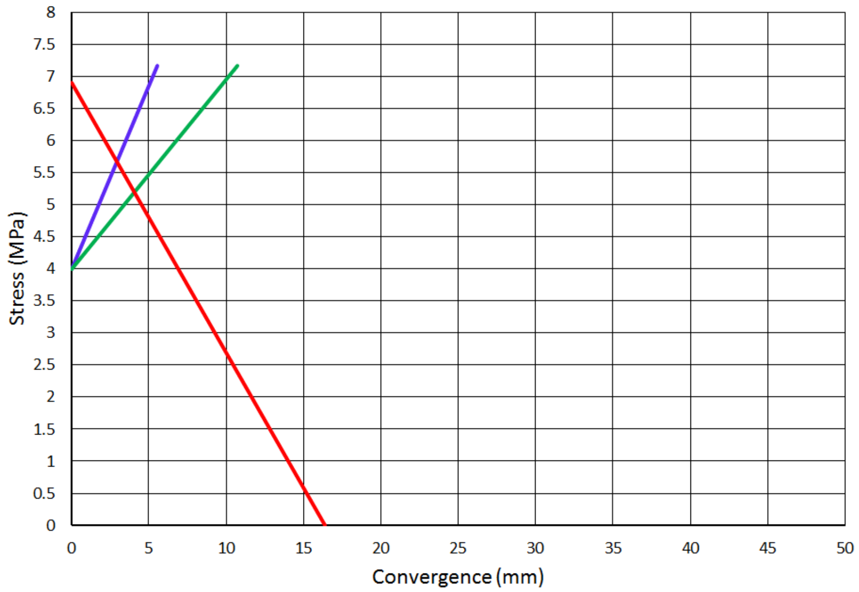

FIGURE 4.4. GRC Representation for 160 m Depth Layout Using UNSW PDP Strength Equation

Figure 4.4 shows the specific GRC curves for the 160 m depth layout, again based on the general representation of Figure 4.2. It is found that at equilibrium (point G), surface settlement or overburden convergence is some 4 mm with the associated web pillar stress being 5.2 MPa, this again being of lower magnitude than that indicated in the LaModel results due to the non-inclusion of coal roof and floor in those models.

With an equilibrium web pillar stress of 5.2 MPa and a web pillar strength of 7.16 MPa, the UNSW PDP FoS is found to be 1.38, this having a PoF in the order of 2 in 100. Again, when it is remembered that this only applies to the centre web pillar, it is self-evident that the PoF for the system of web pillars within a compartment between barriers, is somewhat less than 2 in 100. Critically, as will be discussed later in this section of the report, in understanding the probability for web pillar failure the W/H ratio of the web pillar compartment also needs equal if not greater consideration, which at a depth of 160 m is only 0.32, this being a factor of 3 times less than the commonly used minimum W/H of 1 for the onset of FTA loading to surface.

It is noted that for the pillar only case, the equilibrium convergence is in the order of 4 mm whereas LaModel gave predictions in the range 3.7 mm to 4.2 mm, this variation again relating to the assumed overburden conditions.

With these GRC outcomes to-hand, a final overall summary can now be given justifying the credibility of the proponents position in asserting that the proposed EIS mine layout designs are fit for purpose, in that they are suitably conservative and reliable in relation to both mitigating long-term environmental impacts following the completion of mining activities and safety risks during mining operations.

In summarising the design outcomes and their implications in terms of the requirements of the EIS and associated peer review process that has been conducted by the two independent experts, it is firstly necessary to succinctly state the objectives and associated limitations of a mine layout design process at this stage of mine development, this context being critical when considering the suitability of the design outcomes.

All geotechnical design in underground coal mining, regardless of the risk being designed against, should cater for two distinct elements:

1. Pre-mining designs based on what may be termed as normal or typical geological/geotechnical conditions.

2. The operational management of those risks that cannot be quantified prior to mining, usually in the form of unknown or inadequately defined geotechnical conditions.

By definition, being able to successfully use element 2. during operations, requires that the manifestation of residual risks is sufficiently slow to allow operators to both identify and respond accordingly, this including both the occurrence of unexpected conditions associated with a fully formed-up design and the identification of significant geological anomalies that may render a proposed design as ineffective, the operational response being to then modify the design to be implemented, either in terms of the mine workings or artificial controls such as ground support. This process is known more generally as “strata management” and has been endemic to the Australian coal industry via a formalised system for around two decades.

With this in mind, it is stated that the mine layout designs proposed by Hume have been developed with these two distinct aspects in mind, including the inevitable sources of uncertainty involved in the design process, either related to geotechnical characterisation or implementation during subsequent mining operations, the primary focus at the EIS stage inevitably having been the layout design and associated environmental impacts under typical geological/geotechnical conditions.

The mine layout designs as currently being proposed by Hume, have now been either designed or subsequently reviewed/tested by a range of methodologies, including:

- the ARMPS-HWM empirical method for the design of highwall mining layouts
- an assessment of individual coal pillars within the pillar system using the UNSW PDP strength equations
- 2D numerical modelling using LaModel
- 3D numerical modelling using LaModel
- a web pillar stability analysis under modified tributary area loading according to panel widths between intra-panel barriers using the UNSW PDP rectangular power strength formula
- a web pillar stability analysis using the Ground Reaction Curve method of analysis
- an assessment of post-mining overburden stability between barrier pillars using predicted overburden convergence against published case histories relating to measured surface conditions prior to known overburden collapses above standing mine workings.

The outcomes from each of the listed methods are summarised in Table 4.1, this then leading into a final holistic assessment of both remnant web pillar stability under assumed geological and geotechnical conditions, supplemented with operational management controls to effectively cater for residual risks that cannot be accounted for at the pre-mining design stage.

Stability Indicator	H = 80 m	H = 160 m
web pillar width (m)	3.5	5.5
web pillar w/h ratio	1	1.57
intra-panel barrier width (m)	14	20.9
barrier pillar w/h ratio	4	5.97
web pillar compartment span (m)	56.5	51.5
web pillar compartment w/h ratio	0.71	0.32
ARMPS-HWM SF web pillars under FTA Loading (design assumption)	1.68	1.31
ARMPS-HWM SF barrier pillars under FTA Loading plus Double Abutment Loading (design assumption)	2.69	2
ARMPS-HWM System SF	2.95	2.56
UNSW PDP web pillar FoS under FTA Loading	1.33	1.04
UNSW PDP barrier pillar FoS under FTA Loading	4.95	3.94
ARMPS SF web pillars under modified tributary area loading based on panel span	2.38	3.72
UNSW PDP web pillar FoS under modified tributary area loading based on panel span	1.86	2.91
UNSW PDP at GRC Equilibrium Point	1.63	1.38
Overburden Convergence at GRC Equilibrium Point	5	4
Overburden Convergence Safety Factor (using an assumed critical convergence of no less than 100 mm)	20	25

Note: figures in red are linked to ARMPS-HWM, those in blue to the UNSW PDP considering pillars in isolation, those in green to modified tributary area loading of web pillars due to the span between barriers, and those in brown to the GRC analysis which includes certain numerical modelling outcomes.

TABLE 4.1. Summary of Relevant Web Pillar Stability Indicators, EIS Layout, Hume Project

The contents of Table 4.1 allow the following summary points to be made:

(i) the initial ARMPS-HWM designs (in red) were fully compliant with the requirements of this experience-based design method, and included several deliberately included or inevitable sources of design conservatism over and above the returned values of SF and w/h (e.g. setting minimum web pillar w/h = 1, setting minimum barrier pillar w/h = 4, limiting spans between barriers to 60 m, recognising that planned drive lengths were substantially < than in HWM, recognising the significant stabilising influence of the absence of an open cut highwall in the underground environment).

(ii) the application of the UNSW PDP strength equations to web pillars and intra-panel barriers individually (in blue), returned highly stable barrier pillars, but raised questions as to the likely stability of the web pillars due to the low FoS values returned under FTA loading to surface. In the absence of any ability to readily modify the loading of web pillars to account for the restricted spans between barrier pillars, this uncertainty drove the need to conduct more detailed modelling studies where the stabilising influence of both the overburden and the third-dimension could be brought into the stability analyses.

(iii) the numerical modelling studies were conducted by a world leading expert in the field and the main developer of the LaModel modelling package. This approach is judged to be fully consistent with world's best practice in terms of the use of numerical modelling in evaluating the stability of bord and pillar type mine layouts. The overburden characterisation used in the models was based on a back-analysis of known outcomes at the adjacent Berrima Mine, the modelling outcomes being fully consistent with the original ARMPS-HWM layout designs in terms of the overall interpretation of remnant mine stability. There was no identified need to modify the proposed mine layout to cater for any concerns over pillar loading distributions that emanated from the modelling runs.

(iv) an evaluation of web pillar stability in isolation from barrier pillars under modified tributary area loading according to the panel width between barriers and a W/H ratio of 1 defining the lower limit of super-critical or unstable overburden behaviour (in green), returned ARMPS SF values in excess of 2, thereby complying with the suggested "*prevention*" approach to massive pillar collapses outlined by Mark ***et al*** 1997, and web pillar FoS values in excess of 1.63, resulting in probabilities of failure under the UNSW PDP that are substantially < 1 in 1000.

(v) the stability assessment of centre web pillars using a Ground Reaction Curve approach (in brown), returned individual PoF values of 1 in 1000 at 80 m cover depth (FoS = 1.63) and 2 in 100 at 160 m depth (FoS = 1.38). When these outcomes for the centre web pillar are expanded to all of the web pillars within a web pillar compartment in order to generate a PoF for the web pillar "system", it is inevitable that the resultant PoF values are < 1 in 1000 given the substantial stabilising influence of intra-panel barriers on the remaining web pillars.

(vi) an overall system stability assessment using a Ground Reaction Curve approach (in brown), confirmed that at the point that equilibrium is achieved between the overburden and web pillars, the overburden between barriers is retained in a highly stable state, with SF values relating to predicted overburden movements as compared to critical overburden movements whereby overburden instability and collapse becomes likely, being in the range of 20 to 25.

The stability of the overburden above the web pillars, which is in fact the critical EIS and operational safety consideration, can be summarised from the GRC analysis as a combined function of (a) the stability of the overburden between the intra-panel barrier pillars and (b) the web pillars themselves. The two aspects are inter-related in that the web pillars act to reinforce and so stabilise the overburden via its own self-supporting ability, and the level of stability in the overburden acts to protect the web pillars from excessive vertical compression levels that could otherwise drive them to yield and eventual collapse. When the level of overburden stability is combined with web pillar system stability, it is inevitably concluded that the proposed layout designs meet the previously stated design criterion:

> *"they are fit for purpose in that they are suitably conservative and reliable in relation to both mitigating environmental impacts and mine safety during operations"*

More to the point, the mine stability indicators that have been returned by these analyses are of the same order as would be applied to bord and pillar workings, albeit using a different pillar and roadway layout. This therefore addresses the need for previously worked areas of the mine to be accessed by persons for reasons of inspection and rejects emplacement.

With this outcome to hand, the final requirement is to provide high level commentary as to operational management processes.

Both the initial layout design process conducted as part of the EIS submission and subsequent review process, have highlighted a number of concerns that need to be included within the operational management process as part of ensuring that the intent of the mine layout design is always achieved in practice. Whilst it is inappropriate to develop an actual operational management plan and process at this stage of mine development due to the need to base it on a collaborative risk assessment process, key issues can at least be listed for completeness, as follows:

(a) ensuring that web pillar compartments are not directly influenced by major geological structures such as faults and dykes, this being due to the de-stabilising influence they can have on both coal pillars and in particular, the stability of the overburden.

(b) mapping of mine workings to identify such structures before the commencement of forming plunges in a given area, and potentially modifying the plunge layout to accommodate the presence of anomalous geological conditions.

(c) developing monitoring schemes that allow actual remnant mine stability to be tracked post-mining for both environmental impact and mine safety reasons. The current base-line surveys being conducted using GPS surveys is very encouraging in this regard.

(d) using best practice in terms of CM guidance during plunge formation, accepting that the major control of any impact of off-line drivage on stability, is limiting the number of drives between barriers so that irrespective of any off-line drivage, maximum coal recovery within any one web pillar compartment remains unchanged.

(e) the general requirements of operational strata management also apply, albeit that they are more focused on the safety of the mine workings in terms of changing conditions over time, which in itself may be used as a monitoring scheme for the stability of the overburden in already mined-out areas whilst ever access is available.

The final comment is a response to a statement made by Van Der Merwe 1999 when discussing the application of a Quadrant II mine design, as contained in Figure 2.2:

> "*In Quadrant II the overburden is stable, although the pillars are unable to support the full weight of the overburden. This is potentially the most dangerous situation because there could be a false impression of stability when the OSR is not much greater than 1. The pillars will be stable for as long as the overburden remains intact; however the moment the overburden fails, the pillars will also fail. This may occur because of time-related strength decay of the stressed overburden, or when mining progresses into an area with an unfavourably oriented unseen joint set in the overburden. The closer the OSR is to 1, the more dangerous the situation".*

This statement by another of the world experts in the subject of pillar design and remnant mine stability, is fully encapsulated in both the understanding of the proponent from the outset of the need to adopt a cautious approach to the design of the mine layout, and in particular the need to focus on stabilising the overburden by means other than the web pillars in isolation. The combined effect of the restricted spans between intra-panel barriers, the high stability of said barriers and the typical lithology of the overburden, is one of a highly stable overburden above web pillar compartments with a displacement-based Safety Factor against overburden instability in excess of 20. This is by far the most meaningful indication as to the level of design conservatism that is included within the proposed mine layouts at Hume, with the experts' technical debate in regards to web pillar stability being somewhat secondary in the overall scheme of things.

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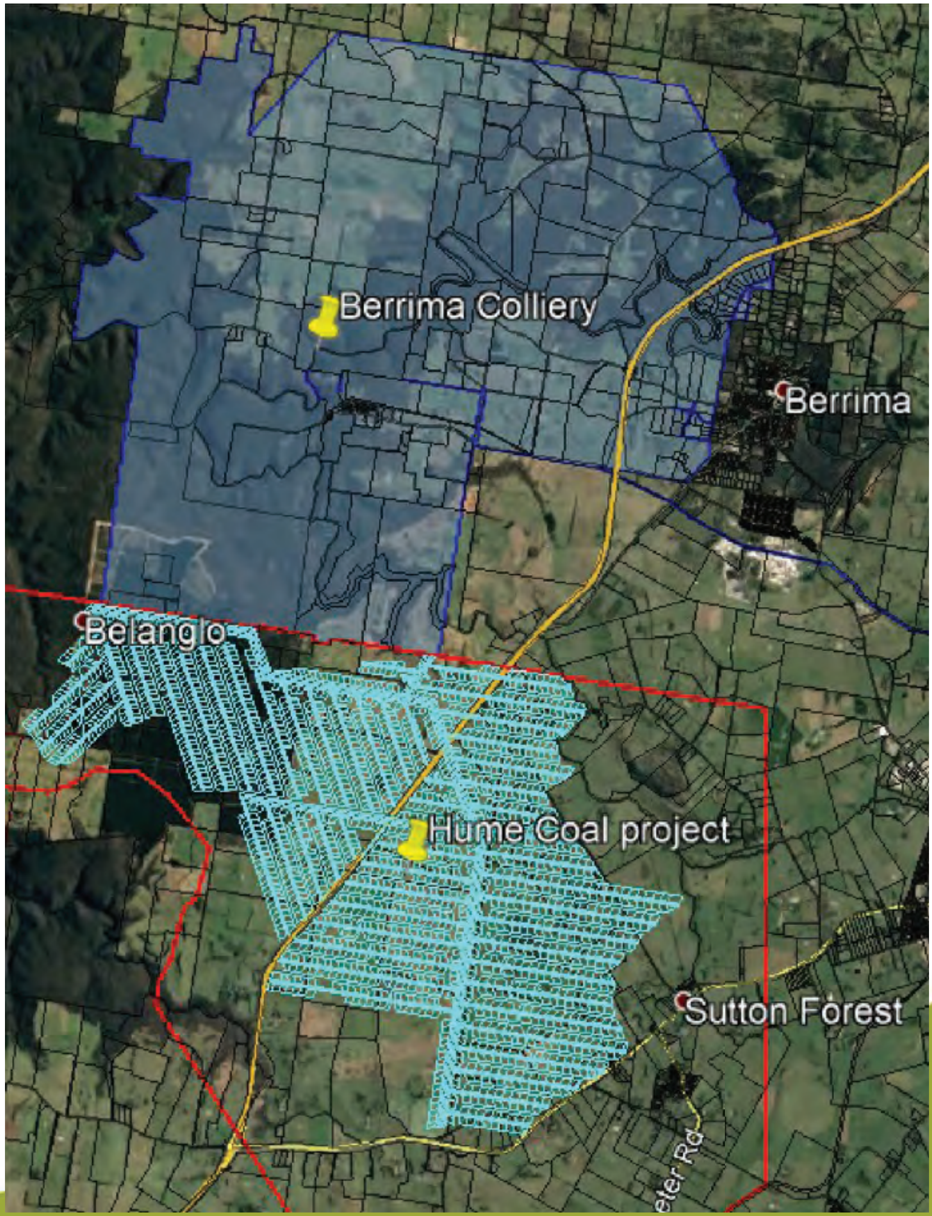
APPENDIX B

Extract from Experts Meeting Presentation: Berrima Subsidence Data

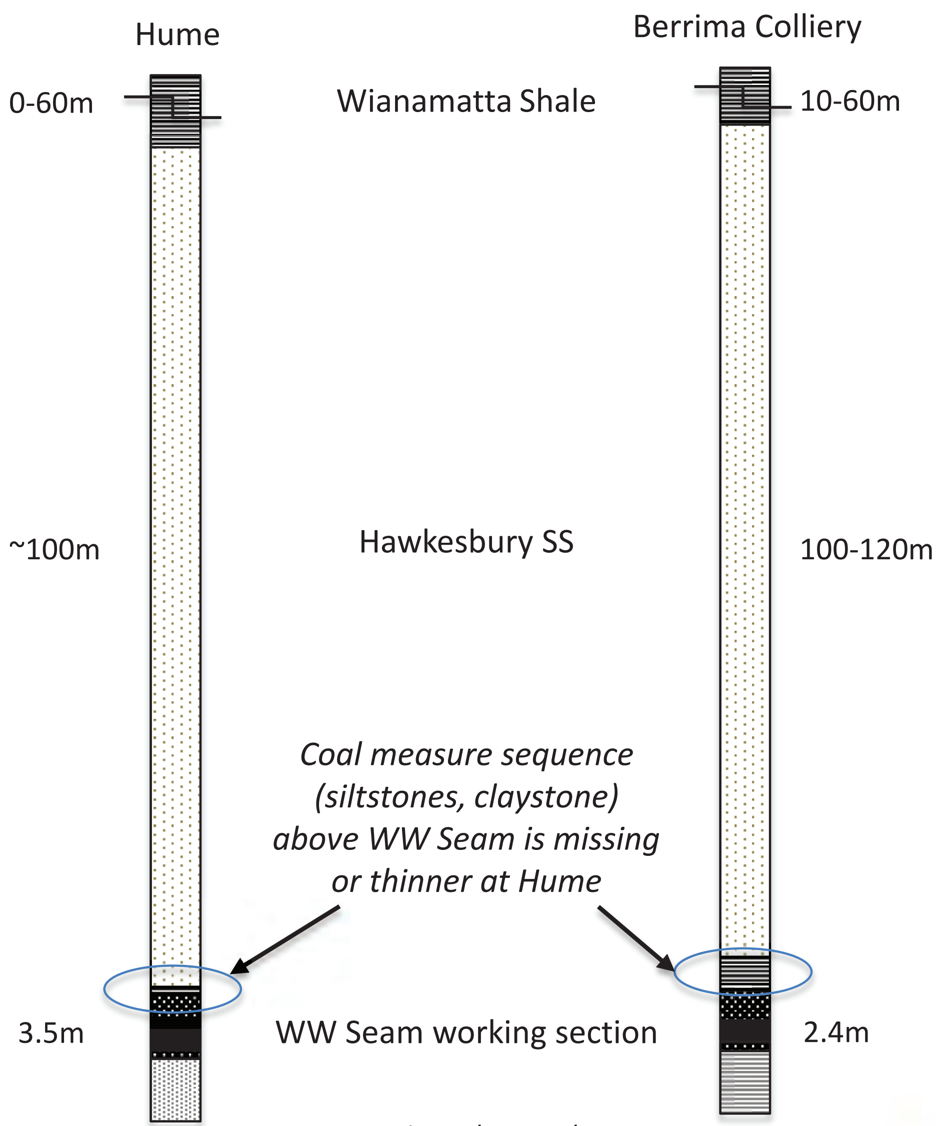
Model Calibration

Berrima Colliery calibration

- Berrima Colliery is immediately to the north
- Similar lithology (see following slide)
- Hume Coal analysed three recent subsidence cross lines
- Full extraction panels, W/H ratios 0.71-0.78
- Hume Coal range is 0.32 - 0.71

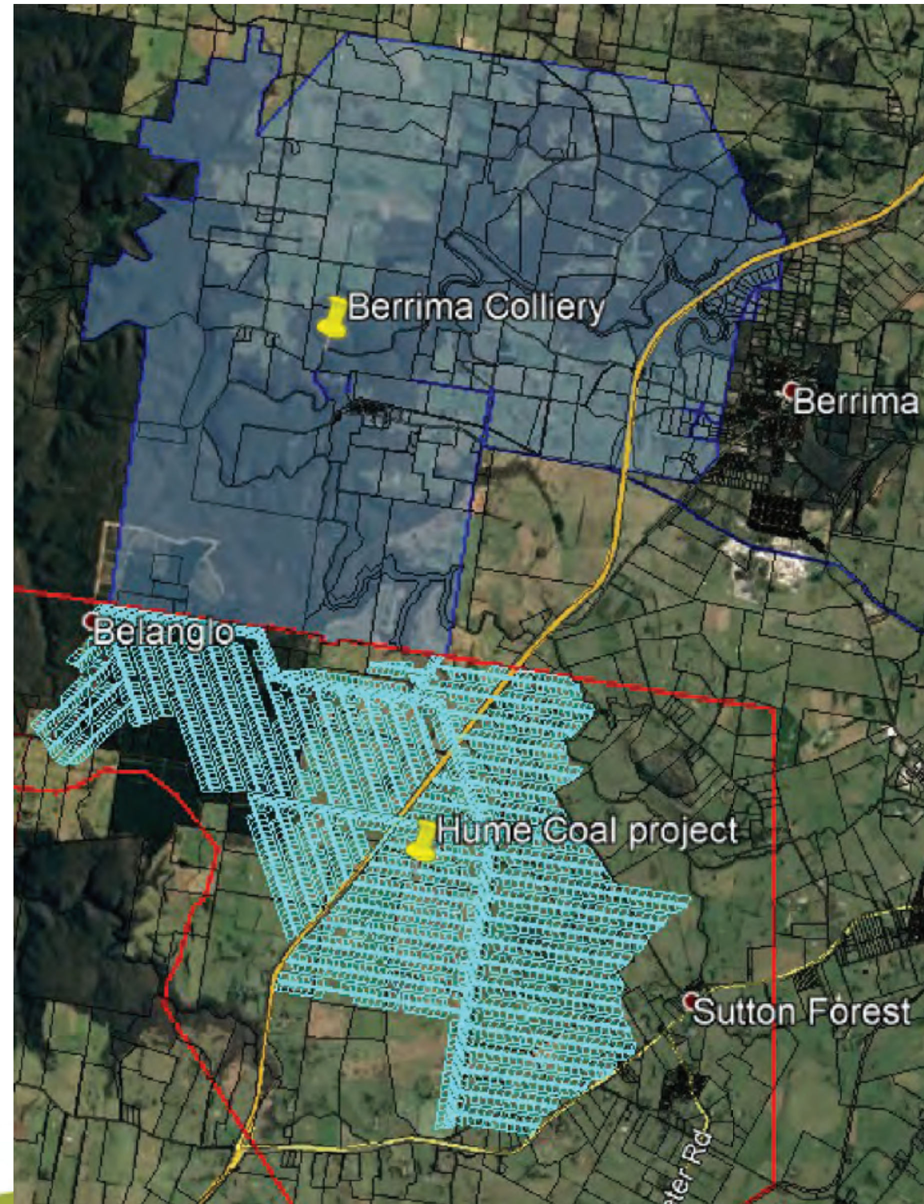


Typical geology



approximately to scale

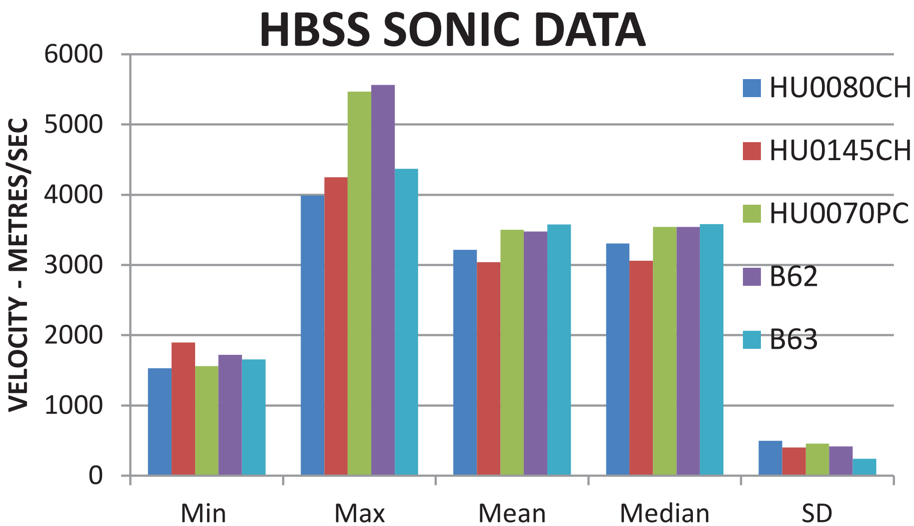
Source: Ditton (2009)

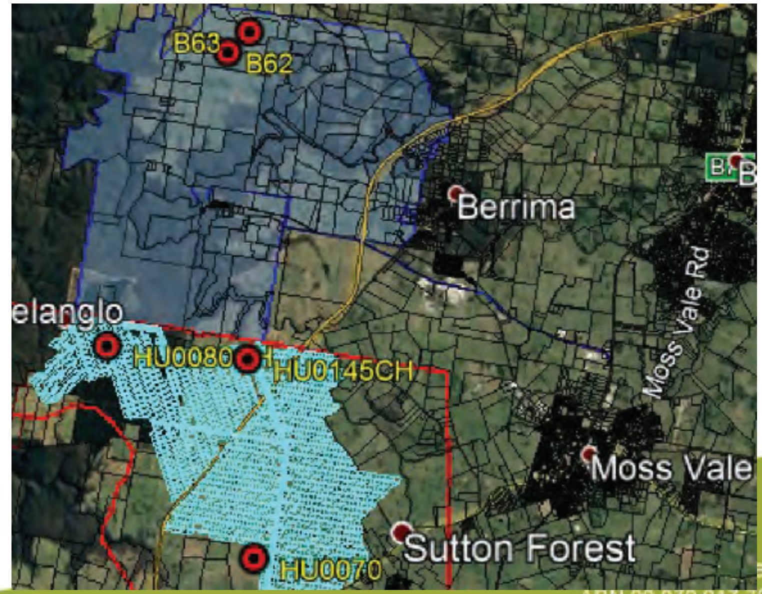


HBSS properties

- No direct UCS or modulus measurements on HBSS at Berrima, however
- Two bores with sonic logs in proximity to recent Berrima workings – B62 and B63
- Compared to three randomly selected Hume bores (080, 145 and 070)
- similar median sonic velocities at both Berrima and Hume

There are many published papers relating P-wave sonic velocity to elastic modulus

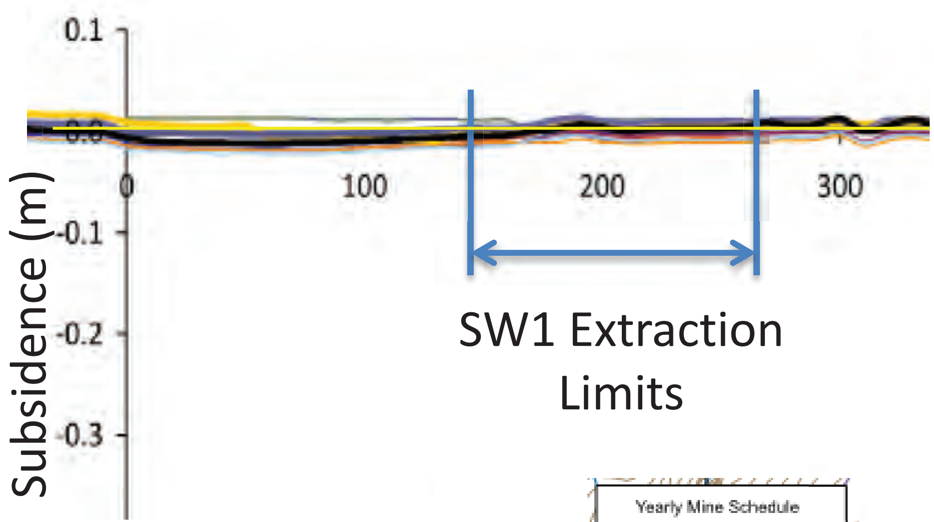


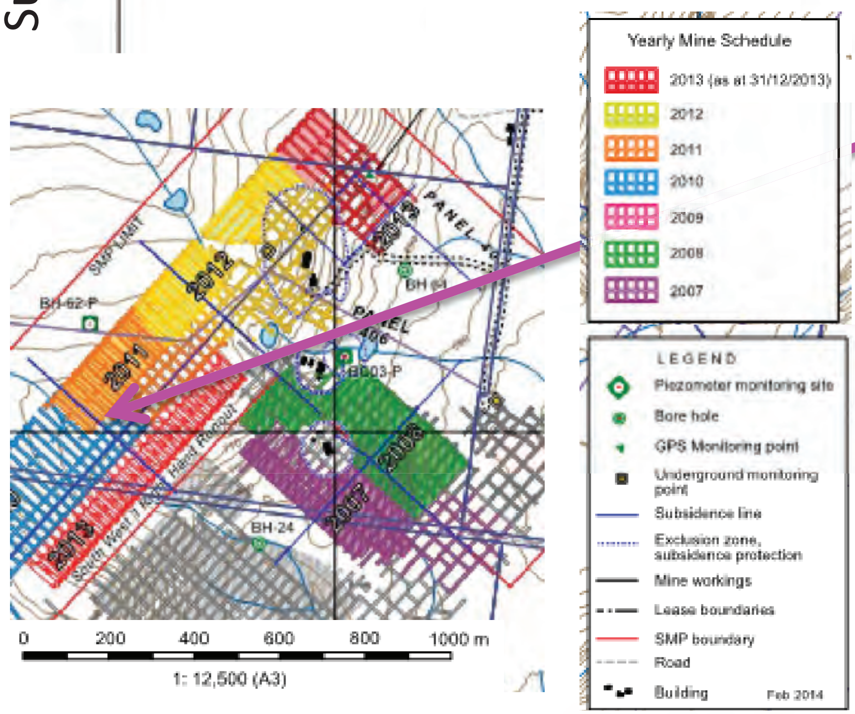


Berrima subsidence monitoring

- 404 panel extraction limits
- 404 panel cross line
- Southwest 1 panel extraction limits
- Southwest 1 Panel cross line 1
- Southwest 1 Panel cross line 2
- Dykes/Faults

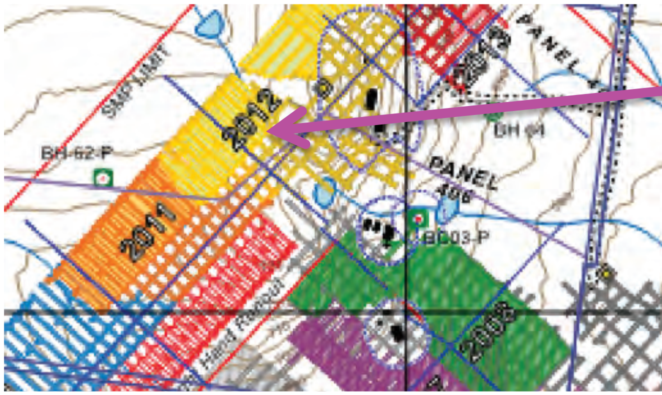
Berrima Colliery SW1 Cross Line 1



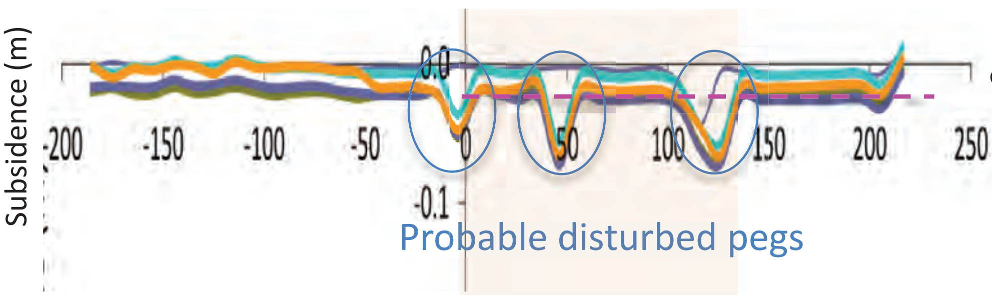


- Southwest 1 Panel was mined between 2010 and 2013
- 120m wide, full extraction panel
- Nominal mining height 2.4m
- Cross line 1 was mined through in early Jan 2011
- Figure opposite covers the period of mining up until November 2011
- 2013 mining (shown in red) is excluded from the analysis
- No discernible centreline sag

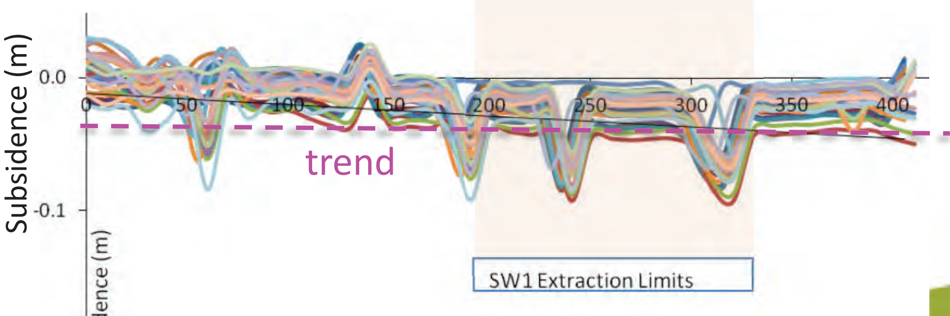
Berrima Colliery SW1 Cross Line 2



Pre-mining surveys – 2011:

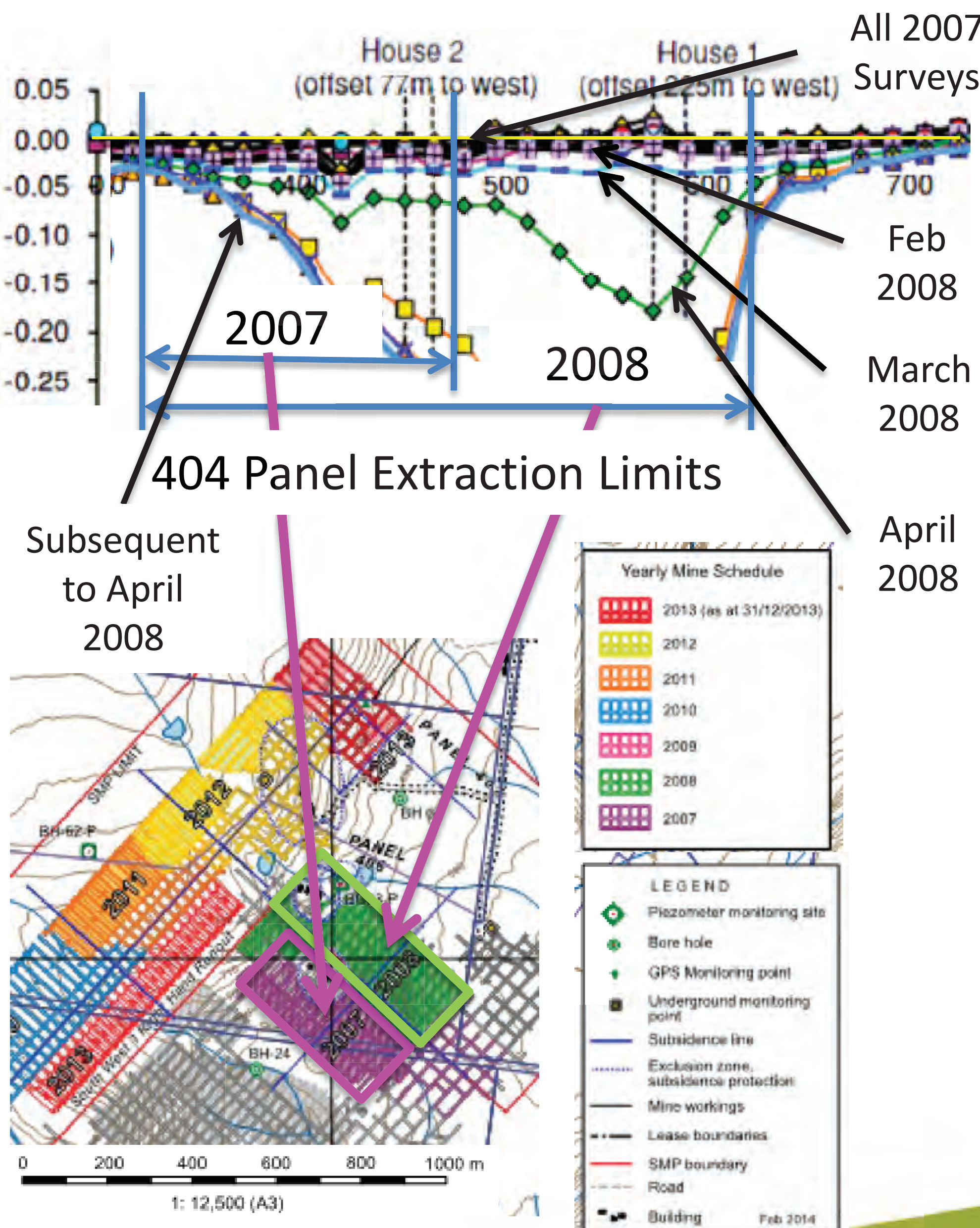


All surveys up to 18 months post-mining:



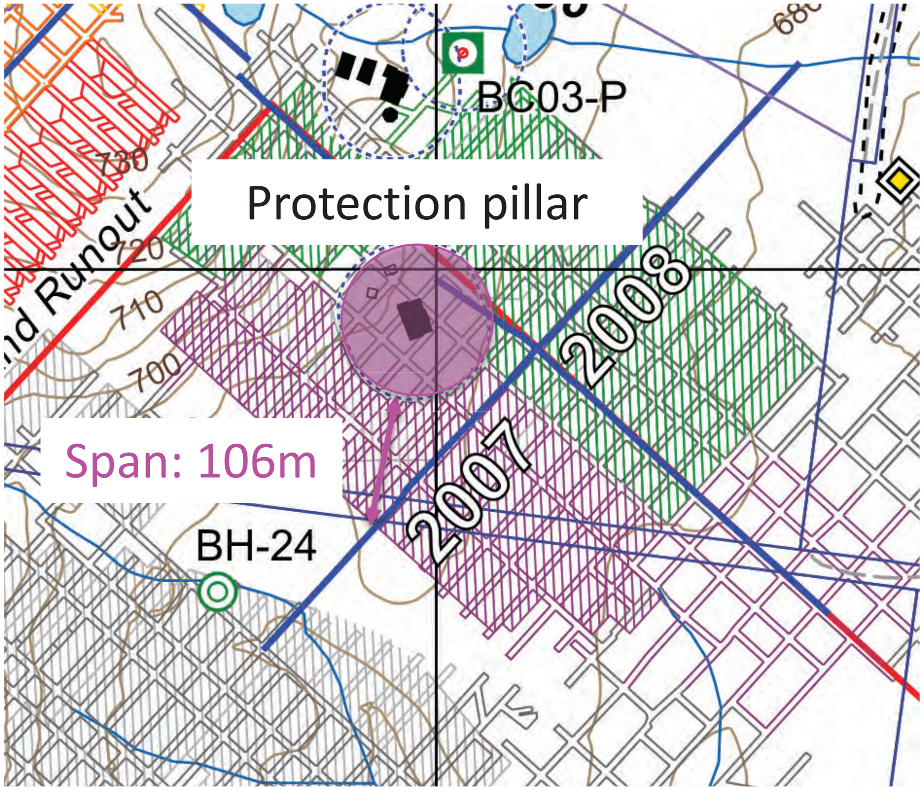
- Cross line 2 was mined through in 2012
- Anomalous results in the **pre-mining** survey suggest survey error, peg damage and/or natural causes
- Approx 30mm of settlement, (excluding probable disturbed pegs). Nearly all of this occurred pre-mining; and
- No discernible centreline sag –see linear trend

Berrima Colliery 404 Panel



- First mined in 2007 and widened in 2008
  - **2007: 160m wide**
  - 2008: widened to 320m
- Figure opposite shows surveys until Dec 2010
  - We are ONLY interested in subsidence that occurred in 2007 **prior to widening**
- Key monitoring series are marked with arrows.
- No discernible movement until Feb/March 2008

Berrima Colliery 404 Panel



- Panel has a protection pillar close to the subsidence cross line
- Taking this into account, minimum panel span is 106m

APPENDIX C

Extract from Experts Meeting Presentation: Berrima Subsidence Data Analysis

Observation summary for numerical model calibration

Panel cross line	Mining Height (m)	Void width (m)	Mining Depth (m)	Width to depth ratio	Max CL Sag (mm)
404 panel (prior to widening in 2008)	2.4	106	135	0.78 (min)	~10 nom.
SW1 cross line 1	2.4	120	160	0.75	~10 nom.
SW1 cross line 2	2.4	120	170	0.71	~10 nom.

This demonstrates the potential spanning ability of the overburden and retention of overburden stiffness across total extraction panels of widths in the order of twice those being planned at Hume

Elastic modulus

- The two key parameters in LaModel are the overburden Young's Modulus (E) and layer thickness (t)
- According to Professor Heasley it is appropriate to use laboratory modulus values
- Hume Coal has analysed a dataset of 15 tests of modulus for the HBSS

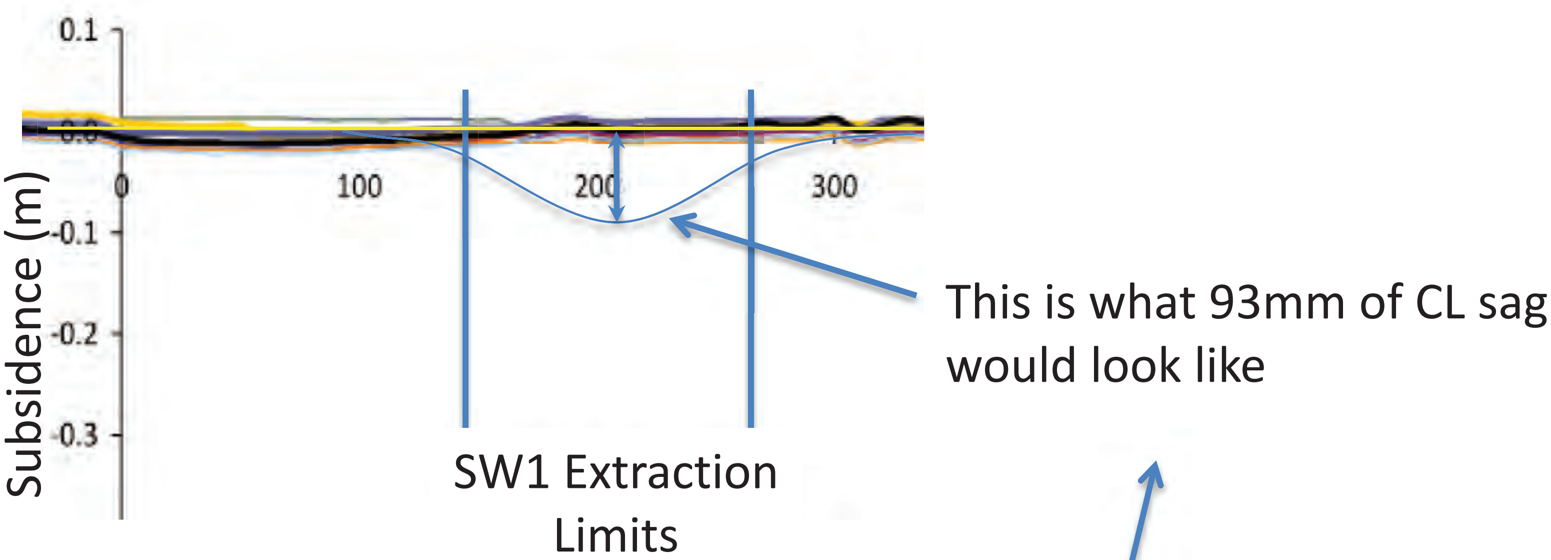
Young's Modulus (E)	Value
Min	8.2
Average	16.5
Max	23.2
n	15

Calibration results - LaModel

- Calibration performed for overburden modulus and layer thickness
- To obtain measured Smax, t needs to be large
  - NB: the depth of cover at Berrima is around 160m, so t = 200m is not possible
- Examples of E, t combinations from calibration:

E (Gpa)	t (m)	Smax (mm)
16.5	200	9.2
23.2	200	7.5
16.5	30	93.1

Calibration results



E (Gpa)	t (m)	Smax (mm)
16.5	200	9.2
23.2	200	7.5
16.5	30	93.1

Therefore beam thickness calibrates a lot higher than 30m.
But 200m is thicker than the entire 165m overburden unit…

Effect of t and E in LaModel

- t, E are multiplicative:
  - t = 20 and E = 8 will give the same result as t = 10 and E = 16
- E = 16.5 and t = 200 multiplies out to 3300
  - E = 20 and t = 165 would provide the same result

t (m)	E (GPa)	t x E (GN/m)	De-rating from LaModel Calibrat'n
20	8.2	164	5% (20.1 x de-rating)
20	16.5	330	10% (10.0 x de-rating)
20	23.2	464	14% (7.1 x de-rating)
40	16.5	660	20% (5.0 x de-rating)
40	23.2	928	28% (3.6 x de-rating)

Effect of E and t in the model

- What is an appropriately conservative de-rating from the calibration?
- We have de-rated the overburden stiffness to between **5%** and **28%** of the calibrated value

APPENDIX D

Copy of Mine Advice 2020

MINE ADVICE
A.B.N. 15 152 928 222

HUME COAL PTY LTD
HUME COAL PROJECT

Assessment of Plunge Breakaway Roof Stability As a Function of Varying Heading Width

JANUARY 2020

REPORT: HUME22/2

Unit 7, 17 Babilla Close
BERESFIELD, NSW 2322
TEL: (02) 4088 0600 FAX: (02) 4028 6342
E-MAIL: admin@mineadvice.com

REPORT TO :	Greig Duncan Project Director Hume Coal Project
REPORT ON :	Assessment of Plunge Breakaway Roof Stability As a Function of Varying Heading Width
REPORT NO :	HUME22/2
REFERENCE :	Your instructions to proceed
PREPARED BY :	Russell Frith
REVIEWED BY :	Trephon Stambolie and Client Representatives
DATE :	9th January 2020

....

Russell Frith
Senior Principal Geotechnical Engineer
FAusIMM(CP) RPEQ

Disclaimer

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Executive Summary

EXECUTIVE SUMMARY

A high-level geotechnical assessment and design study has been undertaken addressing the specific issue of plunge breakaway roof stability both during and post-plunging when working the Parting Band Working Section (PBWS), the main assessment variable being the as-driven heading width prior to plunging.

The geotechnical characterisation has been based on determining CMRR's and related geotechnical parameters that are relevant to roadway roof stability from nine surface boreholes, and a review of the currently available *in situ* stress measurement data for the Hume Project area.

Heading widths of 5.5 m and 6.5 m have been analysed for typical or generic primary roof support requirements, with respective plunge breakaway geometries for both heading widths being supplied by the client. The geotechnical analyses indicate that whilst a wider heading is advantageous in terms of the overall stability of plunge breakaways, some form of additional roof support in addition to primary roof bolting will likely be required in order to reliably maintain heading serviceability during post-plunging rejects emplacement operations.

Driving 6.5 m wide headings will inevitably require the use of a double-pass CM with a head-width likely in the order of 3.3 m, rather than a single-pass wide head CM which could be used at a heading width of up to 5.5 m. This then generates the potential for the same CM to be used for both panel development and subsequent plunging (albeit with bolting rigs removed), as compared to the use of single-pass wide head CM for heading development so that plunging would require a separate CM due to the narrower plunge widths involved.

Driving headings (potentially in all development roadways) up to 6.5 m wide and using a narrow-head CM for both development and plunging, would inevitably result in different heading and plunge widths from those assumed as part of the EIS layout design assessment and subsequent 3D numerical modelling studies that were used to comprehensively evaluate and demonstrate the required long-term stability of the remnant mine layout for subsidence impact mitigation purposes. As such, coal pillar dimensions would need to be slightly modified in order to maintain the same level of retained long-term stability for the remnant mine workings, this being a relevant consideration as and when locked-in definitive heading widths and plunge widths have been defined for use according to the actual mining equipment being procured. In the interim, it is judged that the EIS mine layout remain sufficient for any on-going subsidence impact and/or mining assessments, with the significance of any future minor changes to assumed heading or plunge widths as a result of mining equipment limitations, being immaterial variations.

1.0 INTRODUCTION

This report contains the details and outcomes of a roadway roof stability assessment for the required breakaways when forming up extended, unsupported plunges as part of the proposed mining method at Hume Coal (see Figure 1.1), which unlike intersection breakaways will remain unsupported, the adjacent heading still needing to remain serviceable for back-filling reject emplacement purposes post-plunging.

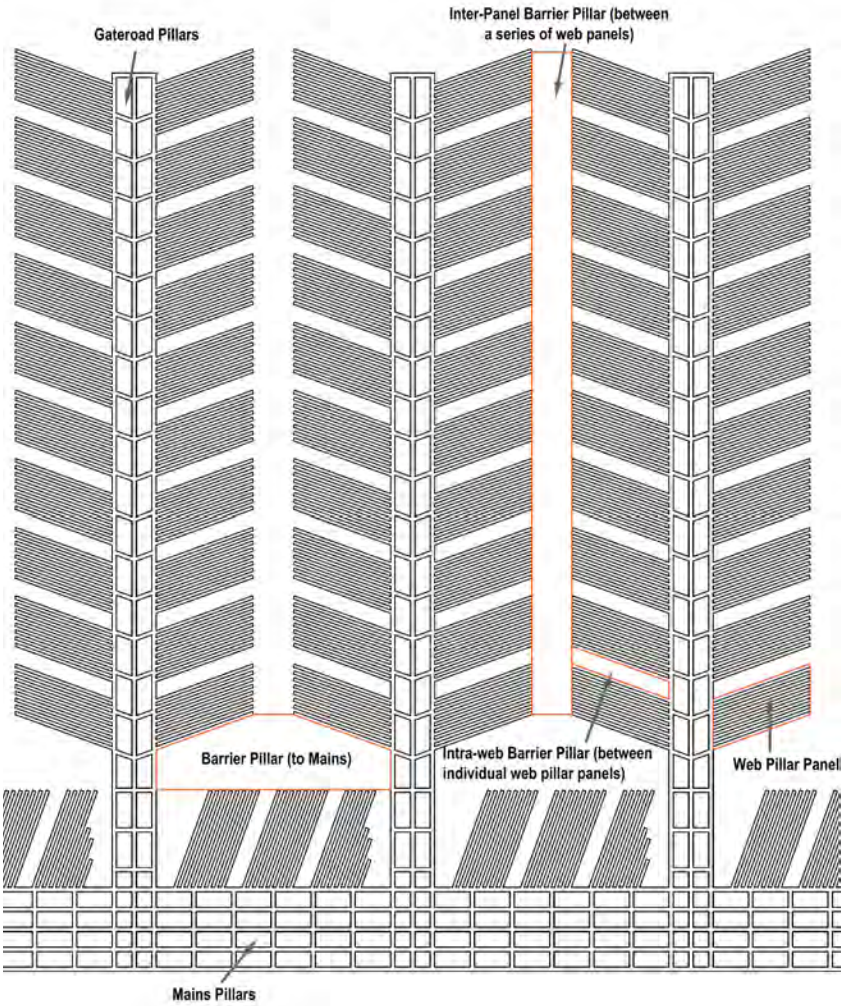

FIGURE 1.1. Basic Mining Layout including Different Coal Pillar Types

Previous formal geotechnical and mine design studies focused on justifying the overall mining layout for EIS purposes (Mine Advice 2016a), including subsidence impact assessment (Mine Advice 2016b). Design work relating to the immediate roof of the working section has consisted of CMRR calculations from a number of surface boreholes (Mine Advice 2013) and an assessment of likely roof stability in unsupported plunges (Mine Advice 2015), these both being directly related to the EIS assessment, rather than a mining feasibility. Related studies include Seedsman 2015 which evaluated place change development potential at Hume using extended plunges in 6.5 m wide roadways and associated primary roof support.

The issue of heading roof stability adjacent to plunge breakaways was raised during an independent third-party mining-systems review, the two primary concerns being:

(i) the increased heading width at the mouth of each plunge caused by the Continuous Miner (CM) turning into the plunge from the heading, termed a “breakaway” (see Figures 1.2 and 1.3 for 5.5 m and 6.5 m wide headings respectively), and

(ii) the need for headings to remain serviceable and travelable post-plunging as part of the rejects emplacement process in mined-out areas, this including roadway/plunge roof stability.

Evaluating these two mineability issues according to the geometries shown in Figures 1.2 and 1.3 for current perceived typical or normal geotechnical conditions, is the main focus of this study.

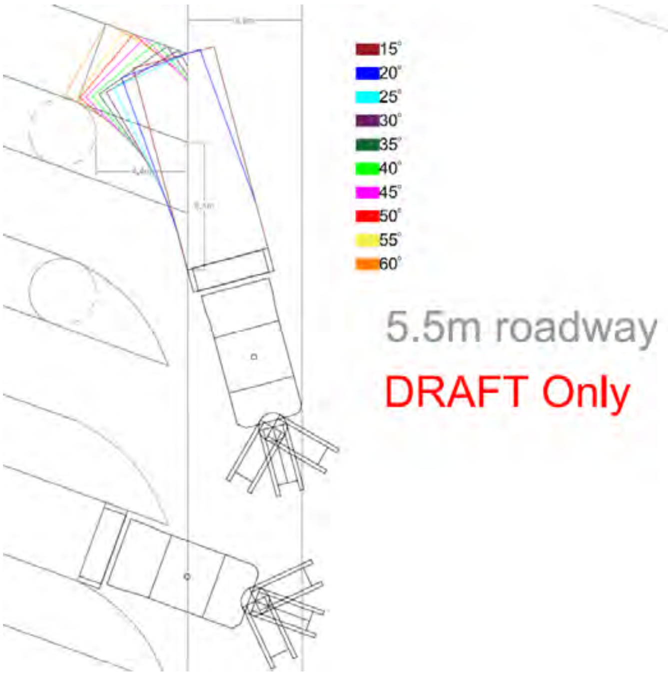

FIGURE 1.2. Plunge Breakaway Geometry for a 5.5 m Wide Heading (*client-supplied*)

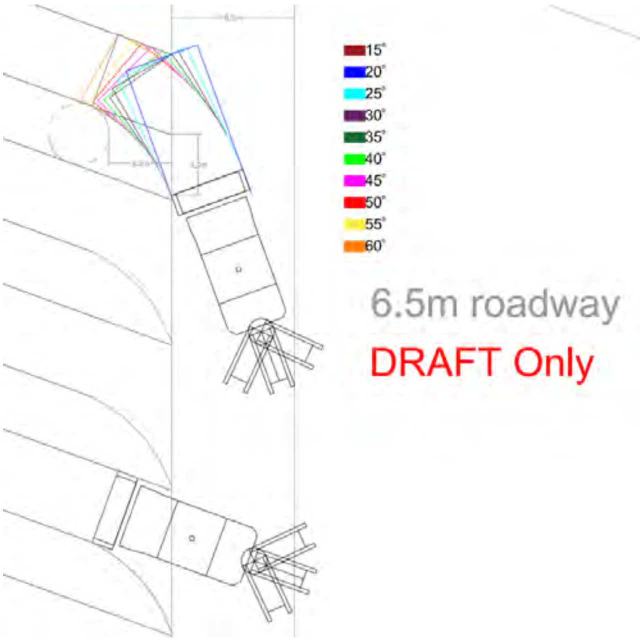

FIGURE 1.3. Plunge Breakaway Geometry for a 6.5 m Wide Heading (*client-supplied*)

It is self-evident that there are two primary and directly relevant differences between plunge breakaway geometries for 5.5 m and 6.5 m heading widths as contained in Figures 1.2 and 1.3, as follows:

(i) the breakaway can start much closer to the outbye rib line of the plunge with a 6.5 m wide rather than 5.5 m wide heading (i.e. 3.2 m versus 6.2 m respectively), this tending to minimise the amount of coal removed from the end of each web pillar between plunges (which is relevant to overall pillar stability), and

(ii) the unsupported roof area and effective span between the breakaway rib line and bolted heading roof is substantially reduced with a 6.5 m wide heading as compared to 5.5 m.

In other words, it makes logical sense to use a 6.5 m wide heading so as to maximise the post-plunging stability of the breakaways and adjacent heading, whilst also minimising the amount of remnant coal that is removed from the end of each web pillar. However, whilst this statement might be self-evident, the drivage of a 6.5 m wide heading may preclude the use of a single-pass wide-head CM, the widest known single-pass CM being an ABM30 used at Syferfontein Colliery in South Africa cutting a 6.6 m wide roadway, the widest in Australia being 5.8 m at Newlands. In other words, using a heading width > 5.5 m for the express purpose of improving plunge breakaway geometry and heading roof stability, will require either an uncommon single-pass CM or some form of double-pass development, either in-place or place change.

FIGURE 1.4. Plunge Breakaway Roof Control Zoning (6.5 m Wide Heading)

Figure 1.4 illustrates the individual roof stability “zones” within a plunge breakaway (for a 6.5 m wide heading), which will need to be considered both individually and in combination as part of this assessment, namely:

(a) supported development (initial) heading (Zone 1),

(b) 4m wide unsupported plunge (Zone 2), and

(c) unsupported plunge breakaway area (Zone 3).

The primary focus of this study is the unsupported and irregularly-shaped Zone 3, it being the link between the 4 m-wide unsupported plunges and the supported previously-driven heading. On its own it needs to typically remain stable during the formation of the breakaway and subsequent mining of the plunge. In addition, the following roof stability outcomes are required for the mining plan to operate as intended:

(i) the 4 m wide unsupported plunge needs to remain suitably stable during mining of the plunge and ideally undergo minimal longer-term roof instability primarily for pillar stability reasons, and

(ii) the combined heading (Zone 1) and unsupported breakaway area (Zone 3) need to remain stable post-plunging to allow persons to continue to access the heading for rejects emplacement purposes.

Each of these three roof stability scenarios will be considered by this study for further project consideration.

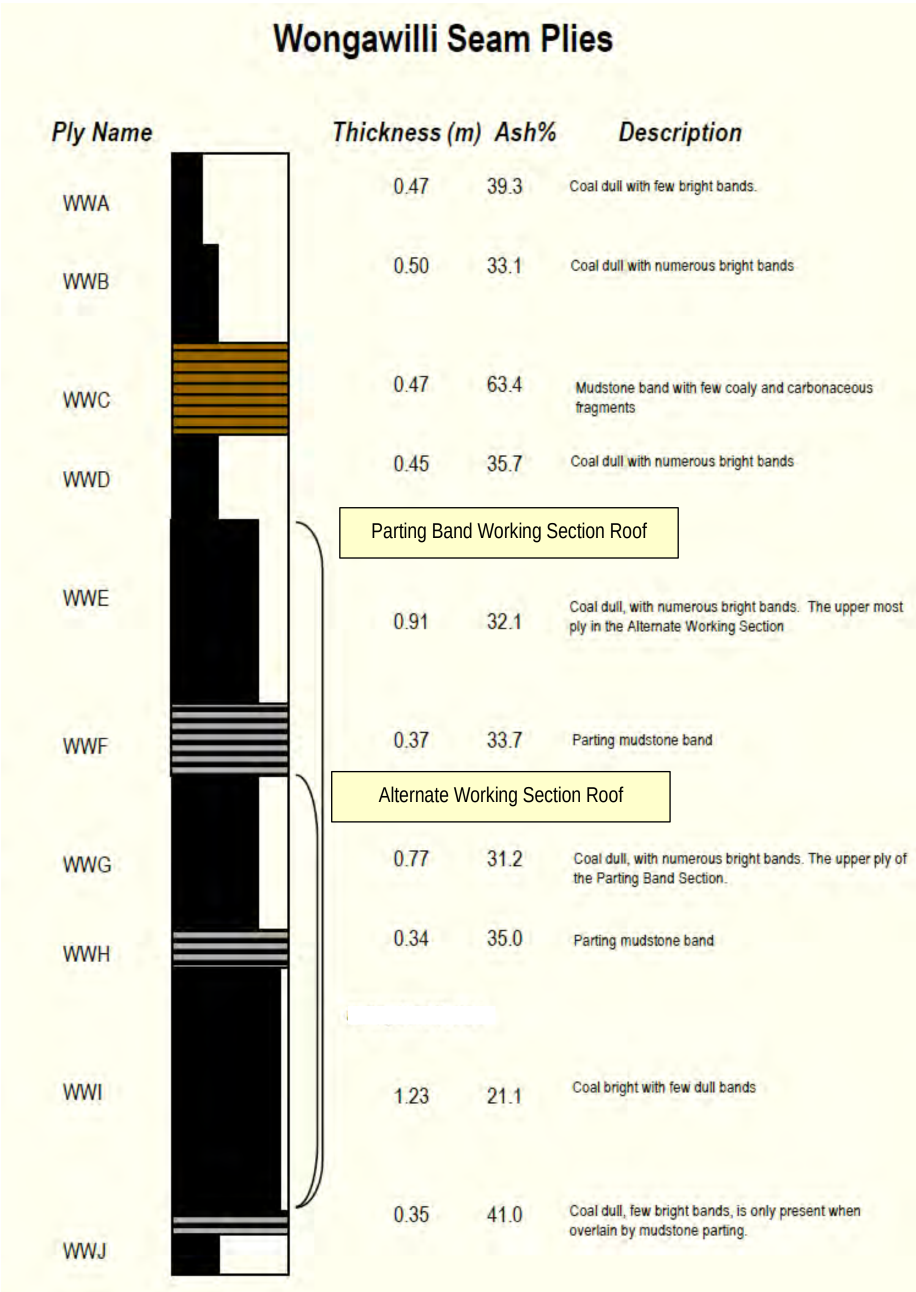

FIGURE 1.5. Generic Wongawilli Seam Plies and Hume Project Working Sections

Figure 1.5 illustrates the two development and plunge working sections (Parting Band or PBWS and Alternate or AWS) that are under consideration, the PBWS (to the base of the WWD Ply) being relevant to the majority of the mining area, hence it is the sole focus of this study.

2.0 GEOTECHNICAL CHARACTERISATION

As with all geotechnical assessment and design works, the credibility and reliability of the outcomes is strongly linked, at least in part, to the geotechnical characterisation inputs in terms of both their relevance and number. This study will utilise the following geotechnical inputs to evaluate roof stability and/or primary roof support for each of the defined roof zones:

- Supported Zone 1 at varying heading widths: Coal Mine Roof Rating (CMRR) for an assumed 1.7 m thick bolted interval (1.8 m long bolt) and the maximum horizontal stress acting within the bolted interval, σ_H.
- Unsupported Zone 2 at a width of 4 m: CMRR for an assumed 1.7 m thick bolted interval (1.8 m long bolt) for global stability supplemented with beam characteristics of the WWD ply for local or skin stability, in conjunction with the maximum horizontal stress acting within the bolted interval, σ_H.
- Unsupported Zone 3 at varying widths according to different heading widths (see Section 2.1): CMRR for an assumed 1.7 m thick bolted interval (1.8 m long bolt) for global stability supplemented with beam characteristics of the WWD ply for local or skin stability, in conjunction with the maximum horizontal stress acting within the bolted interval, σ_H.

Prior to describing the various geotechnical inputs, it is necessary to outline how the effective width (w_e) has been calculated for Zone 3 according to the two heading widths of 5.5 m and 6.5 m.

2.1 Effective Span for Zone 3

Galvin *et al* 1998 present two methods whereby the effective width of a pillar or excavation can be estimated. A basic approach is given in Equation 2.1 and that using the concept of Hydraulic Radius or Diameter is given in Equation 2.2.

$$w_e = \sqrt{(w_1 \times w_2)} \quad [2.1]$$

where:

w_e = effective width,

w_1 = minimum pillar dimension

w_2 = maximum pillar dimension

$$w_e = 4 \times A_p/C_p \quad [2.2]$$

where;

A_p = pillar area

C_p = pillar perimeter

Given the non-uniform and irregular shape of Zone 3 as illustrates in Figure 1.4, it is considered that the Hydraulic Radius approach is more appropriate as given by Equation 2.2. Based on the ACAD drawings provided, it is found that the area of Zone 3 for a 5.5 m wide heading is 27.38 m^2 and the perimeter is 23.28 m, resulting an effective width, w_e, of 4.70 m. For a 6.5 m wide heading, the area of Zone 3 reduces to 19.78 m^2 and the perimeter to 21.11 m, the effective width, w_e, reducing to 3.75 m. These two values of effective width will be utilised by the study in assessing unsupported roof stability within Zone 3.

2.2 Coal Mine Roof Ratings for the PBWS

Mine Advice 2013 determined CMRR values from a number of surface boreholes for the PBWS to the base of the WWD Ply using a 1.8 m long roof bolt. The results of a review of that work are now provided for reference purposes, specifically for those surface boreholes that contain all or most of the Wongawilli Seam (WWS) above the WWE Ply (top of PBWS) such that the working section roof environment is dominated by the WWD Ply and overlying in-seam coal/stone material, rather than those boreholes that contain a clearly washed-out or eroded top section of the WWS.

FIGURE 2.1. Example of Coal Material Broken Up by Over-Drilling (HU60)

FIGURE 2.2. Example of Coal Material Broken Up at a Core Run End (HU83)

FIGURE 2.3. Example of Coal Material Broken Up Around a Vertical Joint/Cleat (HU65)

Unlike most stone material, a number of considerations need to be applied to the analysis of coal-based borecore due to external factors that might adversely influence the state of the core so that it is not representative of actual *in situ* conditions, these being:

(i) over-drilling whereby inadvertent excessive feed rates have been used when coring through the coal, this tending to substantially break-up the coal such that its visible state in the core barrel split is unrepresentative of its *in situ* condition (see Figure 2.1 as an example).

(ii) the start or end of a core run whereby the process of removing the split-tube can have a detrimental effect on the condition of adjacent coal material (see Figure 2.2 as an example).

(iii) as a well-jointed/cleated material, the presence of distinct vertical cleating within the coal can result in the adjacent coal to break up as compared to its *in situ* condition (see Figure 2.3 as an example).

It is important to be aware of these detrimental influences on the condition of coal and other weaker material when determining rock mass ratings such as the CMRR, the guiding principle being that competent *in situ* material can always be broken-up by the drilling process, however fractured *in situ* material cannot be made more competent by the drilling process. Accounting for these external influences on core condition requires a level of engineering judgement to be applied during the rock mass assessment process.

Of the 19 surface boreholes from which CMRR values were derived and reported in Mine Advice 2013, 12 contain a thick coal sequence above the top of the WWE ply/base of WWD ply, this being the assumed development and plunge roof line for the PBWS. Of these 12 boreholes, 3 were discarded as either being substantially over-drilled throughout much of the coal seam section or the quality of the split-tube photos did not allow reliable fracture logs to be produced and/or checked. This left 9 boreholes (boreholes HU64, 65, 67, 71, 75, 78, 82, 83, and 85) from which credible and meaningful CMRR values have been derived, the average CMRR being 39.4 (ranging from 36.2 to 47.0).

These CMRR outcomes will be used for assessment and design purposes later in the report.

Appendix A contains split-tube core photography of the lower section of the PBWS bolted interval from each borehole for reference purposes.

2.3 In Situ Horizontal Stresses

As part of a roadway roof stability assessment, the likely magnitudes of the horizontal stresses acting within the immediate roof strata, including the bolted interval, need to be estimated on a credible basis.

The individual measurement outcomes and associated material properties of the test locations have been evaluated using the basic model of Colwell and Frith 2012 (developed from Nemcik *et al* 2005) where the *in situ* horizontal stresses are sub-divided into a depth of cover and tectonic component. It is the tectonic component that is of most interest when characterising a mining area, particularly at shallow cover depth, with the level of horizontal stress increasing in direct line with the Young's Modulus of the host material. The rate of stress rise with increasing Young's Modulus is defined as the "Tectonic Stress Factor" (TSF), this in effect being a direct measure of the horizontal "tectonic strain" contained within the rock mass.

An estimation of the complete typical 3D virgin or *in situ* stress condition at any location (including within a coal seam) can be obtained by knowing the cover depth, Tectonic Stress Factors for the major and minor horizontal stresses and the Young's Modulus (E) of the strata type in question. The relevant equations are as follows:

$\sigma_H = \sigma_v .(v/1\text{-}v) + E.TSF_H$ [2.1]

$\sigma_h = \sigma_v .(v/1\text{-}v) + E.TSF_h$ [2.2]

$\sigma_v = p.g.h$ [2.3]

where:

σ_H = major horizontal stress

σ_h = minor horizontal stress

v = Poisson's Ratio

E = Young's Modulus

TSF = Tectonic Stress Factor (H = major and h = minor)

σ_v = vertical stress as given by weight of overburden considerations

(v/1-v) = numerical determination of K_o.

These equations can facilitate the back-analysis of *in situ* stress measurement data to determine site-specific values for TSF_H and TSF_h.

The nature of the *in situ* horizontal stresses both above and below the Wongawilli Seam has been estimated from drill hole HU0040 where *in situ* stress measurements were taken using the wireline overcore method of Sigra Pty Ltd, as summarised in Table 2.1 (Sigra 2012).

Test Depth (relative to Wongawilli Seam)	Tectonic Major Horizontal Stress (MPa)	Tectonic Minor Horizontal Stress (MPa)	Young's Modulus (GPa)	Unconfined Compressive Strength (MPa)
101.49 m (Roof 1)	7.92	4.08	12.9	24.3
111.8 m (Roof 2)	9.88	7.96	22.2	62.2
123.63 m (Floor)	8.81	7.01	22.8	83.5

TABLE 2.1. Stress Measurement Data from Drill Hole HU0040 (as reported by Sigra 2012)

Project-specific TSF values have been determined for both the major and minor horizontal stresses. The TSF_H is the gradient of the linear best-fit line when plotting the tectonic major horizontal stress against the Young's Modulus (when forced through the origin). The TSF_h is TSF_H multiplied by the gradient of the linear best-fit line plotting the tectonic major horizontal stress against the tectonic minor horizontal stress (when forced through the origin).

The key *in situ* horizontal parameters determined for the Hume Project area from drill hole HU0040 are summarised as follows:

- Tectonic Stress Factor for the major horizontal stress (TSF_H) = 0.44
- Tectonic Stress Factor for the minor horizontal stress (TSF_h) = 0.44 x 0.73 = 0.31

It is recognised that a small number of horizontal stress measurements from one surface borehole do not on their own, fully characterise the *in situ* horizontal stress environment across any given mine. In fact, no underground coal mine ever has the same density of borehole derived stress measurement data available as compared to rock strength characteristics and associated rock mass rating data. Therefore, this is a limitation of all feasibility type assessments for underground mining.

Location	Major Tectonic Stress Factor Range (average)	Major to Minor Conversion Factor Range (average)
NSW Southern Coalfield	0.7-1.4 (1.04)	0.46 – 0.82 (0.68)
NSW Newcastle Coalfield	0.84-0.84 (0.84)	0.65-0.69 (0.67)
NSW Western Coalfield	0.75-0.94 (0.81)	0.6-0.75 (0.67)
QLD German Creek/Lilyvale Seam	0.47-0.7 (0.6)	0.47-0.58 (0.54)
QLD Rangles Measures	0.46-0.56 (0.51)	0.48-0.55 (0.52)
QLD Moranbah Measures	0.64-0.66 (0.65)	0.54 (0.54)
HUME COAL - HU0040	0.44	0.73

TABLE 2.2. *In Situ* Horizontal Stress Parameters for Various Coalfields Compared with HU0040

The main point of including stress measurement data in detail is to allow a direct general comparison with the same fundamental horizontal stress parameters from other parts of the NSW Southern Coalfield and other coalfields more generally. As a minimum, this provides context as to the potential significance of the locked-in horizontal tectonic strains within the overburden at Hume. Referring to Table 2.2, each coalfield has a range of *in situ* horizontal stress characteristics and there are marked differences between coalfields, particularly between NSW and QLD coalfields.

The most relevant aspect of the Hume horizontal stress data is that the value of TSF_H is substantially below the range for the NSW Southern Coalfield more generally and, in fact, other coalfields in NSW. This apparent anomaly is judged to likely be a direct function of the Wongawilli Seam outcropping nearby to the west and south-east in deeply incised gorges which like the Wollongong Escarpment (located many kilometres to the east) are an obvious source of tectonic strain relief over geological time.

It is noted that a low value of TSF_H provides a possible explanation for the substantially more benign roadway strata conditions at the adjacent Berrima Colliery than those present in many other current mining areas of the NSW Southern Coalfield.

In terms of the direction of the major horizontal stress, the three measurements generally agree on the orientation of the major component of horizontal stress being approximately north-south (010°-190°).

2.4 Beam Characteristics for the WWD Ply

The assessment of the stability of unsupported roof spans needs to consider two different instability magnitudes:

(i) localised instability of the immediate roof skin (in the order of 0.5 m) which primarily effects ROM dilution, as opposed to

(ii) global instability across the full roadway width whereby several metres of roof material might become unstable and collapse, this being sufficient to stop the mining process in both roadway development and plunging.

Point (ii) can be catered for by the application of the CMRR, which by definition is linked to the thickness of the bolted interval. In contrast, point (i) is entirely linked to the immediate 0.5 m or so of roof strata, which whilst included in the CMRR calculation can be mis-characterised by the CMRR according to the structural competence of the remainder of the bolted interval, such that the CMRR value is not necessarily indicative of the "strength" of the initial 0.5 m of roof strata.

The approach used by Mine Advice in this regards to point (i) is to evaluate the immediate 0.5 m or so of roof strata for "beam action" potential, this then being analysed as a direct function of (a) the unsupported roof span, (b) the magnitude of the Tectonic Stress Factor (which dictates the significance of horizontal stress) and (c) the anisotropic nature of the material, this being a measure of the difference in strength horizontally (which is of direct relevance to roadway roof stability) as compared to vertically (which is how roof strength is typically measured both in the laboratory and axial point load testing of core).

The fundamental measure of beam action potential in any section of roof strata is taken to be the logged fracture spacing, this being based on the horizontal planes of weakness that are demonstrably "open" in the split-tube following coring, it being assumed that these are the weakest such planes and therefore the most likely to immediately open up during roadway development.

Each of the 9 boreholes from which CMRR values have been derived, have been assessed for "beam action" potential in the initial 0.5 m or so of immediate roof strata, this typically being related to WWD Ply coal. Appendix A contains photographs of the relevant core sections for each borehole, the objective being to use this information to make an overall judgement as to typical beam action potential in the immediate roof strata, having taken account of and eliminated any sections of core that are adversely influenced by external factors that will not be relevant in the mine, as discussed previously.

Comments on specific cored sections of immediate roof strata in Appendix A that are relevant to this assessment are as follows:

- HU65: the coal in the upper photograph has clearly broken down whilst in the split-tube, even though parts of the same section appear intact in the lower photo. This is likely a joint/cleat effect which requires due consideration.

- HU67: the immediate roof has been picked at the base of a thicker stone band, which is quite friable. The WWD coal is relatively undisturbed above this.

- HU82: the WWD coal is at the end of one and the start of the next core run, hence its more broken/fractured state.

- HU83: a combination of the start of a core run and local jointing/cleating within the core are influencing the fractured state of the coal.

Having taken account of the above-listed external influences as to the state of the core, the overall assessment is that the WWD coal ply, which typically represents the initial 0.4 m to 0.5 m of immediate roof strata, can be characterised by a minimum beam thickness in the order of 0.2 m, this being used in the various roof skin stability analyses in Section 3.

3.0 GEOTECHNICAL ANALYSES

The geotechnical characterisation of the immediate roof strata above the PBWS at Hume, has determined the following geotechnical parameters for use in the various roof stability and roof support analyses defined earlier in the report:

- typical CMRR = 39.4
- minimum typical logged fracture spacing or coal "beam" thickness = 200 mm
- assumed UCS for the bolted interval = 14 MPa (based on site data and comparable data from other sites)
- assumed Young's Modulus E for the bolted interval = 3 GPa (based on site data and published information)
- assumed Poisson's Ratio v for coal = 0.25
- Anisotropy Ratio for the bolted interval = 2 (conservative value based on the visible condition of borecore and substantial point-load testing of comparable material from other sites)
- maximum cover depth = 170 m
- Tectonic Stress Factor for the major horizontal stress, TSF_H = 0.44
- Using Equations 2.1 and 2.3, it is found that the maximum horizontal stress in the coal-dominated bolted interval at the maximum depth of 170 m is 2.74 MPa.

These geotechnical inputs will be applied as required in the various stability analyses that are now presented.

3.1 Zone 1 (Initial Driven Heading)

The initially-driven heading from which plunges will be formed is being assumed to be driven at a width of either 5.5 m or 6.5 m, the analyses herein estimating likely required primary roof support for development purposes.

A significant design input is the type of roof bolting system being used as individual roof bolting effectiveness directly influences the bolting density required to achieve a desired roof stability outcome in any given set of roof conditions. A choice can be made between the standard industry practice of fully-encapsulated bolts (FE bolts) using small diameter holes (< 28 mm) and oil-based 15:1 resins, and partially-encapsulated bolts (PE bolts) using larger diameter holes (> 28 mm) and water-based US-style 2:1 resins, both of which find current industry use.

This report will not provide a detailed discussion as to the various differences between the two bolting systems, other than refer the reader to Frith *et al* 2018 which outlines some of the fundamental issues involved. It will however provide generic designs for both systems for reference purposes.

For FE bolts, the most relevant industry database to refer to is that described in Colwell and Frith 2009, primary roof support densities being given by the following two empirically-derived equations:

$$GRSUP_{Headings} = 207.70 \times e^{-0.0421\ CMRR} \times e^{0.0223\ \sigma R} \quad [3.1]$$

$$GRSUP_{Intersections} = 261.89 \times e^{-0.0463\ CMRR} \times e^{0.0271\ \sigma R} \quad [3.2]$$

where CMRR = Coal Mine Roof Rating

σ_R = horizontal stress acting across the roadway within the bolted interval under the defined roadway loading condition (MPa)

The term GRSUP (or "Ground Support") is a measure of the intensity of the installed roof support and is given by the following:

$$GRSUP = \frac{Lb\ .\ Nb\ .\ Cb}{14.5\ .\ Sb\ .\ we} + \frac{Lb\ .\ Nt\ .\ Ct}{14.5\ .\ St\ .\ we} \quad [3.3]$$

where L_b = length of bolted horizon defined by the primary bolt type (m)

N_b = average number of bolts per row

N_t = average number of longer tendons per row

C_b = ultimate tensile strength of the primary bolt (kN)

C_t = ultimate tensile strength of the longer tendon (kN)

S_b = spacing between rows of the same bolt type (m)

S_t = spacing between rows of the same longer tendon type (m)

w_e = roadway width (m)

For a CMRR of 39.4 and a maximum horizontal stress, σ_R of 2.74 MPa, the required values of GRSUP for heading and intersections are found to be 42.0 and 45.5 respectively. On the assumption of using 1.8 m long, X-grade roof bolts, 6 bolts per m returns a GRSUP value of 46 in a 5.5 m wide roadway and 39 in a 6.5 m wide roadway. This means that 6 x 1.8 m bolts per m is generally suitable in 5.5 m wide headings but may need to be marginally increased in 6.5 m wide headings if FE bolts are used.

The design of roof support using PE bolts uses two different methods, one for headings (to be described) and the other for intersections (Analysis of Roof Bolt Systems or ARBS from the USA – Mark ***et al*** 2001).

The heading design method has been developed by Mine Advice in conjunction with the use of PE bolts in Australia, as summarised in Table 3.1, which provides the key inputs and outputs. The logged average fracture spacing has been described previously in the report and is the initial measure of "beam action" within the immediate roof strata. The term BPF or Bedding Plane Failure Index is a measure of the propensity for the roof strata to break-down more than indicated by the logged average fracture spacing, it being based on the horizontal stress acting (as estimated by TSF and SCF [which is set at 1 for development]) in combination with the level of anisotropy in the roof strata (as given by axial point-load test data divided by diametral point-load-test data or Anisotropy Ratio).

A combination of a minimum logged average fracture spacing of 200 mm, TSF = 0.44 and an Anisotropy Ratio of 2 (returning a BPF Index of 0.88), results in a design outcome of 4 x 1.8 m bolts per 1.2 m as indicated by underlining in Table 3.1, this providing a clear indication of the level of roof bolting density improvement that can be achieved by using more effective roof bolts. It is noted that Seedsman 2015 reached the same basic conclusion, albeit based on a different method of analysis than that herein.

Logged Average Fracture Spacing (mm)	BPF Index SCF x TSF x APLT DPLT	Roof Support Design (1.5 m to 1.8 m long bolts)	Development Method Comments
> 400	0.5 – 2.0	4 bolts per 1.5 m	cut and flit
> 400	2.0 – 3.0	4 bolts per 1.2 m	cut and flit
> 400	3.0 – 4.0	4 bolts per 1 m	miner/bolter – e.g. 12CM12
> 400	> 4.0	6 bolts per 1 to 1.2 m	miner/bolter – e.g. 12CM12
200 – 400	0.5 – 2.0	4 bolts per 1.2 m	miner/bolter – e.g. 12CM12
200 – 400	2.0 – 3.0	4 bolts per 1 m	miner/bolter – e.g. 12CM12
200 – 400	3.0 – 4.0	6 bolts per 1 m	miner/bolter – e.g. 12CM12
200 – 400	> 4.0	6 bolts per 1 m plus centre-span reduction measures (centre bolt or modified inner bolt locations)	bolter/miner – e.g. 12CM30
150 – 200	0.5 – 2.0	4 bolts per 1 m	miner/bolter – e.g. 12CM12
150 – 200	2.0 – 3.0	6 bolts per 1 m	miner/bolter
150 – 200	3.0 – 4.0	6 bolts per 1 m plus centre-span reduction measures (centre bolt or modified inner bolt locations)	bolter/miner
150 – 200	> 4.0	6 bolts per 1 m plus centre span reduction measures and 2 tendons per 2 m	bolter/miner
75 – 150	N/A	6 bolts per 1 m plus centre-span reduction measures (centre bolt or modified inner bolt locations)	bolter/miner
40 - 75	N/A	6 bolts per 1 m plus span reduction measures and 2 tendons per 2 m	bolter/miner
< 40	N/A	6 bolts per 1 m plus span reduction measures and 2 tendons per 1 m	bolter/miner

TABLE 3.1. PE Bolt Design Table for 5 m to 5.5 m Wide Roadways

Applying the same parameters to ARBS for an assumed intersection geometry of 11 m average diagonal spans and a design Stability Factor of 2 (which is analogous to Factor of Safety), returns the outcomes contained in Figure 3.1. These indicate that 4 x 1.8 m bolts per 1.2 m is a suitable general roof bolting design, but that for intersection spans > 9.2 m, a low density of 4 m tendons in intersections is likely required to compensate for both (a) an inadequate roof bolt length and (b) an inadequate roof bolt density, this approach being commonly used in bord and pillar mining to both allow wider intersections to be used without increasing roof bolt length and also eliminate the need for tell-tales in all intersections.

```
ARBS, 12/24/2019, 11:56:11

[ARBS SUITABILITY]

OK to use ARBS, bolt reinforcement mechanism is beam building.

[INTESECTION SPAN INFORMATION]

Suggested Intersection Span.......................9.2 (m)

WARNING: Actual intersection span exceeds suggested intersection span.

[BOLT INFORMATION]

Suggested Bolt Length............................2.2 (m)

WARNING: The actual roof bolt length is shorter than the suggested
         length by more than 30 cm. ARBS is probably not valid.

Bolt Capacity....................................280.5 (kN)

[ARBS DESIGN]

Suggested ARBS...................................20.7
Actual ARBS for this design......................17.7
```

FIGURE 3.1. PBWS ARBS Outputs (with no long tendons)

It is noted that the designs presented herein are not final designs in that they take no account of the development method being used. They are simply initial roof support quantity estimates for typical immediate roof conditions for the PBWS at Hume in order to assist the project team in their on-going deliberations as to specific mining considerations.

3.2 Zone 2 (Unsupported 4-m Wide Plunge)

The most extensive study undertaken addressing the stability of unsupported plunges of varying width in coal mining is that of Mark 1999 in the US, which resulted in a series of equations that defined the transition from stable to unstable roof in extended cuts according to the CMRR, cover depth and roadway width. Figure 3.2 shows the supporting database by reference to CMRR and cover depth.

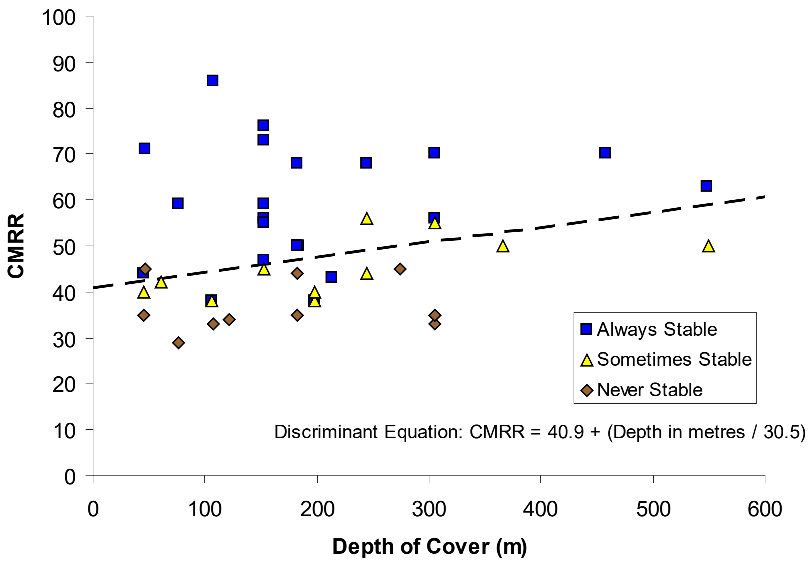

FIGURE 3.2. Extended-Cut Roof Stability Database Analysing CMRR and Cover Depth (Mark 1999)

Figure 3.2 suggests two key points:

(i) The discriminant line (i.e. line of best separation between stable and unstable cases) is very distinct, with few misclassifications. It is clearly a "watershed" dividing two totally different behavioural mechanisms, one associated with natural stability and the other with natural instability. This is linked to bedding cohesion being directly associated with the "static-slender beam" roof behavioural model presented in Colwell and Frith 2012, in which a static roof (bedding planes intact) is naturally stable and a slender beam roof (bedding planes open) naturally unstable.

(ii) Most importantly for this study, none of the case histories in Figure 3.2 relates to a thick coal roof, this being due to the much thinner seams commonly worked in the US and the associated practice of working stone to stone as a direct consequence. The relevance of this is that a coal roof of a given UCS will have a lower Young's Modulus (E) than a stone roof with the same UCS, the result being that the horizontal stress acting in the coal for any given cover depth will be lower than in the comparable stone. The general relationship between UCS and E for coal (E in (GPa) = 0.125 x UCS (in MPa)) is different to that commonly found for stone as shown in Figure 3.3 where E in (GPa) ≈ 0.286 x UCS (in MPa), or 2.3 times that for coal.

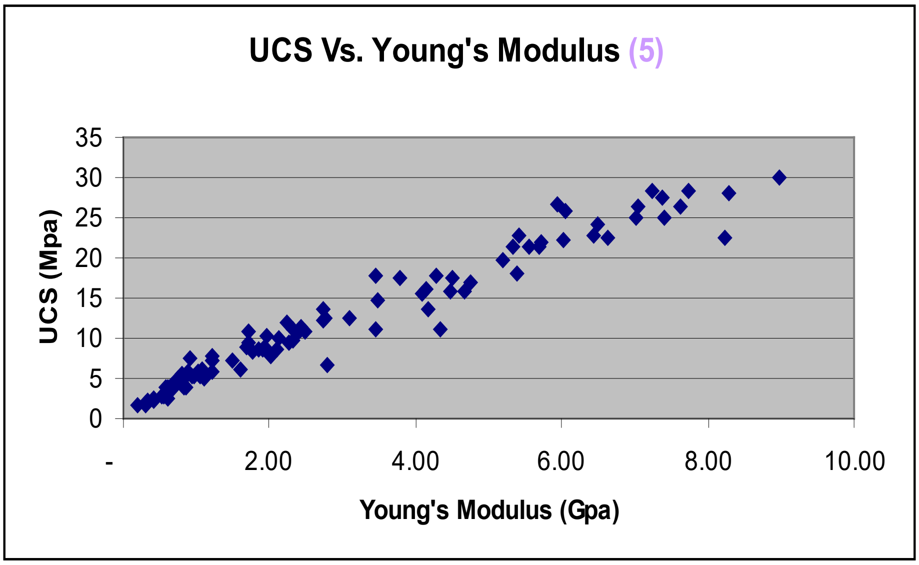

FIGURE 3.3. Laboratory Test Data Showing the Relationship Between E and UCS for Stone Strata Types (UNSW 2010)

The significance of point (ii) is that the application of Figure 3.2 to a thick coal roof without making allowance for the differences in horizontal stress between stone and coal will provide an overly pessimistic assessment of extended-cut stability.

As the discriminant equation shown in Figure 3.2 does not include the roadway width, it does not provide a complete method of analysis. It is only used to provide a simple representation of the nature of the problem. Mark 1999 provides a discriminant equation that includes CMRR, depth and roadway width as follows:

$$CMRR_{discriminant} = 18.6 + H/30.5 + 3.94w \quad [3.4]$$

where: $CMRR_{discriminant}$ is the CMRR that defines the discriminant line for given cover depth and roadway width

H = cover depth (m)

w = roadway width (m).

In applying Equation 3.4 a 4 m plunge width is assumed and a maximum cover depth of 170 m, which returns a $CMRR_{discriminant}$ value of 39.9. Remembering that a discriminant line is comparable to an FoS of 1 with a 50% likelihood of success (or failure), further analyses are required to determine whether a CMRR of 39.4 (as derived in Section 2.2) will result in "*always stable*" 4 m-wide plunges for the PBWS at Hume.

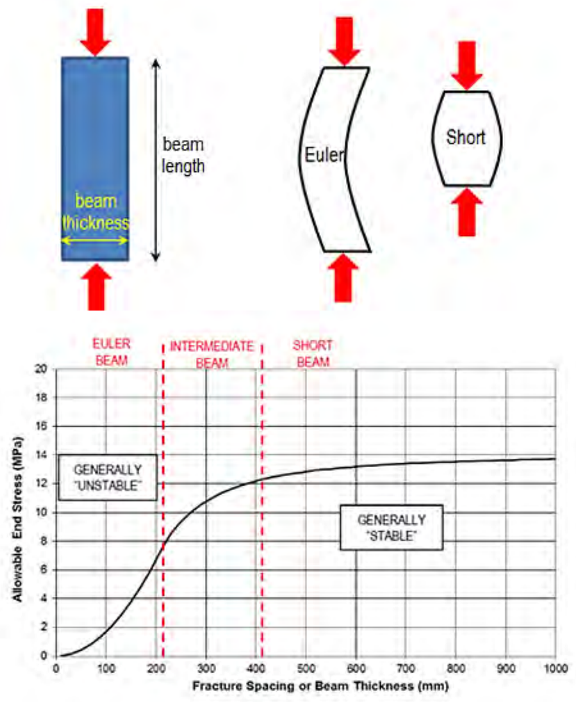

FIGURE 3.4. Beam Behavioural Modes and Changes to Load-Bearing Ability as a Function of Beam Thickness (span = 5.2 m and UCS = 20 MPa)

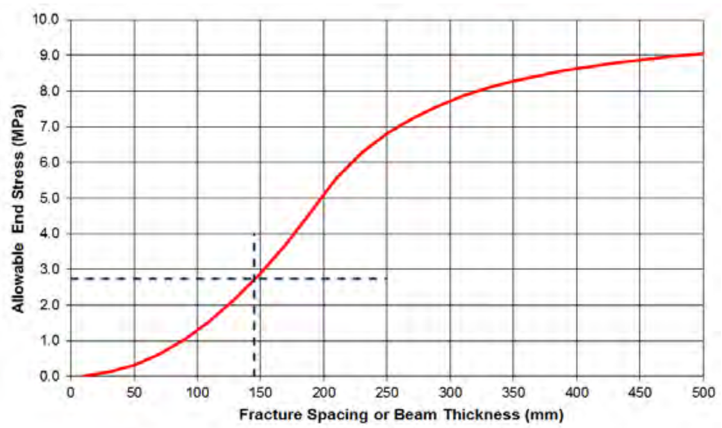

FIGURE 3.5. Allowable Stress versus Beam-Thickness Curve for UCS = 14 MPa, E = 2.5 GPa and a Roof Span of 4 m

As previously described, a positive mitigating factor in this regard is the lower horizontal stress in coal as compared to stone. The work of Mark 1999 does not allow this to be meaningfully considered, therefore another approach is required. This report applies the end-loaded column model, as described in detail in Colwell and Frith 2012 and summarised in Figure 3.4.

Figure 3.5 shows the variation in allowable stress (horizontal stress) as a function of beam thickness for the coal roof at a span of 4 m with assumed material properties of UCS = 14 MPa and E = 3 GPa (as defined previously). When the maximum predicted value of major horizontal stress in the bolted interval (2.74 MPa) is also included, the true significance of the presence of coal in the immediate roof becomes apparent, the critical coal roof beam thickness for an applied horizontal stress of 2.74 MPa being 145 mm, which compares favourably to the minimum logged fracture spacing above the PBWS of 200 mm, which can accommodate a horizontal stress in the order of 5 MPa based on Figure 3.5.

The structural beam analysis contained in Figure 3.5 provides the necessary additional technical justification to conclude that the likely outcome under the worst-case horizontal stress conditions (i.e. the major horizontal stress) at the maximum cover depth (170 m) is that 4 m-wide unsupported plunges remote from major geological structures will be routinely globally stable, with any instability being limited to no more than minor skin falls from the immediate roof.

3.3 Zone 3 (Plunge Breakaway)

The stability of unsupported plunge breakaways can be analysed in exactly the same manner as that for unsupported plunges, with two variations:

(i) the effective width or span as compared to 4 m wide unsupported plunges, and

(ii) the need to form the breakaway at a slightly lower cut-roof horizon than the adjacent heading in order to prevent the CM head impacting roof-bolt tails, at least initially.

The effect of (ii) is to leave marginally more roof coal in place at the start of the breakaway, which in overall roof stability terms is likely a positive rather than negative influence. For the purpose of analysis though, this variation will not be included.

Using Equation 3.4, at an effective width of 4.71 m for a 5.5 m wide heading and 3.75 m for a 6.5 m wide heading, the respective $CMRR_{discriminant}$ values are found to be 42.7 and 39. Unsurprisingly, these are not dissimilar to that found for a span of 4 m and require the structural beam model to be used so as to complete the analysis.

Without providing detailed graphs as per Figure 3.5 for both 3.75 m wide and 4.71 m wide spans, it is found that the required critical beam thickness that can accommodate a horizontal stress of 2.74 MPa, is 135 mm at 3.75 m width and 170 mm at 4.71 m width. These both return "stable" outcomes, although the inherent Factor of Safety with a 6.5 m wide heading is substantially higher than a 5.5 m wide heading, as would logically be expected given the reduced effective span involved.

3.4 Combined Zones 1 and 3 (Breakaway Intersection)

The post-plunging stability of the adjacent heading is an important mining requirement due to the need to emplace rejects into plunges after mining is complete. It is not an acceptable mining outcome for headings to become unserviceable and untravellable once plunging is completed. As such, the post-plunging stability of the heading needs due consideration, the critical geometry being that of the plunge breakaway intersection area in its entirety as illustrated in Figure 3.6, which is a modified version of Figure 1.4.

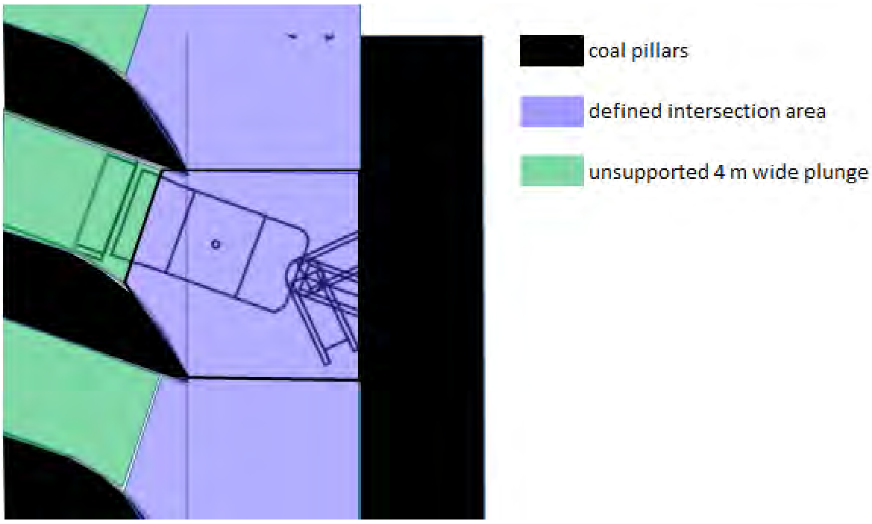

FIGURE 3.6. Plunge Breakaway Intersection Area (6.5 m Wide Heading)

Average diagonal spans for the breakaway intersection areas have been taken from the supplied ACAD drawings, including an allowance for web pillar corner spalling adjacent to the breakaway. For a 5.5 m wide heading, the average diagonal span is found to be 10.4 m and for a 6.5 m wide heading, it is found to be 10.2 m, these both being less than the value of 11 m that was previously assumed for general intersections during roadway development.

```
ARBS, 12/24/2019, 12:31:25

[ARBS SUITABILITY]

OK to use ARBS, bolt reinforcement mechanism is beam building.

[INTESECTION SPAN INFORMATION]

Suggested Intersection Span......................9.2 (m)

WARNING: Actual intersection span exceeds suggested intersection span.

[BOLT INFORMATION]

Suggested Bolt Length............................2.0 (m)

Bolt Length: OK.

Bolt Capacity...................................280.5 (kN)

[ARBS DESIGN]

Suggested ARBS..................................19.3
Actual ARBS for this design.....................17.7
```

FIGURE 3.7. ARBS Output, Plunge Intersection, Heading Width = 6.5 m

From an ARBS analysis perspective, it makes little difference as to whether a span of 10.4 m or 10.2 m is assumed, hence a value of 10.3 m will be used, the key difference being the areal extent of the installed roof support in the heading, which is obviously improved by the use of a wider heading.

The ARBS output in Figure 3.7 indicates that post-plunging, overall intersection stability is likely marginal due to (a) the necessary intersection geometry, (b) longer-term heading serviceability needs, and (c) a primary roof support system of 4 x 1.8 m X-grade bolts per 1.2 m. Therefore, it is necessary to consider how this may be improved without unduly negatively affecting the roadway development process by increasing either bolt length and/or density.

Potential solutions include:

(i) the installation of a low density of short long tendons on the plunge side of the heading, either during roadway development or as secondary support outbye of plunging operations.

(ii) the immediate installation of removable standing support (i.e. not permanent support such as Propsetters) at the mouth of each completed plunge in order to increase the level of installed roof support, compensate for any roof bolt length inadequacies and reduce the effective intersection span.

There are advantages and disadvantages with these two suggested approaches, the specifics of which will need to be considered operationally in deciding how to best address this particular roadway roof control issue.

With the breakaway area itself (Zone 3) being independently stable in an unsupported state, and breakaway intersections supported adequately along the lines described herein, it is concluded that post-plunging headings can be engineered to remain adequately stable for subsequent rejects emplacement purposes, noting the general principle that a wider initial heading significantly assists in this endeavour.

4.0 REFERENCES

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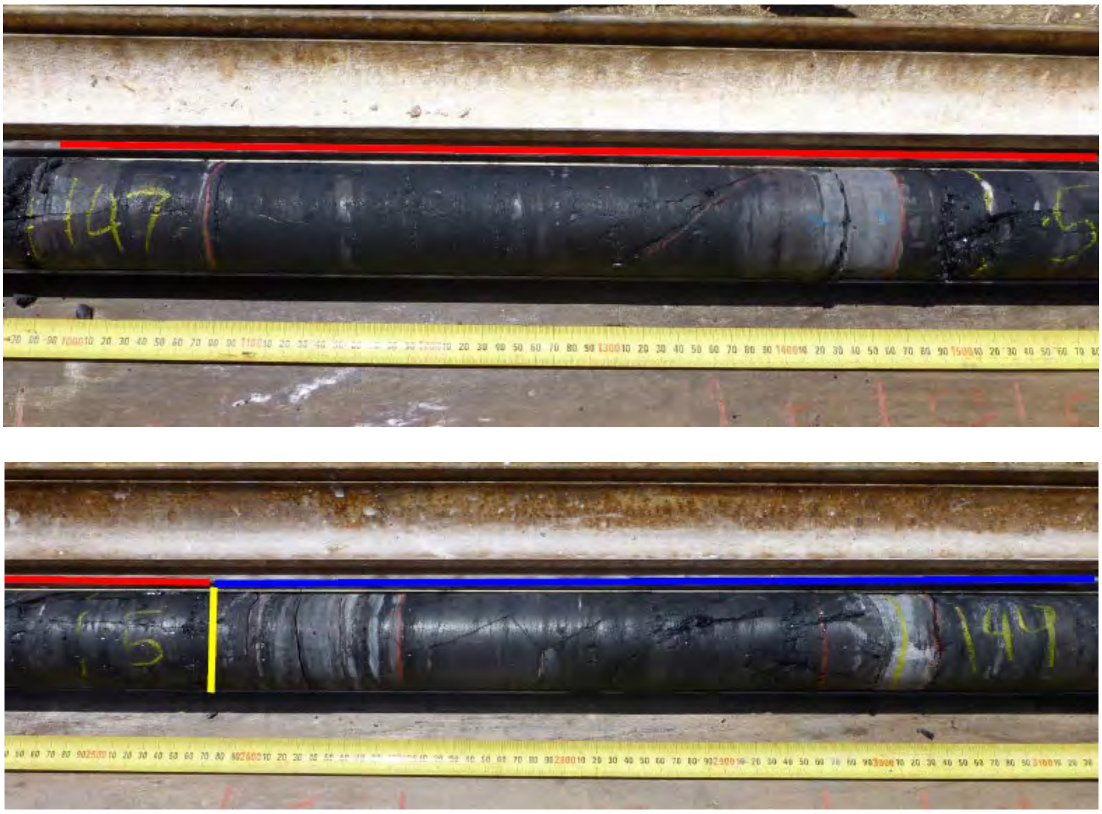
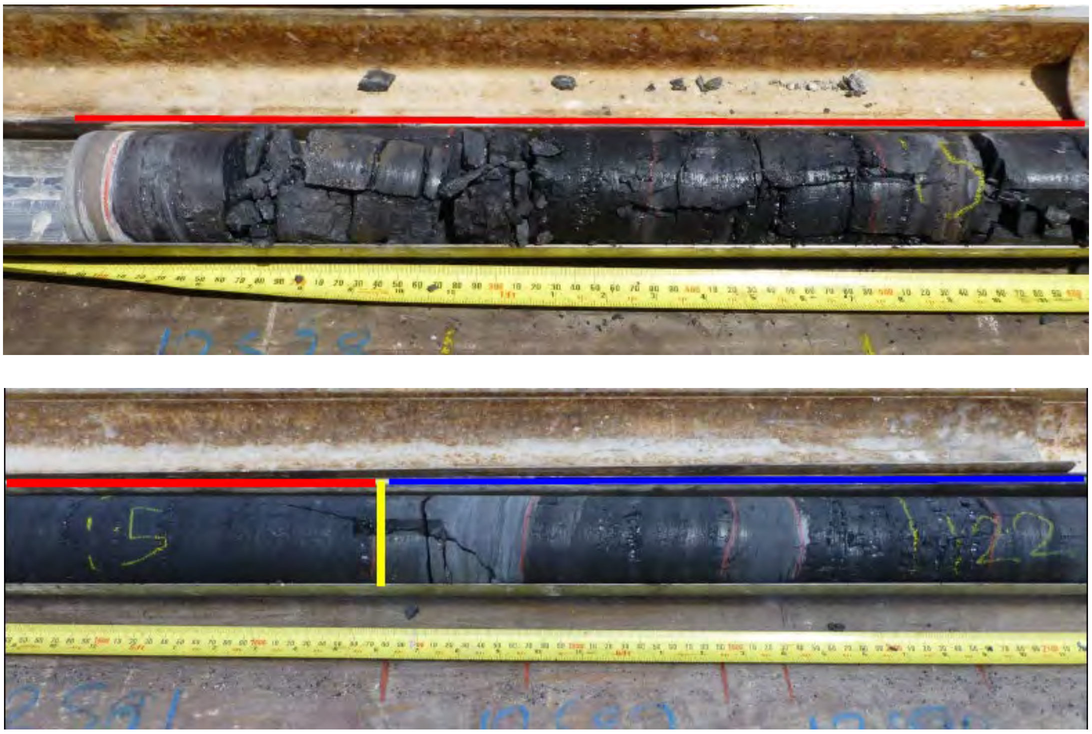
APPENDIX A

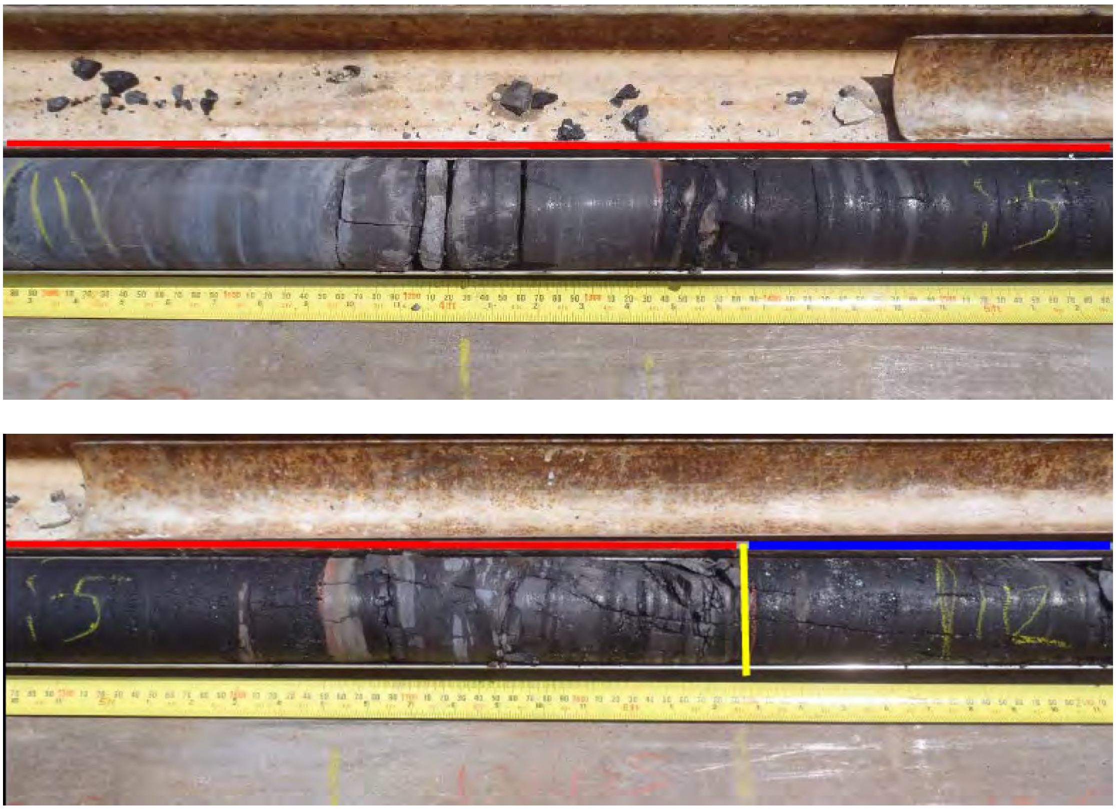
Selected Split-Tube Core Photography



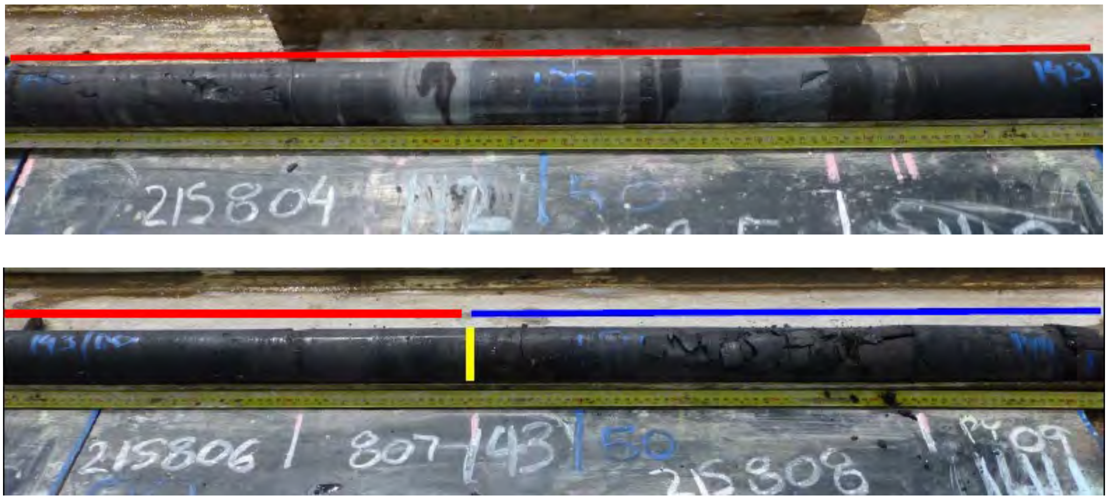
Borehole HU64 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*



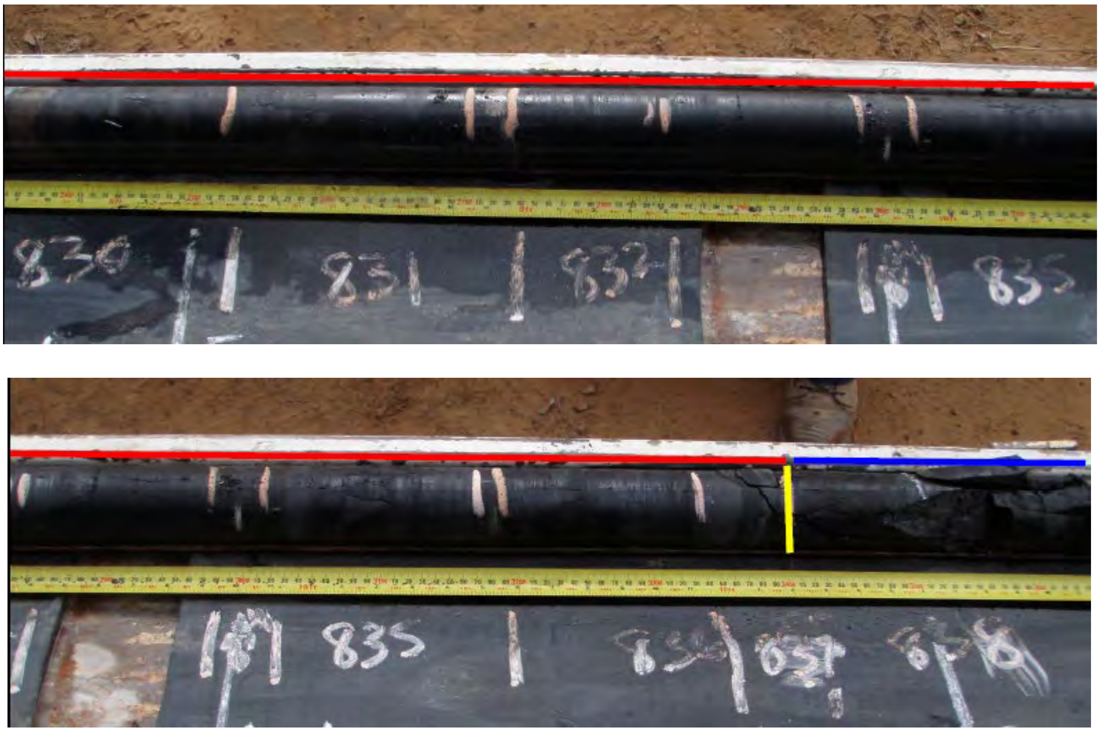
Borehole HU65 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*



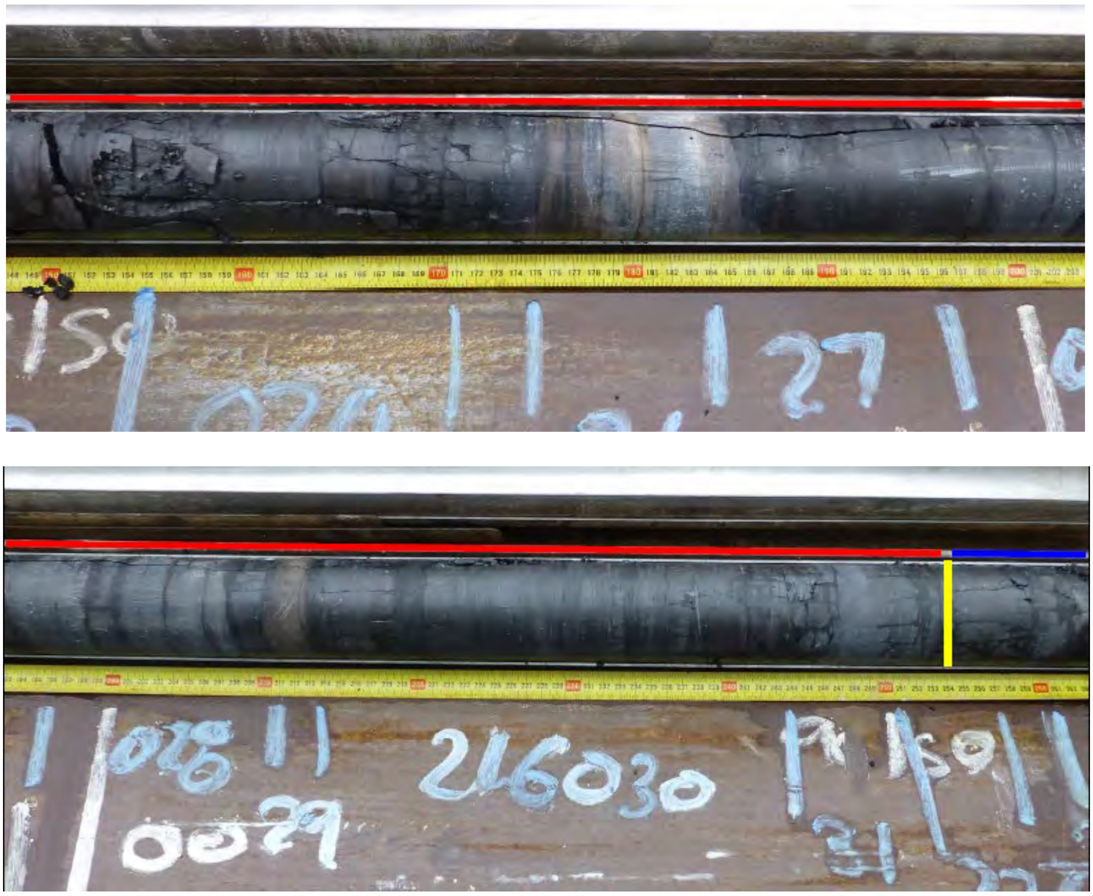
Borehole HU67 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*



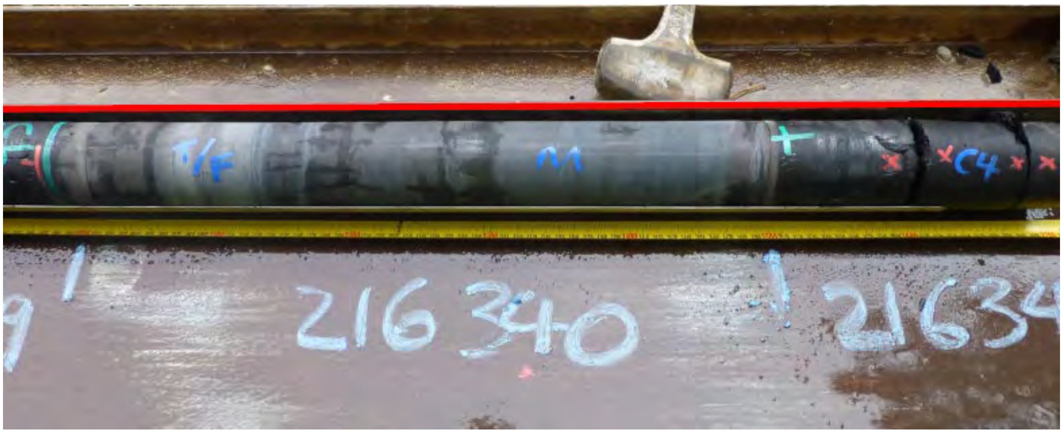
Borehole HU71 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*



Borehole HU75 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*

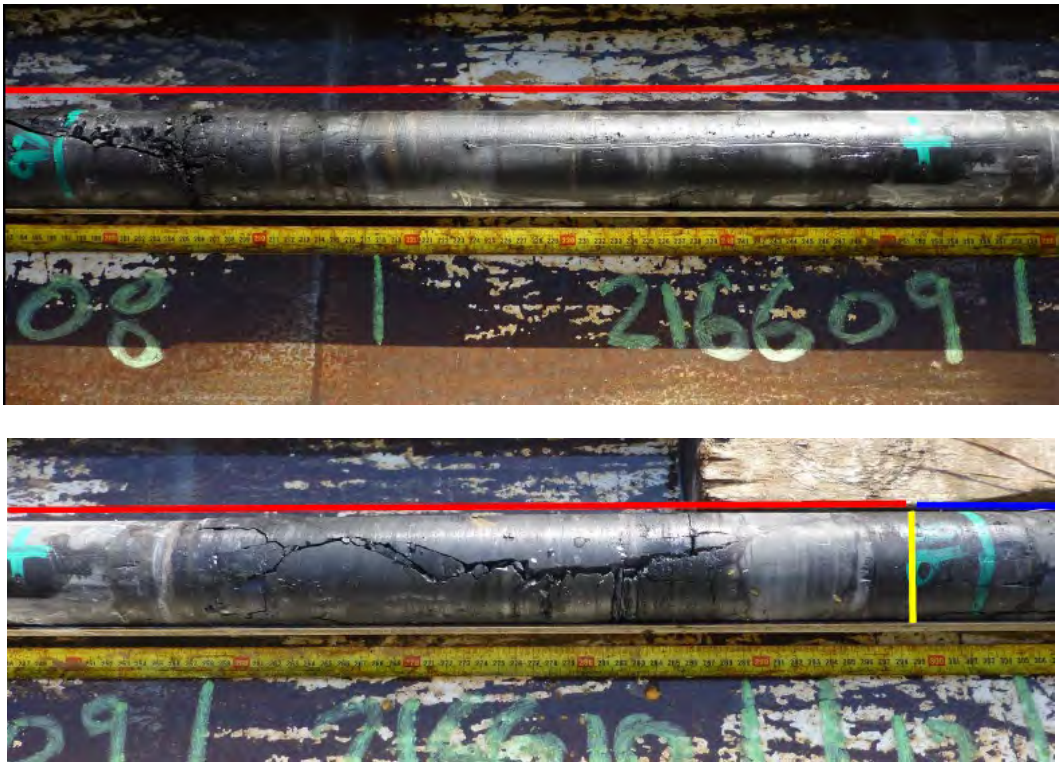


Borehole HU78 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*



Borehole HU82 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*

Borehole HU83 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*



Borehole HU85 (*blue line = working section, yellow line = assumed as-cut roof, red line = immediate roof strata)*

Appendix B11 – Applicant Response to Roads and Maritime advice

A.B.N. 15 152 928 222

HUME COAL PTY LTD

Formal Responses to the Issues Raised by NSW Roads and Maritime Services (RMS) Relating to the Hume Project EIS

APRIL 2017

REPORT: HUME19/1

7/17 Babilla Close
BERESFIELD, NSW 2322
TEL: (02) 4088 0600
E-MAIL: russellfrith@mineadvice.com.au

REPORT TO :	Alex Pauza Manager, Mine Planning Hume Project Hume Coal Pty Ltd
REPORT ON :	Formal Responses to the Issues Raised by NSW Roads and Maritime Services (RMS) Relating to the Hume Project EIS
REPORT NO :	HUME19/1
REFERENCE :	Your instructions to proceed
PREPARED BY :	Russell Frith
REVIEWED BY :	Clients representative
DATE :	4th April 2017

....

Russell Frith (CP (Geotechnical [Mining]), RPEQ [*Registration # 12952*])

Principal Geotechnical Engineer

Disclaimer

This technical report has been prepared based on: (a) instructions by the client as to the required scope of work; (b) technical and other supporting information supplied to Mine Advice by the Client; and (c) the use of relevant technical concepts and methods as determined by Mine Advice in their role as a consulting and professional engineering service provider. The Client warrants that all of the information it provides to Mine Advice is complete and accurate, and that it has fully disclosed to Mine Advice any and all relevant matters which may reasonably affect the conclusions that are reached in this report.

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1.0 INTRODUCTION

Following Hume Coal's receipt of a letter from RMS dated 28th February 2017 and a teleconference with RMS as well as their consulting engineer, Henk Buys of AECOM on 21st March 2017, this report provide formal responses to the various issues raised by RMS to assist in their on-going consideration of the potential impact on various RMS infrastructure in the vicinity of proposed mining as part of the Hume Project.

Based on their letter and the subsequent discussions, it is understood that they require further clarification on the following matters:

(i) Whether RMS can rely on the contents of the various Mine Advice reports relating to the surface and sub-surface subsidence assessment for the Hume Project, the query being based on the wording of the disclaimer contained in said reports.

(ii) A more detailed explanation of the "load-shedding" mechanism between web pillars and the various barrier pillars that is utilised as part of the coal pillar design process, this including addressing the following statements and questions contained in the RMS letter of 28th February 2017:

  (a) "t*he report implies that that once these pillars reach their elastic limit they will continue to behave plastically*"

  (b) "*Please confirm that the pillars will not fail once they have reached their elastic limit and that whilst they may deform plastically, they will continue to support the ground above them*"

  (c) "*Please provide an assessment of long-term pillar stability and surface movements under these conditions*"

  (d) "*Please also confirm that plastic behaviour of the web pillars has been allowed for in the subsidence assessment and if not, what additional subsidence and strains can be expected if these pillars exceed their elastic limit*"

(iii) Ground strain predictions "*both in the longitudinal direction (transverse to the motorway) and in the transverse direction (parallel to the motorway)*" at a number of bridge locations, these being north-bound and south-bound bridges over both (a) the Medway Rivulet and (b) Well Creek.

Each of these issues will now be addressed in detail.

2.0 RMS RELIANCE ON MINE ADVICE REPORTS

The disclaimer included in the various Mine Advice reports is intended to prevent parties that are not directly involved with or do not have a direct interest in the Hume Project, but who may legitimately or illegitimately gain copies of such reports, applying the concepts or principles that are contained in said reports whilst also holding Mine Advice liable for the outcomes of any such use.

It is confirmed that RMS's use of and reliance upon the two Mine Advice reports related to (i) the mine layout design at Hume (report # HUME13/2 dated 30th October 2016 – Mine Advice 2016a) and (ii) surface and sub-surface subsidence predictions for EIS purposes (report # EMM01/2 dated 3rd December 2016 – Mine Advice 2016b) are part of the "*specific purpose*" for which the reports were written (see third paragraph of the disclaimer) and that Mine Advice have agreed to Hume Coal supplying the reports to RMS for their use as part of evaluating mining impacts related to the proposed mining at the Hume Project.

3.0 LOAD-SHEDDING MECHANISM BETWEEN WEB AND BARRIER PILLARS

As a background, the reason for including the load-shedding mechanism in the mine layout design process was the recognition that there was an obvious imperative to incorporate the most robust surface and sub-surface protections within the mine layout given the various non-mining constraints within the Hume Project area.

Whilst the UNSW Pillar Design Procedure (UNSW PDP) provides statistically-derived relationships between coal pillar Factor of Safety (FoS) and an associated Probability of Failure (PoF), the work of others (e.g. Hill 2005, Reed *et al* 2016) has subsequently argued and credibly demonstrated that applying a FoS pillar design approach in isolation is not necessarily as reliable as is stated within the UNSW PDP when low width to height (w/h) ratio pillars are involved. Even putting aside mine safety considerations, when undertaking mine and coal pillar design in areas that are highly sensitive to mining-induced subsidence effects whereby reliance is placed in permanent coal pillars to mitigate such effects, incorporating more than one overburden stability control (i.e. more than coal pillar stability in isolation) into the mine layout has substantial benefits in terms of the reliability of the mine design and hence, the level of confidence that can be applied to its use.

The foundation for the initial mine layout design at Hume has been the application of the ARMPS-HWM (HWM = highwall mining) method from the USA (as detailed in Mine Advice 2016a), primarily as unlike the UNSW PDP, it directly addresses the design of long thin coal pillars per the web pillars that are part of the proposed mine design at Hume. ARMPS-HWM also incorporates three other highly relevant mine layout design features over and above pillar stability, these being:

(i) design criteria relating to the w/h ratio of pillars are applied to the design of all coal pillars within the pillar system

(ii) the distance (or panel width/span) between higher w/h ratio barrier pillars is contained within defined limits in order to ensure that the low w/h ratio web pillars between barrier pillars cannot fail independently of the higher w/h ratio barrier pillars, and

(iii) as a result of (ii), whilst the web and barrier pillars may be sized independently of each other in the initial instance, the design method requires that the pillar system in its entirety (i.e. webs and barriers) meets a suitable high overall or combined Stability Factor (SF) for the layout design to be suitable for use.

It is for these reasons that the initial mine layout designs at Hume were established using the ARMPS-HWM design method (which were subsequently checked and verified by the application of the UNSW pillar strength equations in conjunction with other considerations relating to how and why panel widths between barriers should be limited) and why the "load-shedding" mechanism between web and barrier pillars has needed to be included as part of the Hume mine layout justification process.

Load-shedding between coal pillars within a pillar system is directly linked to whether the overburden above any given mined-area is either "sub-critical" or "super-critical", these being terms that are more commonly applied to subsidence behaviour of the surface above areas of total extraction. A super-critical extraction is one whereby maximum subsidence develops at surface via complete de-stabilisation of the overburden to surface. In contrast, a sub-critical extraction width is one whereby maximum subsidence does not develop at surface, due to some portion of the overburden having retained a level of self-supporting ability across the extraction width (termed “bridging” or “spanning” in common engineering language).

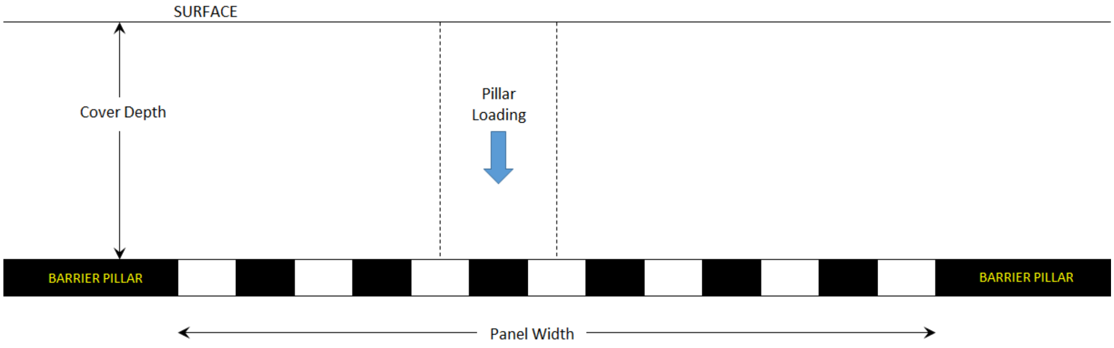

FIGURE 1. Schematic Illustration of a Super-Critical Panel of Pillars and Full Tributary Area Loading to Surface

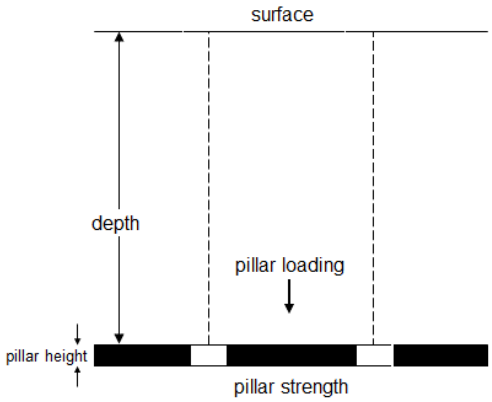

FIGURE 2. Schematic Illustration Full Tributary Area (FTA) to Surface Pillar Loading

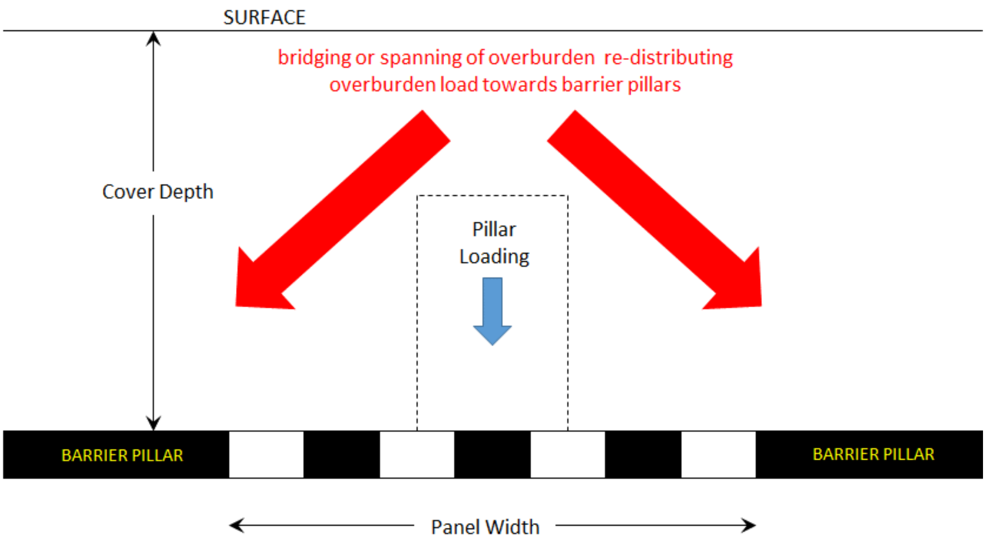

FIGURE 3. Schematic Illustration of a Sub-Critical Panel of Pillars and Overburden Load Being Re-Distributed Towards Barrier Pillars

In terms of coal pillar design, the same concept of sub- and super-critical overburden behaviour has a direct influence on the magnitude of overburden load that is likely to be applied to any given pillar within a pillar system. Figure 1 shows a super-critical environment between barrier pillars whereby any smaller production pillars between the barriers are likely to be loaded under full weight of overburden to surface according to their individual geometry (Figure 2). In contrast, Figure 3 shows a sub-critical environment between barriers whereby some portion of the overburden load directly above the smaller production pillars in-between the barriers is likely to be transferred or re-distributed towards the barrier pillars, hence the use of the term “load-shedding”.

Panels of production pillars between larger barrier pillars can be designed to be sub-critical by limiting the distance between barriers as a direct function of either (a) cover depth (compare Figure 3 to Figure 1) or (b) the thickness and location of structurally competent strata units within the overburden such as sandstones and conglomerates, as was applied by Ditton and Frith 2003 in their back-analysis of surface subsidence above longwall panels in the Newcastle Coalfield. Both mechanisms of overburden stabilisation across a sub-critical mining panel have been incorporated into the design of panel widths for web pillars between intra-panel barriers at Hume.

The load-shedding mechanism due to the use of sub-critical panels of web pillars between barrier pillars was included within the Hume layout and coal pillar design process via the two extreme coal pillar loading scenarios of:

(a) full tributary area (FTA) loading whereby all coal pillars were initially evaluated according to their own FTA to surface (Figure 2), followed by an analysis whereby the panel width between barriers was taken to be sub-critical so that pillar system stability could be determined by combining the stabilising influence of both web and barrier pillars (see Figure 4) – this is essentially the basis of the ARMPS-HWM model.

(b) the assumed (for the purpose of analysis) development of an abutment angle out from the barrier pillars, resulting in the maximum possible overburden load transfer from the web pillars to the barrier pillars (see Figure 5), as would be utilised in the design of longwall chain pillars for example.

The reason for evaluating the two extreme pillar loading cases shown in Figures 4 and 5, was to demonstrate that the stability of the overall pillar system (i.e. webs and intra-panel barriers combined) did not materially change as a result of any level of overburden load-shedding that may occur between the web and barrier pillars, the primary control being the sub-critical spans between intra-panel barriers that have been designed into the mining layout at Hume for exactly this reason.

With the technical background being explained, the use of FTA loading of web pillars as one part of the layout design sensitivity analysis, should not be taken as implying that web pillars will ever be loaded under FTA to surface and so achieve their lowest stated stability. In fact, the inclusion of sub-critical spans between intra-panel barriers is a specific aspect of the proposed Hume mine layout that is intended to prevent this scenario from ever occurring.

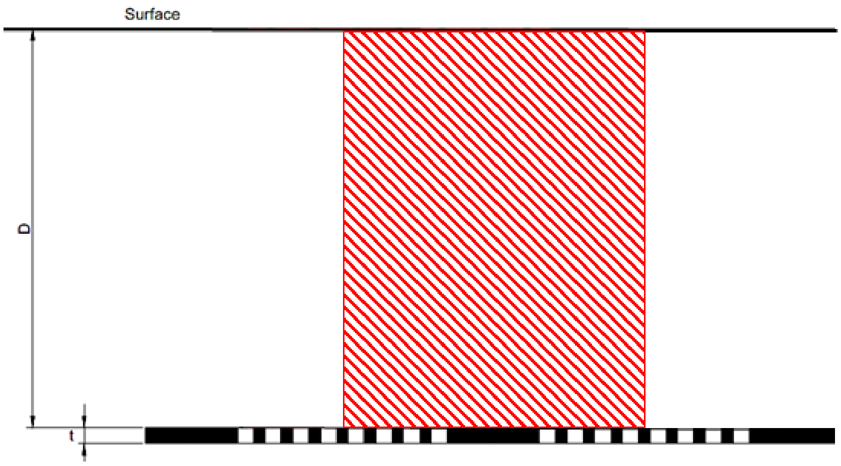

FIGURE 4. Bord and Pillar Type Assessment of Pillar Stability (Pillar Load Distribution Based Solely on Individual Pillar Width)

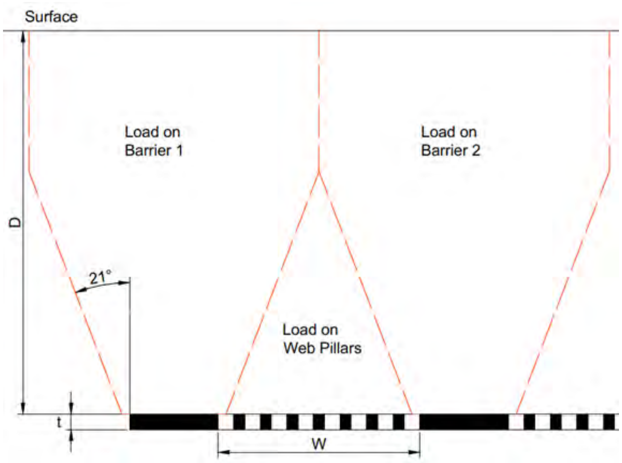

FIGURE 5. "Double Goaf Loading" of Intra-Panel Barrier Pillars (Worst Case Unequal Pillar Load Distribution)

Depth (m)	Web Width (m)	Barrier Width (m)	Number of Drives	Number of Webs	Span Between Barriers (m)	Web Pillar FoS (w/h)	Barrier Pillar FoS (w/h)	System Stability
80	3.5	14	8	7	56.5	1.33 (1)	4.95 (4)	2.25
120	4.1	16.8	7	6	52.6	1.04 (1.2)	4.05 (4.8)	1.94
160	5.5	20.9	6	5	51.5	1.04 (1.6)	3.94 (6)	2.03

TABLE 1. Two-Dimensional Pillar Stability Review using UNSW Pillar Strength Equations and Pillar Load Distribution According to Pillar Width

Table 1 (reproduced from Mine Advice 2016a) indicates that the web pillars have an FoS when using UNSW pillar strength equations, of 1.04 (which equates to an ARMPS-HWM SF in the order of 1.3) based on the application of FTA loading to surface at cover depths of 120 m and greater. At face value, this could perhaps be taken as inferring that the web pillars are likely to reach and potentially exceed their elastic limit and so enter a "plastic" state. However, the credibility of such an inference is directly linked to the credibility of the assumed web pillar loading scenario used to generate the FoS values in the first instance, namely the application of FTA to surface for a panel width between barriers of slightly less than 60 m, a cover depth in the order of 120 m (giving a panel width to depth value of only 0.5 which is sub-critical in its own right) and the substantial spanning ability of the Hawkesbury Sandstone unit located immediately above the coal seam.

When the sub-critical nature of the span between intra-panel barriers is considered, it must be inevitably concluded that despite the stated FoS of the web pillars under FTA approaching 1, in reality a substantial amount of the assumed FTA load on the web pillars will be "shed" to the intra-panel barriers, which have FoS values in the order of 4 and w/h ratios in excess of 4. Therefore, the actual *in situ* FoS values for the web pillars will be greater than that which has been determined under the worst-case and highly conservative assumption of FTA loading to surface.

An independent proof of the load-shedding mechanism associated with production pillars being formed up within sub-critical spans between barrier pillars, is fund in Tulu ***et al*** 2010 whereby they apply a numerical model (LaModel) in an attempt to better define the actual load-distribution amongst the various coal pillars within the pillar system, as compared to that given by either the assumption of FTA (Figures 1 and 2) or conversely, the development of an abutment angle (Figures 3 and 5). It is noted that the abutment angle scenario (Figure 5) was introduced into US coal pillar design for underground coal mines, specifically to address the scenario of sub-critical bord and pillar panels at high cover depth due to the recognition that the application of FTA loading to surface inevitably resulted in overly conservative design outcomes (Mark ***et al*** 2011).

Tulu ***et al*** 2010 make the following statement which is fully supportive of the manner by which the web pillars and intra-panel barrier pillars within the proposed Hume mine layout have been analysed for an acceptable level of overall stability, namely in combination so as to determine Pillar System Stability (as included in Table 1):

> *The addition of the pressure arch factor to ARMPS 2010 has resulted in improved estimation of both AMZ* (i.e. web pillars in the case of Hume) *and barrier* (i.e. intra-panel barriers in the case of Hume) *pillar loads. First, for deep cover panels, it has generally lowered the load on the AMZ and therefore generally increased the stability factor and eliminated the depth effect on the stability factor as previously seen with ARMPS 2002. Furthermore, since the excess load due to the presence of the arch factor originally goes to the outbye barrier pillar, but then comes back to the AMZ if the barrier pillar fails, ARMPS 2010 <u>has implicitly incorporated the importance of the barrier pillar stability factor into the stability factor of the AMZ. This eliminates the need for a dual barrier pillar – AMZ stability factor criteria</u>.*

In other words, for sub-critical spans between barriers, the potential for load-shedding is fully recognised by Tulu ***et al*** 2010 as is the need to evaluate overall pillar system stability based on the combined stabilising influence of both web pillars (AMZ in the terminology of the US paper) and barrier pillars. This is a key aspect of the Hume project layout design which is confirmed by both ARMPS-HWM and other US research studies.

In terms of quantifying the exact amount of load shedding from the smaller production pillars across to the barrier pillars under sub-critical overburden conditions, Tulu ***et al*** 2010 make the following further statement:

> *In general, the critical loading on the AMZ in this deep cover analysis, ARMPS 2002* (using FTA to surface) *predicts the greatest load, ARMPS 2010* (using the abutment angle model) *predicts the least load and LaModel (*i.e. the numerical model*) falls somewhere in between.*

In other words, the actual load distribution between web pillars and barrier pillars when a sub-critical span between barriers is used, lies somewhere between the two extremes of FTA to surface and an abutment angle model, this again being indicative of a load-shedding mechanism between web and barrier pillars being at work. This published finding was the basis for including the pillar design assumptions of both FTA loading to surface and that of the abutment angle model into the pillar layout analyses at Hume, the objective being to demonstrate that irrespective of the actual magnitude of load-shedding in practice, overall pillar system stability would still be consistent with the retention of long-term stability.

Having provided a detailed background as to the reasons why pillar load-shedding has been included within the layout design analyses for Hume, formal responses to the questions posed can now be provided.

(a) "t*he report implies that that once these pillars reach their elastic limit they will continue to behave plastically*"

<u>RESPONSE</u>: the report did not intend to imply that web pillars would reach their elastic limit and therefore behave plastically as a direct consequence. The mechanism of load-shedding from the web pillars to the barrier pillars is primarily driven by the sub-critical nature of the overburden between barrier pillars as incorporated within the mine layout design via the use of spans between intra-panel barriers of no more than 60 m. The inevitable load-shedding mechanism from the web pillars to the barrier pillars will act to decrease the loads on the web pillars and increase those on the barrier pillars, as compared to those assumed under FTA loading to surface. Therefore, FoS values for web pillars being as low as 1.04 under assumed FTA loading, should not be taken to imply a high likelihood of the web pillars exceeding their elastic limit and so behaving plastically with a lower inherent stiffness as in reality, the actual FoS on the web pillars will be higher than the FTA loading determined values.

(b) "*Please confirm that the pillars will not fail once they have reached their elastic limit and that whilst they may deform plastically, they will continue to support the ground above them*"

<u>RESPONSE</u>: the mine layout design has been formulated to ensure that the web pillars will not exceed their elastic limit, the controls being the highly sub-critical nature of the spans between intra-barrier pillars and the substantial stabilising influence of those barrier pillars via their combined FoS and w/h values. Therefore, the question of web pillars reaching or exceeding their elastic limit is irrelevant, other than to state that the combined stabilising influence of both web pillars and intra-barrier pillars has been designed sufficient to prevent a pillar system (i.e. webs and barriers) failure. Therefore, the pillar system will continue to support the overlying strata to surface.

(c) "*Please provide an assessment of long-term pillar stability and surface movements under these conditions*"

RESPONSE: long-term pillar stability has been designed into the mine layout via the leaving of suitably spaced barrier pillars within the overall pillar system, so that the likelihood of a pillar failure occurring is governed by the stabilising influence of the web and various barrier pillars in combination. System Stability in the order of 2 combined with closely-spaced barrier pillars with w/h values in the order of 4 to 6, is assessed to be consistent with the long-term mine design requirement of protecting the surface and sub-surface environment from significant ground movements due to mining-induced subsidence. As a result, surface movements under these conditions are based primarily on the elastic compression of the various pillars within the pillar system, as has been undertaken and reported.

(d) "*Please also confirm that plastic behaviour of the web pillars has been allowed for in the subsidence assessment and if not, what additional subsidence and strains can be expected if these pillars exceed their elastic limit*"

RESPONSE: as the plastic behaviour of web pillars is not considered to be a credible outcome due to the pillar system and mine layout design that is being put forward, there is no rational basis for considering the magnitude of any additional subsidence and ground strains associated with web pillars exceeding their elastic limit.

4.0 HORIZONTAL STRAIN PREDICTIONS AT THE NOMINATED RMS ROAD BRIDGES

RMS have identified two bridge structures along the Hume Highway, both having individual north-bound and south-bound structures, for which they require site-specific horizontal ground strain predictions due to the proposed mining upon which they can undertake a mining impact analysis.

Figure 6 (taken from Mine Advice 2016b) shows the complete mine layout as submitted as part of the EIS, the location of the two bridges in question, "A" marking the location of the two bridges over the Medway Rivulet and "B" the two bridges over Wells Creek and also the measured alignment of the major horizontal stress.

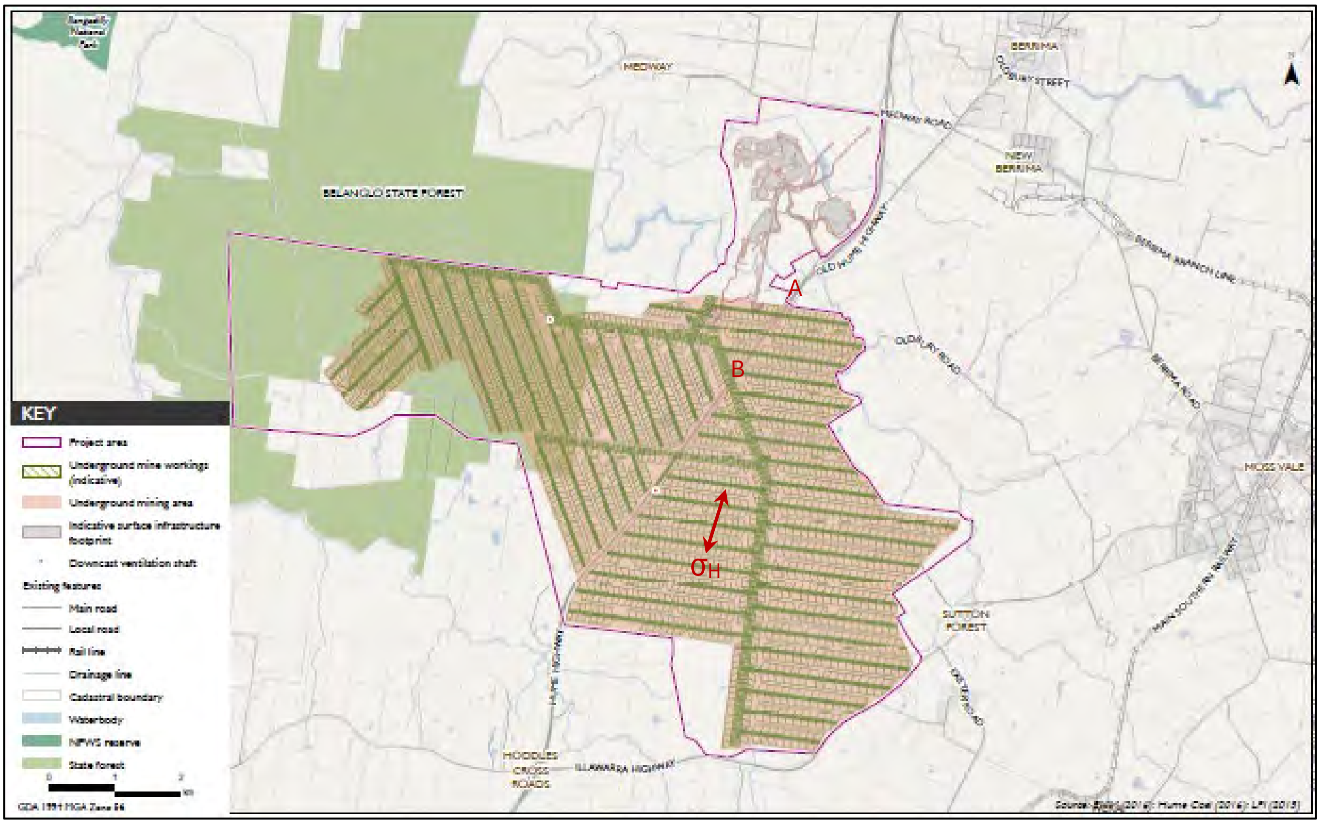

FIGURE 6. Hume Project EIS Mine Layout and Locations of the Two Hume Highway Bridges

4.1 Vertical Subsidence Effects

As a background, the predicted tilts, curvatures, and horizontal strain values due to vertical subsidence that were included in Mine Advice 2016b, are based on what is considered to be a credible worse-case scenario whereby:

(i) S_{max} for any span containing web pillars between intra-panel barriers is predicted to be up to 20 mm (which includes allowances for both pillar compression and coal de-pressurisation), this being slightly in excess of the maximum predicted value at the highest cover depth of 170 m, and

(ii) the surface lowering above any of the barrier pillars is conservatively assumed to be zero.

This combination results in predictions of maximum possible surface tilt, from which curvature and horizontal strain due to vertical subsidence effects are also maximised, as compared to the more likely broader consistent lowering of the surface across all pillar types, this being comparable with that shown for sub-critical at shallow depth panels separated by standing coal pillars (see Figure 7 from Galvin 2016).

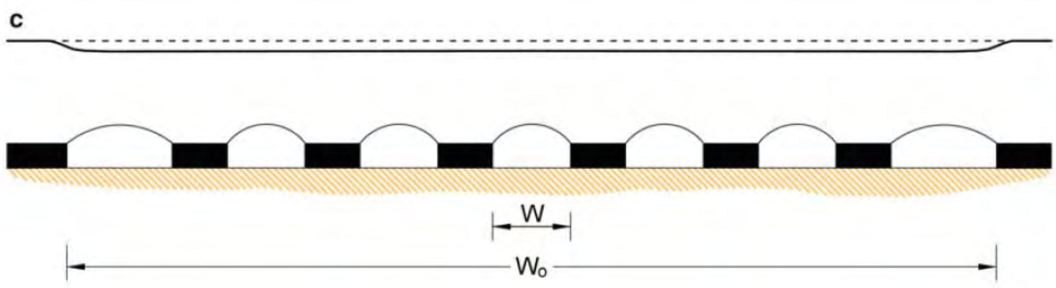

FIGURE 7. Two-Dimensional Visualisation of Generic Secondary Extraction Layouts Pertaining to Underground Coal Mining and the Vertical Displacement Surface Profile – Individual Panel Width to Depth Ratio, W/H, Sub-Critical in a Shallow Mining Situation (Galvin 2016)

In terms of the location of maximum tilts, curvatures and horizontal strains due to vertical subsidence, the analyses conducted for Hume demonstrated that due to the very low values of S_{max}, it was not possible to reliably distinguish between maximum and average values of tilt within the spans between intra-panel barriers. Therefore it was logically concluded as being a meaningless exercise to attempt to identify the likely locations of maximum values and is preferable, given the very low magnitudes involved, to simply apply predicted maximum values more broadly for impact assessment purposes.

4.2 Causal Mechanism for Far-Field Horizontal Movements Outside Angle of Draw

According to Pells 2011, the occurrence of far-field horizontal movements at surface well outside Angle of Draw (AoD) was first recognised in the early 1990's at the Cataract Dam. Since that time, data collected around areas of longwall extraction, particularly in the Southern Coalfield, has demonstrated significant horizontal movements up to 2 km away from areas of longwall extraction.

The driver for far-field horizontal movements outside of Angle of Draw is reasonably well defined based on a review of published literature on the subject and there appears to be minimal disagreement amongst the various researchers (e.g. Hebblewhite 2008, MSEC 2002, Pells 2011 and Seedsman and Watson 2001) at least in terms of general causation. The driving mechanism is commonly described as one of horizontal stress re-distribution around large mining excavations such as a longwall goaf with a bias in the general direction of movement either towards the mining area (as evident in Figure 8) or orientated in line with the major horizontal stress. The significant magnitude of a number of the measured horizontal movements outside of AoD and the associated impact potential is noted.

Ground stress re-distributions caused by excavating mine openings are well known. Figure 9 illustrates the changes in a pre-excavation hydrostatic (equal in all directions) stress field due to the formation of a circular opening.

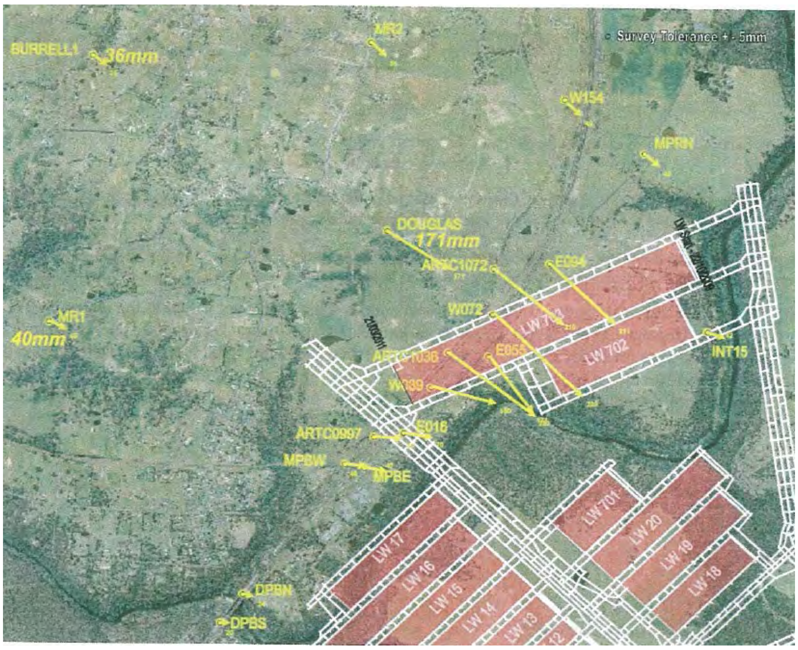

FIGURE 8. Measured Far-Field Movements at the Completion of LW703 (Pells 2011)

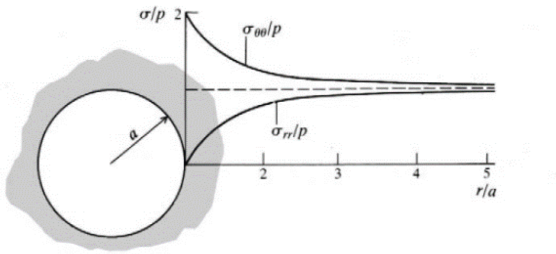

FIGURE 9. Axisymmetric Stress Distribution Around a Circular Opening in a Hydrostatic Stress Field (Brady and Brown 2005)

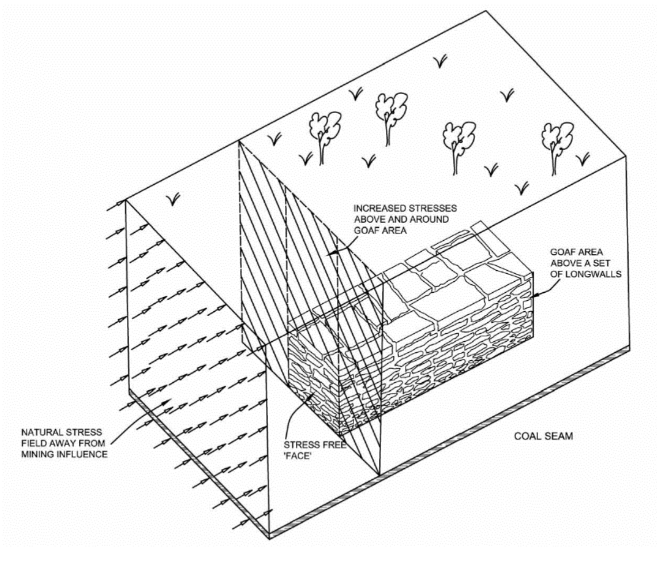

FIGURE 10. “Cartoon” Illustrating Stress Re-Distribution Around a Goaf Area (Pells 2011)

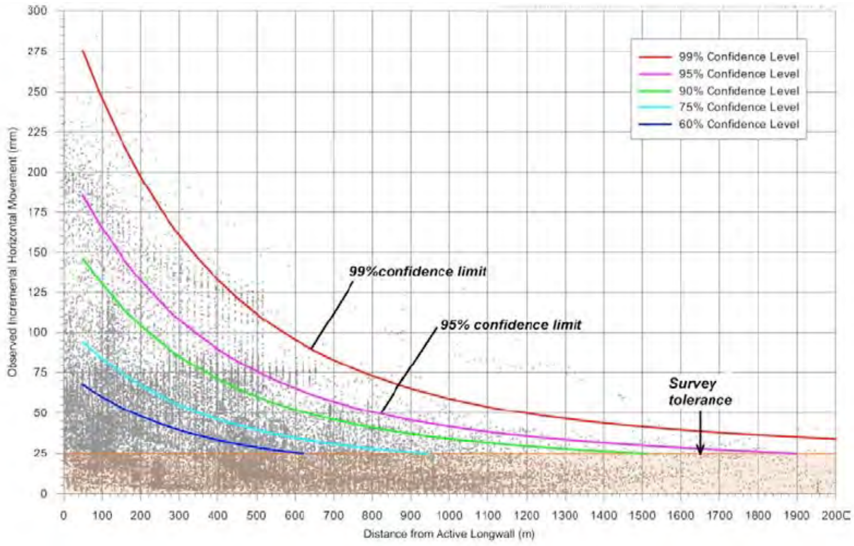

FIGURE 11. Data on Far-Field Movements in the Southern Coalfield, NSW (Pells 2011)

As a direct result of excavating an opening in a pre-stressed medium under bi-axial compression, the general effects on the ground stresses are as follows:

(i) all ground stresses are completely eliminated from inside the excavation

(ii) compressive stress levels outside the excavation increase in some directions and decrease in others, this specifically relating to the shape of the opening and the magnitude ratio between the two principal ground stresses acting in orthogonal directions (as contained within the Kirsch Solution), Figure 9 showing the hydrostatic example whereby the ratio between principal stresses in the Kirsch Solution (K) = 1.

(iii) inevitably the removal of the previously stressed material by the formation of the opening will result in the surrounding material moving into the excavation by varying amounts

(iv) the location where the state of stress is largely unaffected by the formation of the excavation is in the order of twice the excavation diameter (r/a = 4 in Figure 9 from the excavation perimeter).

If one considers Figure 9 in plan rather than section so that the stresses being re-distributed are all horizontal, it provides a credible mechanistic explanation for both (a) the commonly measured directions of far-field horizontal movements into the area of mining as well as (b) the significant distances away from mined areas where horizontal movements have been measured.

Whilst Figure 9 shows a completely formed excavation, in reality the overburden above a wide longwall panel contains sections of fully caved material immediately above the extraction horizon that have completely de-coupled from the surrounding strata, as well as overlying areas whereby the overburden may have subsided, but not completely de-coupled thereby resulting in only partial relief of the pre-mining compressive horizontal stresses.

Pells 2011 recognises the same basic causation model for far-field horizontal movements as illustrated in Figure 10 and describes the associated prediction of such movements as "*essentially a simple elastic analysis*".

In terms of horizontal ground strains due to mining in two orthogonal directions, Figure 9 illustrates that for hydrostatic stress conditions, a reduction in compressive horizontal stress (or horizontal strain) in the radial direction (σ_{rr}) results in a corresponding equal increase in compressive horizontal stress (or strain) in the tangential direction ($\sigma_{\theta\theta}$). With the TSF values for the tectonic components of the major and minor horizontal stresses being 0.44 and 0.31 respectively (see Mine Advice 2016b), this results in a ratio between these components of 1.42, which is relatively close to the hydrostatic condition with a ratio of 1. For the purpose of the predictions herein, it will be assumed that any tensile horizontal strains induced in the radial direction towards the mining footprint, will be accompanied by an increase in compressive horizontal strain by the same magnitude in the tangential direction.

One other technical principle requires due consideration, namely that unlike an elastic stress analysis outcome as shown in Figure 9 whereby the two orthogonal ground stresses are assumed to act independently of one another, the analysis of stress measurement data from Australian coal measures shows that the tectonic component of the minor horizontal stress is almost certainly directly generated as a result of the action of the tectonic major horizontal stress (Frith and Colwell 2006). Therefore, if the major horizontal stress or strain is being relieved in the radial direction, it is more logical to conclude that the minor horizontal stress or strain in the tangential direction is also likely to be relieved rather than increased.

Figure 11 (Pells 2011) contains a summary of the many measured horizontal movements outside of longwall panels in the Southern Coalfield. Two important deductions can be drawn from this data set:

(i) the higher the magnitude of horizontal movement at the limit of the mining excavation, the further out from the excavation that horizontal movements develop.

(ii) there is a general decay in horizontal movement magnitudes away from the limit of the mining excavation.

Both characteristics have some relevance to the far-field horizontal strain predictions contained in this report.

4.3 Specific Predictions for Hume Highway Bridge Locations

Having provided background information in terms of the predicted levels of vertical subsdience above the proposed Hume workings and a general causation model for far-field horizontal movements outside of AoD, predictions of horizontal ground strains at the two nominated Hume Highway bridge sites can now be given.

Figure 12 contains a schematic of the predicted general overburden condition following the completion of the proposed mining at Hume, the main points being (a) little or no overburden caving and (b) the very low magnitudes of S_{max} for each of the web pillar spans between intra-panel barrier pillars. As compared to Figure 10 for longwall extraction containing a range of post-mining overburden conditions, the intended post-mining overburden condition at Hume has the entire overburden being permanently supported on coal pillars. Therefore, the magnitude of horizontal stress reduction in the overburden is entirely related to the magnitude of vertical subsidence and associated horizontal "unloading" of the overburden within the mining footprint.

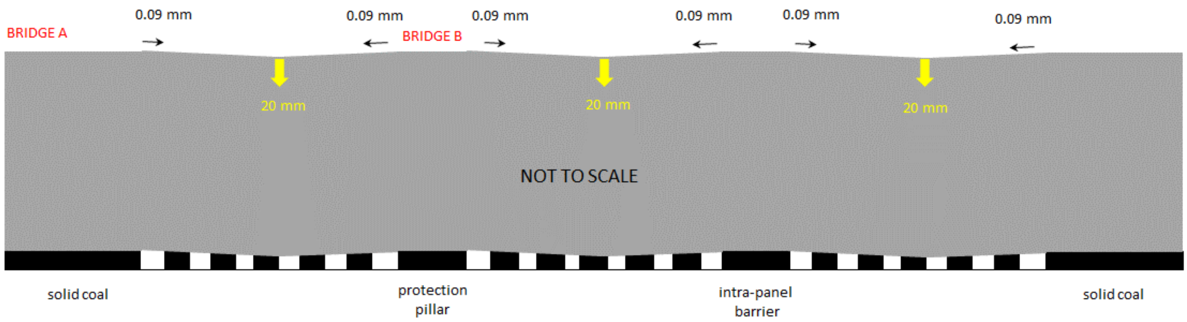

FIGURE 12. Schematic Illustration of Generic Pillar Layout, Resultant Overburden Movements and Location of Bridges A and B Relative to Mining Excavations (exaggerated vertical scale)

4.3.1 Bridges Over Medway Rivulet (Bridge A)

The two bridges over the Medway Rivulet are located outside the proposed mining area as shown in Figure 6 and the proposed mine workings closest to Bridge A are relatively shallow with a typical cover depth in the order of 120 m.

Being outside of the proposed mining area and with vertical subsidence outside of the proposed mining area being characterised by an Angle of Draw of 0° (by definition due to the predicted S_{max} being no greater than 20 mm), the first prediction is that the two bridge structures over the Medway Rivulet are almost certainly located outside the influence of vertical subsidence. This then means that the only potential mechanism by which horizontal ground strains can develop at Bridge A is due to far-field horizontal movements outside of Angle of Draw.

Far-field horizontal effects are addressed in Section 5.7 of Mine Advice 2016b whereby it is determined that the maximum reduction in compressive horizontal strain across an individual 60 m wide panel between intra-panel barriers due to an S_{max} at the centre of the panel of 20 mm, is 3×10^{-7} or 0.0003mm/m. This equates to a total horizontal extension or "expansion" of the overburden of 0.018 mm for each individual 60 m wide span, this being the primary source of far-field horizontal movements outside of Angle of Draw in-towards the mined area.

Figure 12 provides a schematic illustration of how the individual 60 m spans containing web pillars between intra-panel barrier pillars combine together within and across the proposed mining area. Furthermore, Figure 6 shows that it is the major horizontal stress that is likely to be relieved in the radial direction in towards the mining area, which closely corresponds to the approximate north-south alignment of the two structures at Bridge A.

With the overburden behaviour illustrated in Figure 12, the major horizontal stress being relieved into towards the mining area and the manner by which horizontal strain relaxation effects are both minimised and compartmentalised within the overburden by the mine layout, given that the predicted general compressive horizontal strain loss within the mining footprint is 3×10^{-7} or 0.0003 mm/m, for simplicity it is suggested that for impact purposes at Bridge A:

(i) this level of tensile horizontal strain be applied parallel with the freeway, whereas

(ii) in the approximate east-west or transverse direction, the same level of induced horizontal strain also be applied, but that both compressive and or tensile horizontal strains of this magnitude be considered in an impact assessment due to east-west being the tangential direction relative to the mining footprint just to the south.

4.3.2 Bridges Over Wells Creek (Bridge B)

Whilst Bridge B is located within the proposed mining area, the mine layout contains a substantial and largely solid (i.e. no roadways driven though it) protection pillar of at least 100 m width directly beneath and either side of the Hume Highway, as is evident in Figure 6. With the cover depth in the area of Bridge B being in the order of 120 m and predicted maximum vertical subsidence levels above adjacent web pillar panels being no more than 20 mm, the Hume Highway is predicted to be outside the influence of differential vertical subsidence effects other than negligible surface lowering along the full length of the barrier pillar due to compression effects (estimated at in the order of 2 mm given a cover depth of 120 mm and a solid barrier width of at least 100 m).

Unlike Bridge A, Bridge B will potentially be influenced by compressive horizontal strain reductions due to mining on both the eastern and western sides. Furthermore, Bridge B will be directly influenced by the incremental development of the mining footprint around its location over time, meaning that the Bridge B structures may be aligned both tangentially and radially to the mining footprint at various times during the mining process.

Tensile and compressive horizontal strains of $6x10^{-7}$ or 0.0006 mm/m are predicted and both should be applied in both the longitudinal and transverse directions for overall impact purposes at both the north-bound and south-bound structures that make up Bridge B.

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