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17 May 2019

Professor Chris Fell
Chairperson
Independent Planning Commission NSW
Level 3, 201 Elizabeth Street
Sydney NSW 2000

Re: Groundwater consultant reply to DOI Water response to IPC questions

Dear Professor Fell,

Please find attached (Attachment 1) the reply from Hume Coal to the Department of Industry - Water (DoI Water) response dated 24 April 2019.

Hume Coal submits that the DoI Water response to questions from the Independent Planning Commission (IPC) contain errors and unsupported claims, and as such, should be given little weight.

The NSW Government's Department of Planning and Environment's (DPE) independent groundwater peer reviewer, Hugh Middlemis, is an extremely experienced, accomplished and reputable hydrogeologist and groundwater modeller. Hugh Middlemis' review (Middlemis 2017) found the Hume Coal groundwater model to be suitable for mining impact assessment purposes (Class 2 confidence level) and confirmed that the model is therefore 'fit for purpose'. This clear finding appears to have been overlooked by DoI Water in its response to the IPC's questions.

It was assumed that DoI Water would have been provided a copy of the Middlemis review by DPE for consideration when it drafted its first response to the Hume Coal Response to Submissions (RTS) Report. The Hume Coal RTS referenced and drew heavily from the Middlemis review, so it would be assumed that DoI Water would have had access to the document; however, in forming its opinion the following was stated:

> '(Note: DoI Water is aware that DPE has engaged an independent groundwater expert to review the latest model work. DoI Water has not had access to this document in the preparation of this advice).'

Consultation between Hume Coal and DoI Water on the groundwater model has occurred over the past eight years. Many of the concerns raised in their latest response have been raised previously by DoI Water and adequately addressed in Hume Coal's previous responses. Certainly, most of Hume Coal's responses (within the RTS) have been considered by the DPE peer reviewer, Hugh Middlemis, to adequately address the issues raised, and that therefore, the Hume Coal groundwater model is fundamentally consistent with best practice in design and execution.

Continual repetition of claims regarding the adequacy of the model and groundwater assessment by DoI Water must be supported by evidence and made with reference to clear specifics as to how they can be addressed in more detail.

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. The peer reviewer, Hugh Middlemis, is one of the key people in Australia who understands uncertainty and the mathematics involved and this is why his assessment can be relied upon.

Therefore, it is questioned why DoI Water refute Hugh Middlemis' conclusions without disclosing the identity, experience, and qualifications of the opinions provided.

Hume Coal recommends that the IPC ask DoI Water to disclose the qualifications of the collective authors so that the IPC can discern whether the response was written by a qualified expert with relevant experience. Hume Coal submits that that is necessary to give proper weight to the DoI Water's rejection of the conclusions reached by DPE's peer reviewer. Some key concerns regarding DoI Water's latest response to the IPC are summarised below.

Statements made without evidence, reference or sufficient details

Many of the claims made by DoI Water are difficult to respond to as they are not referenced or supported by evidence or actual data. For example, one of the repeated claims made by DoI Water is that the fractured rock has a higher conductivity at depth. This is a misconception, or local anecdote. It is not supported by the collated empirical data, which was provided and explained in detail in the original Environmental Impact Statement (EIS) (within the data review by Coffey (2017)).

In another example, DoI Water claims that the modelling is "uncalibrated" without providing sufficient reference or evidence indicating which calibration targets are considered to be uncertain. This vague assertion is unhelpful to the IPC because it is impossible to verify that firstly, an issue exists, and secondly, how the issue can be addressed, when DoI Water does not reference specific examples or provide recommendations.

Statements that contradict or do not reflect policy

There appears to be a lack of understanding of how the technical model results relate directly to NSW Government policy and planning requirements. Some comments made require Hume Coal to depart from the minimal impact criteria provided in the Aquifer Interference Policy (AIP), and are at odds with the guidance provided in the Australian Groundwater Modelling Guidelines (Barnett et al 2012).

Hume Coal submits that the IPC will assess the project based on existing regulations and policies. It is inappropriate to enforce standards not provided by the NSW Government policy and planning requirements.

Incorrect understanding of groundwater modelling features/ functions/ processes.

The DoI Water's response letter indicates a lack of understanding of groundwater modelling for mining situations, and scientific principles. Two key examples of this are:

- the comments from DoI Water concerning the transfer of water from the primary water dam to underground voids and DoI Water's suggestion, contrary to the independent peer reviewer's belief, that this makes the model less conservative. The approach **is** conservative as putting any additional water underground can only scientifically have an equal or lesser drawdown impact due to the scientific law of 'the conservation of mass'; and

- the comment from DoI Water that the model should use 'wells' to simulate the mine void rather than 'drains'. This suggests a lack of understanding of how MODFLOW (the modelling software) works. The use of 'wells' to mimic mining means you force an extraction rate at the well (ie the modeller pre-determines the mine inflow). Intervention by the modeller in terms of forced extraction would be counter to the objective of using known data to calculate the unknown mine inflow.

Attachment 1 provides Hume Coal's full reply (*this response)* to DoI Water's responses to the IPC's specific questions.

Hume Coal's response provides detail to support the key issues outlined above. This response is fully substantiated and supported by an extensive data set, a groundwater model considered by DPE's independent groundwater peer reviewer to be suitable for mining impact assessment purposes (Class 2 confidence level), and sensitivity and uncertainty analysis, conducted in consultation with DoI Water, and considered (by the groundwater consultants and DPE's independent expert) to be world class and appropriate for the proposed Hume Coal project.

Yours sincerely

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Attachment 1: Hume Coal's full reply to DoI Water's responses to the IPC's specific questions.

Attachment 1

Consultation between Hume Coal and the NSW Government on water related matters is summarised in the Response to Submissions report as per the following (Table 1). It is noted that DPE committed to Hume Coal that a meeting with DoI Water would be organised to discuss the groundwater modelling aspects of the RTS; this meeting never eventuated despite several requests by Hume Coal to hold this meeting.

Table 1 Summary of consultation on water related matters between submission of the EIS and submission of the RTS

Date	Objective	Attendees	Outcome
4 July 2017	Make good concept discussion	**DPE:** (David Kitto, Clay Preshaw and Paul Freeman) **DPI:** Mitchell Isaacs **Hume Coal**: Greig Duncan, Ben Anderson, **EMM:** Liz Webb	Hume and EMM confirmed groundwater would remain available for the licensed purpose of the relevant water bore. More detail about make good strategies has been included in this RTS report.
25 August 2017	DI Water submission discussion	**DI Water:** Mitchell Isaacs, Tim Baker, Greg Russell, Graeme White, Fabienne d'Hautefeuille, Andrew Drusneski, **Hume Coal:** Greig Duncan, Ben Anderson, Luke Edminson, **EMM:** Liz Webb Noel Merrick, Frans Kalf **Posco**: Patrick Yeou	Open discussion and clarification of issues raised by DI Water in their submission. Hume committed to undertaking a model audit and rework as per discussion and agreement at this meeting.
9 October 2017	Consultation and discussion on model details	Hugh Middlemis and Noel Merrick	Revised model subsequently tailored to ensure Middlemis' outstanding concerns could be addressed.
24 October 2017	Water NSW submission discussion	**Hume**: Luke Edminson, Ben Anderson, Alex Pauza, **WSP**: Rob Leslie, Leigh Doeleman, **EMM Coal**: Liz Webb, Nicola Fry, **WaterNSW:** Girja Sharma, Neil Cowley, Malcolm Hughes, Maria Dubikova, Peter Dupen, Hemantha DeSilva	Focused on surface water quality and water management in dams (including the first flush). Hume to provide further details around potential water quality offsetting measures and black water treatment.
2 November 2017	Water NSW submission discussion	**Hume Coal**: Luke Edminson, Alex Pauza **WaterNSW**: Girja Sharma, Neil Cowley	Discussion on surface water quality and water management in dams

Question 1 – Has the class of the groundwater model been resolved in your opinion? We note there has been at least one meeting between modellers.

DoI Water response: the additional work has not improved upon a number of key indicators which are required to:

- predict water level and volume impacts to the water supply aquifer due to mine dewatering (to a sub metre scale resolution for drawdowns)
- allow assessment of volume losses at the resolution of individual agricultural users
- confirm licensed allocation volumes.

Water level and volumetric impact predictions to the groundwater system near to the proposed Hume Coal Project have been provided through groundwater modelling documented both in the EIS (Coffey, 2016) and Response to Submissions (RTS) (HydroSimulations, 2018). This response questions the requirement for 'sub metre scale resolution for drawdowns'. While groundwater modelling software can output predictive results to a sub-metre scale, when considering the uncertainty in model inputs, the requirement for sub-metre scale resolution may introduce false precision. There is no requirement for 'sub metre scale resolution for drawdowns' within the NSW Aquifer Interference Policy (AIP).

The AIP requires for groundwater level drawdown to be quantified at water supply works, with a further requirement for make-good provisions if this drawdown exceeds 2 m. This quantification has been completed in modelling documented in both the EIS (2016) and RTS (HydroSimulations, 2018). There is no requirement for assessment of volume loss to water supply works within the AIP.

The water assessment and groundwater model were conducted in line with the requirements of the AIP and the Independent Expert Scientific Committee (IESC) guidelines. The predicted drawdown at landholder bore sites has been assessed and provided as per the AIP. Assessment of volume availability changes are not required by the AIP and there appears no precedent for this.

The groundwater model is a regional scale model and NSW Government's own independent expert, Hugh Middlemis, advised that the groundwater model is 'fit for purpose'.

DoI Water response: DoI Water considers this latest model to be incomplete, with the model neither optimally using all the available field data nor incorporating prior recommendations.

All available data collected by Hume Coal has been used in developing the conceptual and numerical model. There are 345 individual exploration and groundwater monitoring drill holes for the project (179 of which are within the proposed mining area). The hydraulic conductivity data in the model calibration is extensive and all available data for the project and surrounding mines was utilised in this calibration. The data set is extensive and the groundwater model build and calibration followed best practice in that all data and natural variations were considered.

It is not clear what "prior recommendations" DoI Water are referring to.

DoI Water response: As such we (DoI Water) do not consider it appropriate to be classified, however it resembles a Class 1 model with some higher class indicators. According to the checklist in the peer review the model incorporates some Level 2 and Level 3 elements. However that does not rationalise the overall classification to an acceptable degree.

As per Hume Coal's submission to the IPC (March 2019), DPE's own independent peer review expert (Hugh Middlemis) agreed that the groundwater model is suitable for the mining impact assessment purpose (Class 2 confidence level) and that downgrading of the model to Class 1 is invalid.

DoI Water's response suggests that DoI Water have completed their own checklist that may contradict work by Hugh Middlemis. Hume Coal would like this to be shared to allow open and frank discussion against specific points of the checklist that DoI Water believe differ to HydroSimulations review (within the RTS) and Hugh Middlemis' expert independent peer review.

DoI Water response: The Australian Groundwater Modelling Guidelines are clear on the distinction between levels based on reported error statistics falling within defined ranges. Failure to achieve error statistics within these ranges imply that, although parts of the model might be well developed, as a functional predictive tool the model is lacking in certain aspects. That position is supported by the range of error statistics that suggest the replication of existing conditions has not been reasonably achieved, and therefore the predictive capability is not certain.

The above statement by DoI Water suggests that the groundwater model calibration is not adequate for predicting mine related groundwater impacts. The groundwater consultants operating on behalf of the Hume Coal Project dispute the claim by DoI Water that "The Australian Groundwater Modelling Guidelines (AGMG) (Barnett et al 2012) are clear on the distinction between levels based on reported error statistics falling within defined ranges" and finds there to be no evidence within the AGMG of error statistic ranges that define confidence classes or the ability of a groundwater model to serve as a functional predictive tool.

The groundwater consultants find the approach of the AGMG in relation to the use of error statistics to be nearly the opposite to claims made by DoI Water in its responses to the IPC questions. The following excerpts from Section 5.4.5 – Performance measures and targets of the AGMG (Barnet et al 2012) aim to highlight this.

Guiding Principle 5.4 (page 73 AGMG) states:

> Performance measures should be agreed prior to calibration and should include a combination of quantitative and non-quantitative measures… A target SRMS of 5% or 10% is only meaningful when those setting the target know that it is achievable for a particular kind of problem and a particular environment with a known density of informative data.'

There were no pre-determined performance measures agreed upon by the proponent prior to calibration of the EIS groundwater model. There is a lack of informative data, particularly in relation to landholder pumping rates, that limit the ability for meaningful SRMS targets to be created for a groundwater model developed in the region of the proposed Hume Coal Project.

Section 5.4.5 of the AGMG (Barnet et al 2012) also describes circumstances where it may not be desirable to define specific target values for modelling performance measures, and that predefined performance measures may prevent a modeller from obtaining the best possible calibration, based on the information contained in all available data. A simple application of a strict SRMS error is deemed too simplistic an approach for mining models in particular.

Assessing model calibration using SRMS error alone is not a failproof approach to assessing model quality and representation of the conceptual hydrogeological understanding. It is possible to manipulate the model to produce a low SRMS error, however this may not result in a good quality model.

As per Hume Coal's submission to the IPC (March 2019), sensitivity and uncertainty analysis was developed in consultation with DoI Water. The uncertainty analysis focused on hydraulic conductivity, the model parameter thought to be most sensitive that also had a substantial set of field data to support the parameter distributions explored. The Hume Coal model uncertainty analysis tested a large range of hydraulic conductivity values from known data within the area, but produced a relatively 'tight' range of inflow volumes and drawdown. This equals high confidence in model results (ie drawdown and inflow).

The groundwater consultant considers the DoI Water statement above to be invalid. As per Hume Coal's submission to the IPC (March 2019), DPE's own expert (Hugh Middlemis) agreed that the groundwater model is suitable for the mining impact assessment purpose and that the model is "fundamentally consistent with best practice in design and execution".

This response would like to highlight that unknown and unmetered extraction rates at both licensed and unlicensed water supply works is a significant uncertainty within the groundwater system near the proposed Hume Coal Project. This response considers this uncertainty to be significant enough to advise against defining specific target values for modelling performance measures.

DoI Water has the following concerns:

The model is uncalibrated and calibration statistics require further explanation and improvement. The calibration methodology is unsound as it uses uncertain calibration targets.

As per the above and Hume Coal's submission in March 2019, DoI Water's concern regarding model calibration is considered invalid.

The statement that groundwater modelling presented in both the EIS (Coffey, 2016) and RTS HydroSimulations (2018), that have both undergone peer review is uncalibrated undermines the integrity of the consultancies performing the work and the peer review process. The claim by DoI Water that the modelling is "uncalibrated" degrades the integrity of the groundwater modelling without specific reference or evidence indicating which calibration targets are considered to be uncertain.

The claim is considered as derogatory and unsubstantiated since it is made without providing specific or reference examples or recommendations.

Some model parameters are outside the range of a reasonable hydrogeological analysis of field information and literature values.

It is unclear which parameters DoI Water consider to be outside the "reasonable" range referred to above. The groundwater consultant conducted statistical analysis for field collated hydraulic conductivity data. Specific storage parameters lie within values deemed reasonable by peer review.

There remains conceptual geological uncertainty.

The conceptual geology is deemed sufficiently certain for the purposes required to assess the impacts of this project. Further detail on which aspects of this DoI Water consider to remain uncertain are required to address this comment.

The spatial refinement is too coarse in key parts of the model domain.

The NSW Government independent peer reviewer does not consider the spatial refinement of the model to be too course to meet the objectives of the model and deems the model 'fit for purpose'. Generally, for groundwater models to be considered useable they should aim to have under 1,000,000 cells. The Hume Coal model has 1,200,000 cells and has 50 m resolution over the mine area and this is deemed sufficient.

It is not stated which aspects of the model domain are considered too coarse by DoI Water.

There is inadequate uncertainty analysis of the parameters applied (narrow range).

As stated above and in Hume Coal's submission to the IPC (March 2019), sensitivity and uncertainty analysis was developed in consultation and in agreement with DoI Water. The Hume Coal model uncertainty analysis tested a large range of hydraulic conductivity values from empirical collected data within the area but produced a relatively 'tight' range of inflow volume and drawdown. This equals high confidence in model results (ie drawdown and inflow).

It is not clear which aspect of the uncertainty analysis that DoI Water considers inadequate.

There is uncertainty about recharge and the manner in which evapotranspiration has been applied.

Groundwater recharge and evapotranspiration and how it is applied in the model is discussed in detail in the Revised Water Assessment and RTS document.

Rainfall recharge for this area was suggested in Pritchard (2004) to be 5% for exposed sandstone and 0.5% for non-sandstone areas. The Hume Coal mine model is approximately 50% exposed sandstone and 50% shale cover. Rainfall recharge adopted in the model (1.8%) is based on literature reviews, hydrograph analysis, and nearby mine data. The rainfall recharge value is constrained by calibration to baseflows.

Question 2 – Do you have concerns on how the interburden layer was modelled in the upgraded Merrick (2018) model?

Questions remain as to the extent of the Narrabeen Formation directly above the coal seams and the adequate representation of this in the model (thickness of the interburden and hydraulic parameters chosen for the groundwater model).

With respect to the location and thickness of the interburden, there is continuing uncertainty with regards to the thickness of the interburden in the Modified EIS USG-T model. The thickness and therefore significance of the interburden is modelled differently to the conceptualization of it. (Figure 3 in HS2018/02 vs Figure 4.3 and 4.4 in GEOTLCOV25281AB-ACA). The numerical model interburden thickness attains 6 - 10 m while the conceptualization of it in the Coffey report barely attains 2 m thickness in the exploration licence area A349.

The representation of the 'interburden' in the model is layer 8. This thickness is shown in Figure 1, which has been generated for this response and has not been presented in previous responses.

The maximum thickness of layer 8 within the Hume Coal Project Area does not exceed 3 m but is mostly less than 0.5-m thick. The Layer 8 'interburden', is a combination of:

- the Narrabeen Formation (which clearly only occurs **outside of the A349 lease area**);
- the Wongawilli Seam R Ply; and
- the Farmborough Claystone (which occur within the A349 lease area).

The combination of these three geologies are lumped as Layer 8 in the model and represented in a newly generated Figure 1 below and are considered the official 'interburden' in the model.

The RTS, Figure 3 in HS 2018/02 (published in the RTS in 2018), is reproduced here as Figure 2. This figure states 'interburden' in the title block, and represents model layer 8 (ie Narrabeen - which only occurs outside of the A349 lease area, Wongawilli Sean R Ply, and the Farmborough Claystone), **PLUS**, the unmined section of the Wongawilli Seam (ie above the working or mining section). This figure therefore presents the thickness of the sum of three model layers - layer 8, layer 9 and layer 10.

Submissions received on the EIS Model questioned whether the EIS Model had implemented a non-realistic, uniform layer thickness between the base of the Hawkesbury Sandstone and the proposed working section of the Wongawilli Seam. Therefore, the model was reviewed and Figure 2 was generated to show the 'interburden' (Layer 8), PLUS the unmined sections of the Wongawilli Seam (layers 9 and 10). This figure successfully answered the questions raised and demonstrates that the separation between the base of the Hawkesbury Sandstone and the proposed working section of the Wongawilli Seam is generally 1-3 m across a majority of the Hume Coal Project Area and ranges up to 10m in some places.

Figures 3 and 4 are reproduced figures from the EIS (Figure 4.3 and 4.4 in GEOTLCOV25281AB-ACA), and although also labelled 'interburden' show a different thickness. This map is produced in the data analysis section and is not in the numerical model section.

Although termed 'interburden' it is noted in the RTS groundwater model (HydroSimulations, 2018) that modelled aquifer properties were identical for the basal subdivision of the Hawkesbury Sandstone (model layer 7) down to the mined section of the Wongawilli Seam (model layer 11). Therefore, these layers do not provide a barrier to simulated drawdown in the Hawkesbury Sandstone as a result of mining.

The fit between measured and modelled interburden thickness is good, and the independent peer reviewer Hugh Middlemis considered this in detail and confirmed that the model *'conceptualisation is sound'* in this regard.

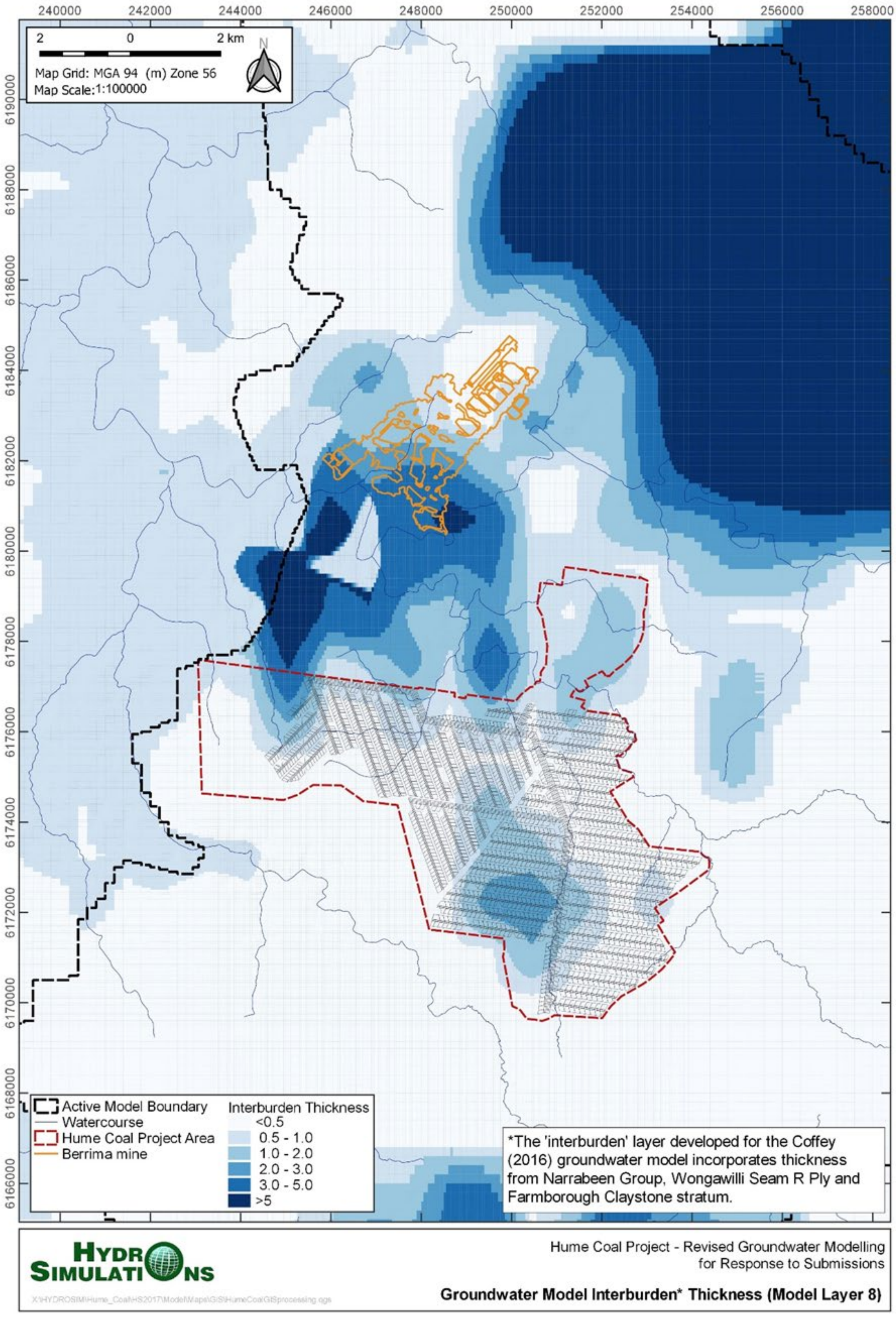

Figure 1 **Groundwater model interburden thickness – Model Layer 8**

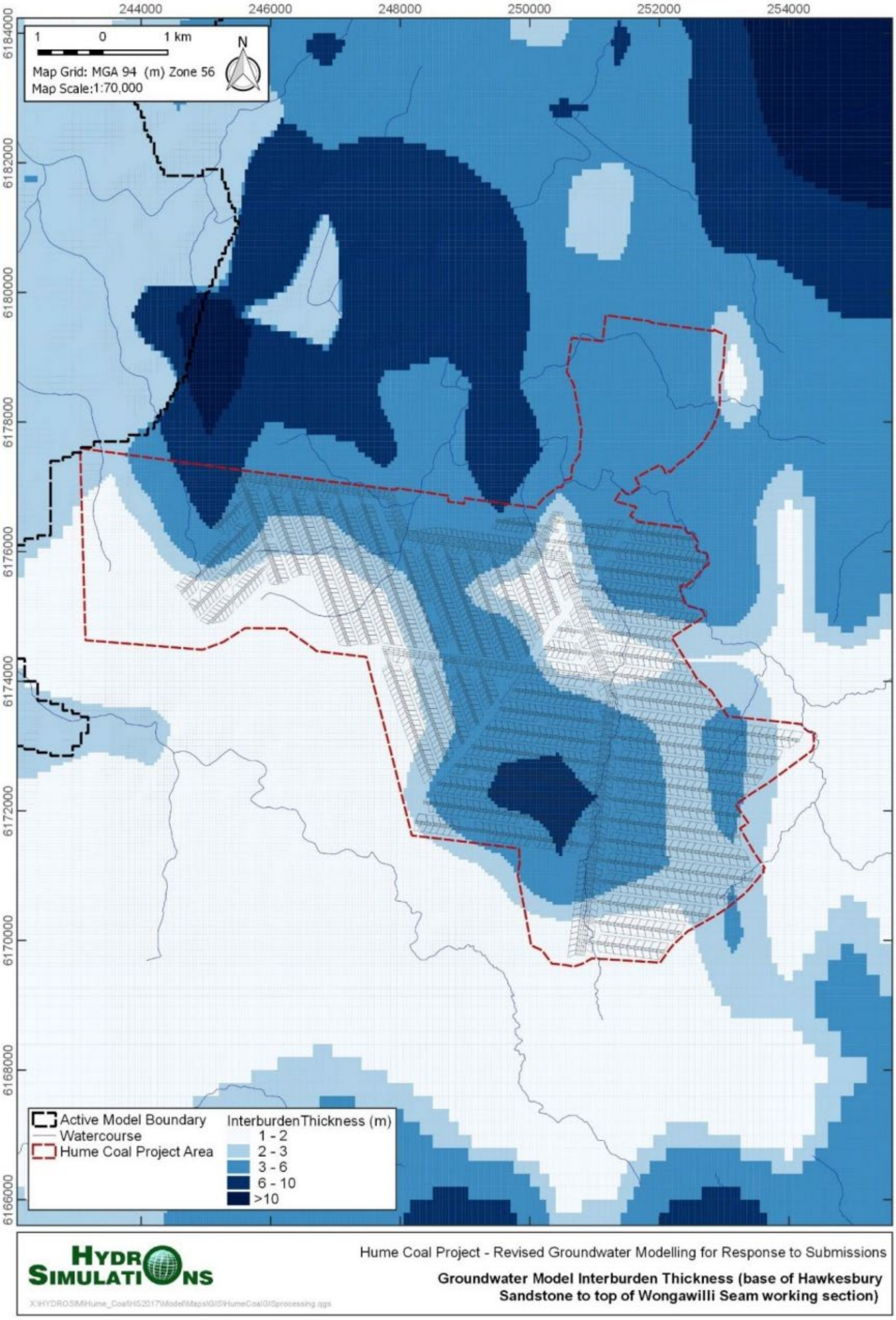

Figure 3 Groundwater model 'interburden' thickness

Figure 2 Interburden thickness reproduced from RTS (2018) - layers 8, 9 and 10 (Figure 3/HS2018/02 in the RTS, HydroSimulations 2018)

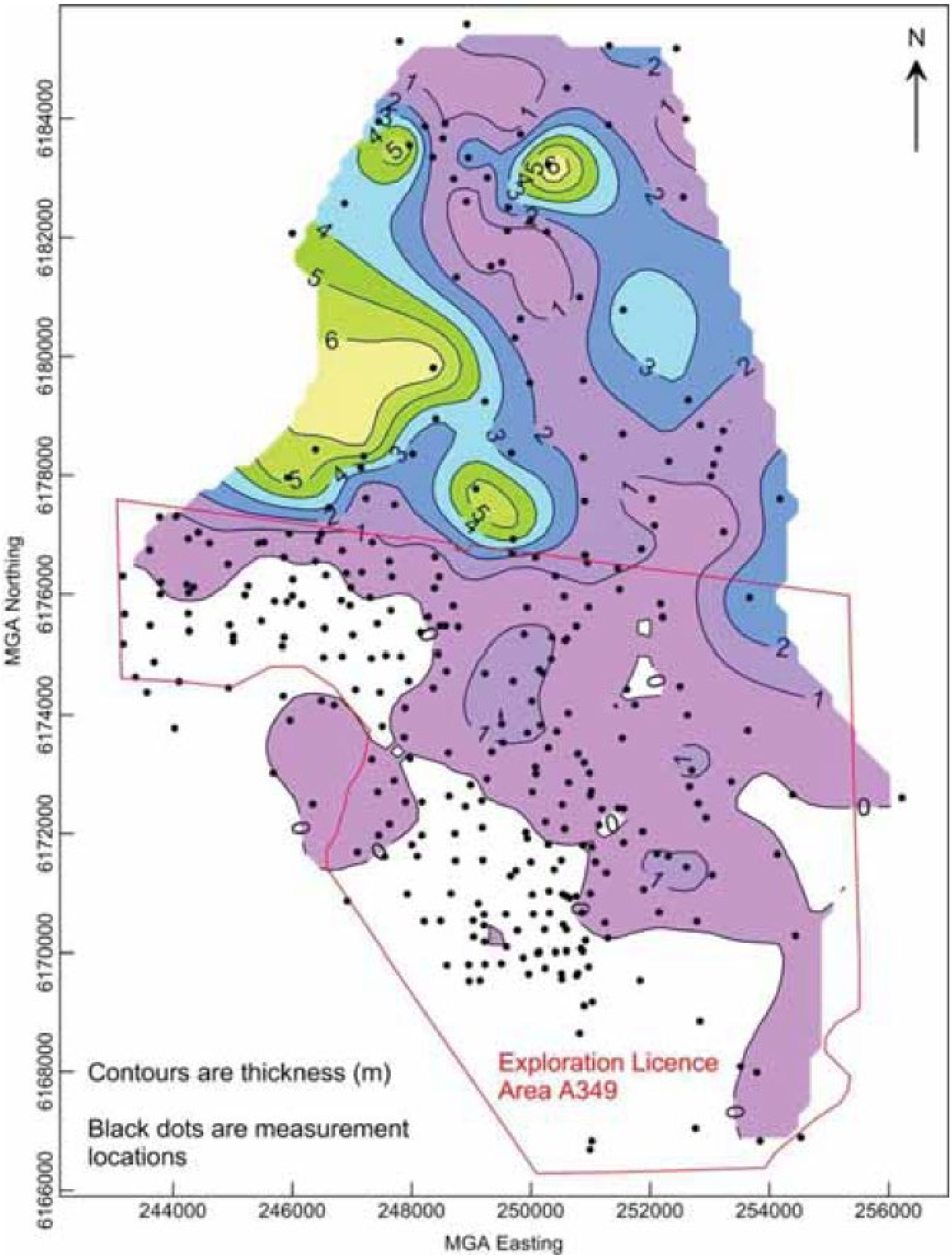

Figure 3 **Interburden thickness reproduced from the EIS in 2017 (referred to as Figure 4.3 in GEOTLCOV25281AB-ACA, Coffey 2016)**

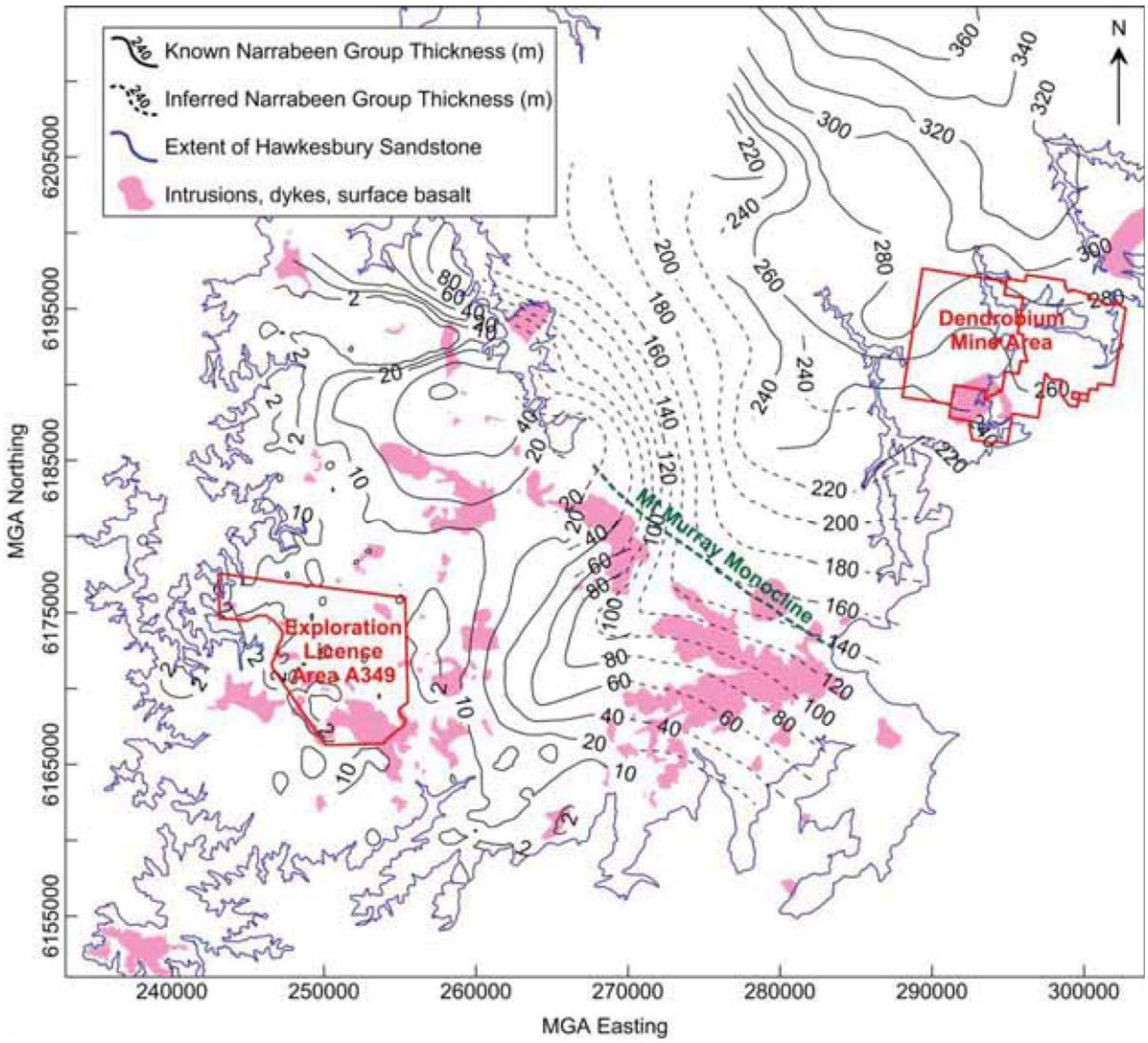

Figure 4 Structure contours and interburden thickness reproduced from the EIS in 2017 (referred to as Figure 4.4 in GEOTLCOV25281AB-ACA, Coffey 2016)

With respect to hydraulic parameters chosen by the report, there is evidence to support the Hawkesbury Sandstone hydraulic conductivity (Kh and Kv) being highest immediately above the coal seam to be mined. There are concerns about the adequate representation of this in the model. Alternative realizations of the model with higher Kv values applied were not presented as requested and agreed to during a meeting with the proponents modelling consultant.

There is no evidence in the data (field data or external references) to support the claim that the conductivity of the Hawkesbury Sandstone is highest immediately above the coal seam. This theory has been proposed by John Lee at various forums over the years, but is not supported by available data. This claim was also adopted in the Southern Highlands Coal Action Group report (Pells 2013).

The report by John Ross (Ross 2018), states that:

> 'there are no compelling data sets to confirm there is an increase in permeability of the sandstone strata at the base of the Hawkesbury Sandstone'.

Ross (2018) then explains that deeper bores, by their very nature of being deep, have more available head and can pump high volumes (sometimes only for short periods). The observed high yield from deep bores is then often incorrectly correlated to higher hydraulic conductivity at depth – which is not the case based on the data – the fact that the bore is deep and has storage allows the high yield – but the permeability providing the inflow to the bore may be higher in the formation (ie not necessarily at the base of the bore).

Question 3 - The transfer of water from the primary water dam to underground voids was not included in the modelling due to lack of mining details. Middlemis (2018) says this makes the model conservative. What is your opinion?

DoI Water response: The lack of this aspect in the model does not necessarily make it conservative but reflects the difficulty in attempting to reasonably incorporate what could be extremely variable behaviour under pressurisation. Speculation about the impact of this issue is best performed with an appropriate sensitivity and uncertainty analysis on a fit for purpose model. The combination of insufficient information and model not being fit for purpose, does not allow an effective judgement of the degree of how conservative the model is.

The approach is conservative as putting any additional water underground can only scientifically have an equal or lesser drawdown impact due to the law of 'the conservation of mass'.

DPE's independent expert (Hugh Middlemis) has advised that this is a conservative approach to assessing the potential impacts of the proposed mining operation on the groundwater system. The inclusion of more water underground will mean that less groundwater has to drain from the overlying strata to fill the void space. If this was simulated, there would be less drawdown. As such, the approach is considered conservative.

Hugh Middlemis further advised that the model is fit for purpose and is suitable for the mining impact assessment purpose (Class 2 confidence level). The groundwater consultant considers the simulation of mining without the addition of above ground water is conservative when compared to a version with water injected into the void. The groundwater consultant is however not stating that the groundwater model is conservative in all aspects of the model.

As stated above and in Hume Coal's submission to the IPC in March 2019, sensitivity and uncertainty analysis was conducted in consultation with DoI Water and the approach is considered (by the groundwater consultants and DPE's independent expert) world class and appropriate for the proposed Hume Coal project.

Question 4- The DoI-W Nov 2018 submission indicated that there were inconsistencies between the geological and groundwater model. The DPE independent reviewer (Middlemis, 2018) has indicated that the 3D semi regional model of Merrick (2018) is fit for purpose. Does your recommendation to use 90th percentile predictions allay some of your concerns regarding lack of geological detail? Would the use of the 67th percentile predictions of impacts, also be acceptable?

<u>DoI Response:</u> DOI Water considers that the model is not currently a suitable tool to predict and understand the likely impacts with a reasonable level of certainty for this project

The consideration that the model is not currently a suitable tool contradicts the independent peer review process conducted by Hugh Middlemis on behalf of the NSW Government. DoI Water are entitled to its own interpretation; however, in making this declaration DoI Water appear to have some fundamental misconceptions of the groundwater model, modelling processes generally (particularly for mining situations), and the application of the Aquifer Interference Policy. DoI Water do not provide specific references to support the contradictory view, or the individuals involved in forming these opinions.

<u>DoI Response:</u> DoI Water supports comprehensive uncertainty and sensitivity analyses being performed on a model that has been improved and fit for purpose. DoI Water provided recommendations about the methodology of the analyses which were not implemented.

This comment infers that Hume Coal consultants did not act on recommendations provided by DoI Water despite having the opportunity to do so in an appropriate manner. This statement is not correct.

During the submissions process, DoI Water and others made comments relating to concerns on the sensitivity of model parameters in the EIS model. Hume Coal therefore committed to undertake additional sensitivity analysis.

Consultation with the NSW Government (DoI Water) occurred in August 2017, in the form of a meeting with DoI technical experts, Hume Coal groundwater modelling team, EMM and Hume Coal. This meeting specifically addressed the groundwater modelling components of the DoI Water submission and additional sensitivity and uncertainty modelling was discussed and agreed to at that meeting. This work was then undertaken by HydroSimulations and the results were included in the RTS for the Hume Coal project. The model and associated reporting provided in the RTS was endorsed by the independent peer reviewer engaged by the NSW Government, Hugh Middlemis.

Question 5 - What is your opinion on hydraulic conductivity decreasing with depth, as modelled? Some groundwater specialists believe this interpretation is wrong.

<u>DoI Response</u>: In summary, we do not believe that the data presented by the proponent demonstrates clear field evidence for the assertion that hydraulic conductivity decreases with depth. In addition, we believe that the behaviour of hydraulic conductivity in the vertical and horizontal directions can vary significantly in the aquifers present in the Hume Coal project area.

It is uncertain which ‘specialists believe that conductivity increases with depth’. As per Hume Coal’s submission to the IPC (March 2019), the geological and hydrogeological data for the project considered the extensive, 345 individual drill holes for the project area (179 of which are within the proposed mining area). The hydraulic conductivity data in the model calibration is extensive and all available data for the project and surrounding mines was utilised in this calibration. The utilisation of this extensive data set and the groundwater model set-up and calibration followed best practice in that all data and natural variations were considered.

At other sites in the Sydney Basin, shown in the Coffey report, there is a clear decreasing trend with depth.

Within the groundwater work conducted for the RTS by HydroSimulations (2018) statistical analysis of the packer and specific capacity data at Hume subdivided hydraulic conductivities into depth bins at 50 m intervals. This was done for the creation of probability distributions for use within the uncertainty analysis. This scientific approach shows a very clear trend of conductivity decreasing with depth.

The Hawkesbury Sandstone aquifer in the Hume Coal project area is primarily a fractured rock aquifer as well as a secondary porous rock aquifer.

The Sydney Basin, which includes the Nepean Management Zone 1, is classified as a porous rock groundwater system in the water sharing plan There is has been no evidence or references presented that indicates the Hawkesbury Sandstone in the Hume Coal project area is primarily fractured rock.

<u>DoI Water Response:</u> DoI Water experience from groundwater exploration drilling into fractured rock aquifer environments confirms that in such aquifers hydraulic conductivity in the vertical (Kv) and horizontal (Kh) directions is highly variable. In some situations Kv and Kh can be similar and in others Kv is higher than Kh. Increasing hydraulic conductivity with depth in such aquifers can also be common nor is it particularly rare even in primary porous aquifers.

It is acknowledged that the hydraulic conductivity in the Hawkesbury Sandstone is highly variable and dependent on the interception of fractures and their connectivity to other fractures. However, there is no evidence to suggest that vertical hydraulic conductivity (Kv) is greater than the horizontal conductivity (Kh) in the Sydney Basin. The DoI Water claim is unsubstantiated, and references are not provided.

No references have been cited to support this claim, and it appears to be the fundamental pillar that DoI Water have based their critical assessment of the model on. Scientific analysis of field and previously published hydraulic conductivity data for the Southern Sydney Basin clearly demonstrates decreasing hydraulic conductivity with depth.

The EIS data review by Coffey provided evidence for the decreasing K with depth based on available data and are reproduced here as Figure 5 (Figure 5.2 GEOTLCOV25281AB-ACA) and Figure 6 (Figure 5.4 GEOTLCOV25281AB-ACA). Decreasing K with depth is scientifically demonstrated in the literature and local data and the Coffey (2016) report states:

> 'The relationship between the K field and principal horizontal stress magnitude was explored by considering only the stiffer media within the profile. This included general interburden (mostly sandstone) only and excludes coal seams. Figure 5.4 **(reproduced here as Figure 6)** shows the running 10-point log-average K down the depth profile for Permian Coal Measures (excluding coal seams) at a site in Kentucky (Hutcheson et al 2000a, 2000b), the Southern Coalfield (Reid 1996), the Hunter Valley, and the Bowen Basin, compared to the Hume area. Figure 5.4 also shows the measured principal horizontal stress in the Southern Sydney Basin (Hillis et al 1999) and three measurements undertaken on the Hume lease. **All five datasets identify a reducing K with depth,** caused by increasing overburden pressure. Average horizontal stress magnitudes for a depth of 100 m as estimated from field measurements are labelled at the average K for each K distribution. **Each distribution has approximately the same rate of decrease in K with depth, mostly caused by increasing overburden pressure (with media densities being similar between areas).**'

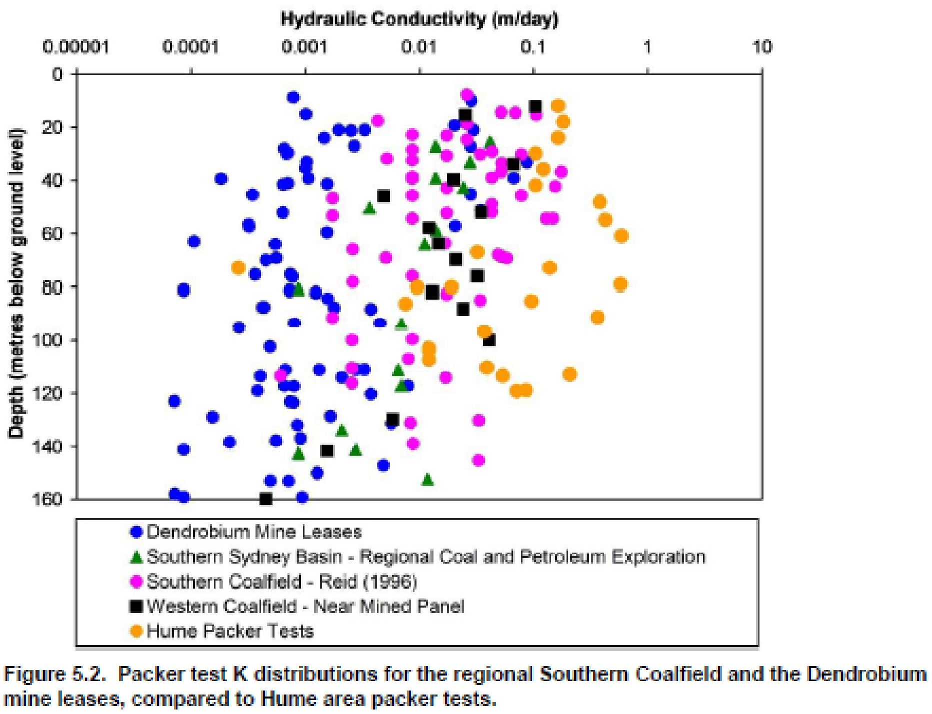

Figure 5 Packer Test K distribution - reproduced from the EIS in 2017 (referred to as Figure 5.2 in GEOTLCOV25281AB-ACA, Coffey 2016)

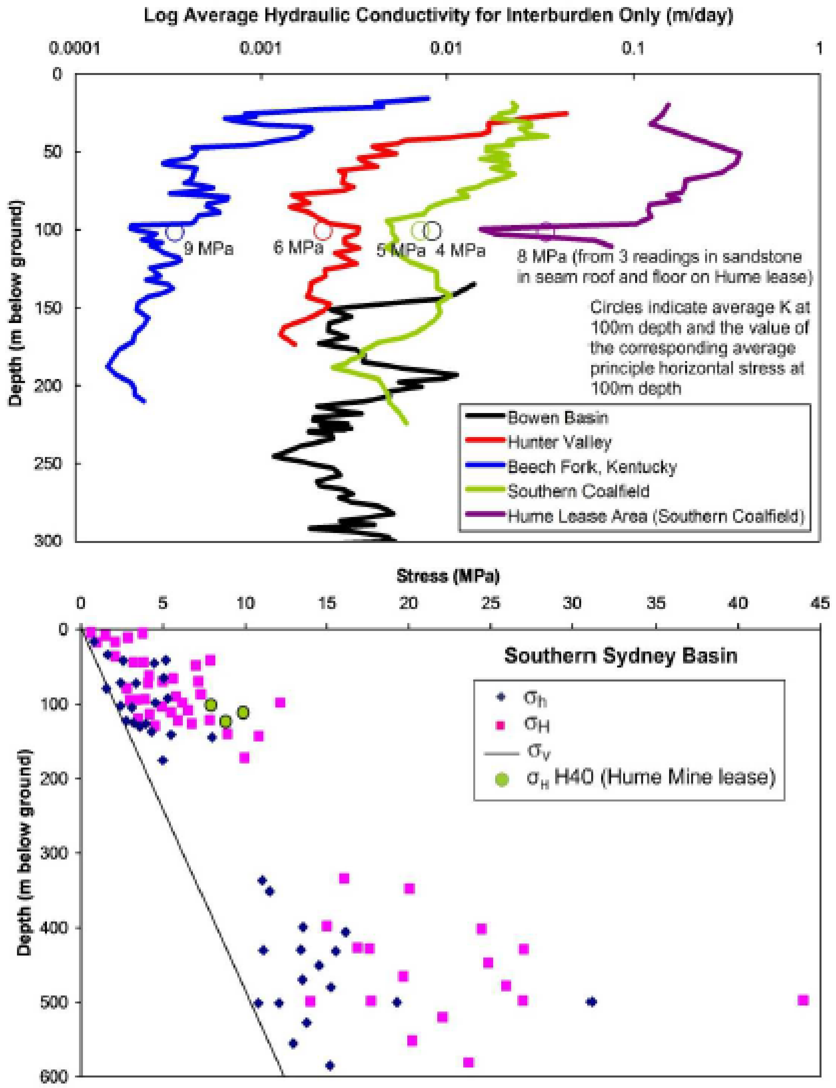

Figure 5.4. Comparison of stress and hydraulic conductivity (K). The upper chart shows K and regional stress magnitude for Permian Coal Measures (excluding coal seams) at four locations in Australia and one in the USA. The lower chart shows actual stress measurements unsegregated by media stiffness, for the southern Sydney Basin (base from Hillis et al 1999). σ_H and σ_h are the maximum and minimum horizontal stresses respectively; σ_v is the vertical stress.

Figure 6 Comparison of stress and hydraulic conductivity - reproduced from the EIS in 2017 (referred to as Figure 5.2 in GEOTLCOV25281AB-ACA, Coffey 2016)

DoI Water Response: during the sensitivity analysis, K_v was not varied over a sufficient range (towards higher, more reasonable vertical hydraulic conductivity values), resulting in the model results not being sensitive to the narrow and unsuitable K_v range applied. DoI Water recommended that an uncertainty and sensitivity analysis on K_v be performed on the entire range of values with a maximum K_v of 10 m/d to be applied.

Appropriate values for Kv have been selected based on field data and reference data for the area. Higher hydraulic conductivity values, particularly Kv, if used, would not be based on available evidence and would not be appropriate when applied to the regional model.

The uncertainty analysis conducted as a component of the RTS modelling by HydroSimulations (2018) considered a range of conductivity values used that encompass the values recommended by DoI Water at pilot point locations across the model domain within the 512 realisations used. Reference to Section 7.2.2

and associated figures with HydroSimulations (2018) further details the full range of conductivity values explored in the uncertainty analysis.

DOI Water response: The data presented by the proponent does not demonstrate clear field evidence for the assertion that hydraulic conductivity decreases with depth. In contrast as demonstrated in the above figure, conductivity remains high at depth. The upper range values are of approximately 3 m/day occurring to depths of 140 m.

Statistical analysis conducted separately by both HydroSimulations and Coffey demonstrates the decrease of conductivity with depth within both the model domain as well as the broader Sydney Basin.

DOI Water response: The linear regression as applied by the proponents modelling consultant to prove a decrease of hydraulic conductivity with depth is in the opinion of DoI Water an unreasonable and inappropriate fit of the data.

The groundwater model built by Coffey (2016) and refined by HydroSimulations (2018) have developed an opinion on appropriate aquifer properties to be utilised in the groundwater model based on statistical analysis of field data at Hume, coalfields in the broader Sydney Basin, and coalfields at other locations around the world. The claim that this is an 'unreasonable fit of the data' is disputed and unsupported by the bulk of evidence presented.

DoI Water response: DoI Water highlights that K_v and K_h values used in the model and also in the uncertainty analysis and sensitivity testing did not adequately range over the field values with depth. A model must reasonably represent field values, including with depth, and in this case the model clearly falls short of demonstrating this. The geology also indicates the presence of geological intrusions such as dykes, sills, laccoliths, diatremes and plutons plus faulting in multiple orientations (Figures 4.5 – 4.8 of GEOTLCOV25281AB-ACA). It has been indicated that many of the dykes are vertical and weathered to significant depth indicating groundwater presence. It has also been indicated that haloes or zones around the intrusions are known to yield higher quantities of groundwater. Some of the fault orientations are likely to be open allowing groundwater flow. These features provide further justification for performing a complete sensitivity analysis on K_v over the entire range of field obtained values. There seems to be no clear justification to not test the model for the full range of K_h and K_v uncertainty and sensitivities for all layers (including the Wongawilli seam), as was recommended by DoI Water.

There is no evidence to suggest that haloes or zones around the intrusions yield higher quantities of groundwater, and there is no reference provided to support this. There is no evidence to suggest that fault orientations are open.

Question 6 - What is your opinion on the approach taken to decide on the drain conductance values used in the modelling?

DoI Water response: The drain sensitivity analysis has highlighted incomplete follow up modelling tasks that should have been performed to decrease the uncertainty about mine inflows and their impacts onto drawdowns affecting other water users. The conductance equation is sensitive to its inputs derived from an equation that considers hydraulic conductivity, length and width of a cell boundary condition and the thickness. The conductance value is potentially sensitive to each of these. DoI Water was specifically concerned about the hydraulic conductivity and thickness applied in the equation used in order to assess the suitability of the drain conductance value used. DoI Water requested further information about the drain conductance parameter and the derivation of its value.

The calculation of an appropriate value for the conductance term is reasonable, and the parameter is best considered a 'calibrated parameter'. This effectively means it is altered to fit measurable data such as inflow data from surrounding mines and applied to the area of impact being assessed.

The calibrated conductance value for Berrima is consistent with values utilised at Dendrobium (Coffey 2012) and, with cell size being half the cross-sectional area within the Hume Lease, the value of 0.05 m/day is considered appropriate.

The 0.05 m^2/day drain conductance value used in the EIS model was calibrated against the discharge volumes from the Berrima mine void, and the relative area of the cell sizes between Berrima mine and Hume Coal within the model domain (Coffey, 2016b).

Sensitivity analysis in the original EIS model concluded that there is only a small change in inflows with realistic variations in mine conductance (doubling). This original EIS value was challenged, and it was therefore agreed to undertake further sensitivity analysis on conductance in the RTS.

HydroSimulations modelled sensitivity on drain conductance in the RTS by increasing the drain conductance parameter to 0.5 m^2/day (a factor of 10).

Increasing the drain conductance by an order of magnitude (1,000%) resulted in an increase of the 'to sump' mine inflow by 100%, however total mine inflow did not increase. The 1,000% increase in drain conductance resulted in a 10% increase in the number of bores drawn down by more than 2m. These changes are not significant and demonstrates the model is not particularly sensitive to small realistic changes in drain conductance.

If the 1,000% increase in conductance was applied to the drains simulating mining at Berrima, the modelled inflow would greatly exceed the observed and measured discharge data from the Berrima mine void.

The NSW Government independent peer review by (Middlemis 2017) concluded that the drain conductance in both original EIS model and subsequent revised model were appropriate.

DOI Water response: *DoI Water also recommended that wells are alternatively used also, instead of drains to effect dewatering. This is so that it can be determined what is the real rate that the geological formation can provide water to the unrestricted wells in the model, as opposed to the modeller imposed rate assigned to the drains.*

The suggested use of the wells to simulate mining suggests a lack of understanding of how MODFLOW works. The use wells to simulate mining requires a forced extraction rate at the well (ie the modeller pre-determines the mine inflow).

Using drains to simulate mining allows the model to establish a mechanism for Darcy's Law to operate and calculate inflow. Intervention by the modeller in terms of forced extraction would be counter to the objective of using known data to calculate the unknown mine inflow (ie model the known data).

The use of the DRN package to simulate the progression of mining is standard across the GW modelling industry.

DoI Water Response: Drain conductance values were found by Merrick (2018) (Section 8.2) to be highly sensitive to an order of magnitude change nearly doubling the inflow intercepted by the drains.

Hydrosimulations (2018) stated that:

> 'Increasing the drain conductance by an order of magnitude has resulted in a near doubling of the 'to sump' mine inflow within the sensitivity run…..showing the model is overall not particularly sensitive to changes in mine drain conductance….'

It appears that DoI Water has determined that an 1,000% increase in conductance leading to a 100% increase in 'to sump' inflow, but no change in total inflow, is classified as 'highly sensitive'.

Whereas, HydroSimulations stated the opposite and said that it was 'not particularly sensitive'.

Question 7 - The updated model is said by Middlemis (2018) to be a best practice model as it is simultaneously calibrated to four data sets and contains a detailed uncertainty analysis. What is your opinion?

DoI Water Response: DoI Water notes that Middlemis (2018) states the calibration to be acceptable in this case because of simultaneous calibration performance on four other key criteria:

- *matches to baseflow*
- *matches to mine dewatering fluxes*
- *aquifer parameters consistent with field measurements*
- *a calibration history match.*

DoI Water does not agree that the model is calibrated to four datasets simultaneously. However, this means that other parameters in the model that are not constrained may have to be varied across unnaturally large ranges to achieve some form of calibration.

It is also not clear how parameters might have been lumped together to enable the modelling to progress in the absence of specific data (e.g. specific storage values derived from site investigations), and whether these are a significant part of the four data sets being calibrated against.

The specific storage values implemented in the model come from literature. Criticisms in submissions against the EIS resulted in the revision of Specific Storage (Ss) values to sit more in line with those taken from literature, and a site pumping test.

DoI Water are not clear on the parameters it suggests are being varied across 'unnatural ranges' or 'lumped together' to achieve 'some form of calibration'. All model parameters have been carefully considered in accordance with site data and reputable reference material, and all have been subject to external peer review by the NSW Government peer reviewer.

The above response is highly critical of the Coffey (2016) and HydroSimulations (2018) modelling, as well as the independent peer review by Middlemis (2018). However, the DoI Water criticism does not provide detail around the specifics or support these negative statements with reference material.

DoI Water Response: DoI Water notes that a visual analysis of the calibration hydrographs concludes that the vast majority of bores are uncalibrated. A residual of far less than 2 m for the majority of the bores would be regarded as more acceptable to assess drawdown impact and impact on private bores (refer to response to Question 8 for more details).

Agreed that there is a range in calibration performance at hydrographs, which is normal with complex mining models.

The assertion that the 2 m drawdown criterion in the AIP is the same as an expected residual of <2 m appears incorrect. These qualities are not the same, and the AIP does not require this 2 m residual accuracy.

The Guiding Principle in Section 7.4 of the Australian Groundwater Modelling Guidelines indicates that groundwater models are far more effective at producing differential effects (mining induced drawdown) rather than absolute.

The Australian Modelling Guidelines also state that:

> 'It is not unusual for modellers to find that the calibration does not allow all aspects of historical measurements to be reproduced. Sometimes absolute values of heads are too high or too low, suggesting

> that hydraulic conductivities and recharge are not in balance, but trends are reasonable, suggesting that the relationship between hydraulic conductivity and storage coefficient is reasonable, or that the relationship between perturbations in recharge and specific yield are reasonable (refer section 5.4.1). In such cases calibration may be considered reasonable if differences in heads seem to be reasonable. There may be no theoretical reason to support this conclusion, but sometimes there appears to be no alternative.'

This above text from the Australian Modelling Guidelines suggests that to accurately predict impacts at landholder bores, the model does not need to be predicting simulated groundwater levels to within 2 m of observed groundwater levels. The AIP does not reference the 2 m measurement for absolute predictions of water levels. Instead, it suggests that if the relative impact of the mine is predicted to be greater than 2 m at a landholder bore, then that bore is subject to make good provisions.

Monitoring of landholder and purposely constructed monitoring bores will occur to monitor mining impacts and the 'make good' provisions will apply based on these observations.

The NSW Government independent peer reviewer, Hugh Middlemis states that:

> 'Acceptable model calibration performance and good time series matches at most bores (except 2 of the 6 VWP's, which is not unreasonable).' - Hydrogeologic 2017

DoI Water Response: Matches to baseflow.

DoI Water considers that there has been insufficient detailed information provided about this criteria showing the match. Apart from this, the model is not considered fit for purpose and therefore DoI Water regards the current results as unreliable.

There was a very thorough baseflow analysis was conducted in the Volume 1: Data Analysis report that was submitted by Coffey (2016) as component on the EIS groundwater impact assessment. The model results match to baseflow calculations indicates the model is fit for purpose. The EIS reporting on the model calibration (Coffey 2016) was minimal. However, it is considered sufficient and the model is determined to be adequate. The independent peer reviewer found the calibration to baseflow to be fit for purpose.

DoI Water Response: Matches to mine dewatering fluxes at Berrima mine

DoI Water does not consider this a reliable calibration parameter. The use of drains to represent mine voids at Hume Coal voids is not adequately clarified to understand the details of the drain parameters selected for matching to a pre-selected flow at Berrima mine. DOI Water highlights that the Berrima mine is in a very different hydrogeological situation:

Matching groundwater fluxes to regional and nearby mining has been used as a calibration tool in approved groundwater models assessing the impacts of mining for decades. Drains are the industry standard in simulating removal of mine inflow from both first workings and full extraction underground mines as well as open cut mines.

The NSW Government independent peer reviewer, Hugh Middlemis states that:

> 'Calibration of aquifer property values (Kh, Kv, S, Sy) has been well constrained by pumping test estimates of property values, and by simultaneously honouring observed groundwater levels, along with the measured Berrima mine inflow (deep system) and inferred stream baseflows (shallow system). **This is a best practice approach that reduces model non-uniqueness problems** (that many different sets of model inputs can produce nearly identical aquifer head distributions).'

DoI Water statement '*matching to a pre-selected flow at Berrima mine'* appears to target the integrity of the work. The flux values for Berrima mine used in the model are publicly available and represent the volume of water freely draining from the mine workings into the Wingecarribee River. The volume of water discharged in to Wingercarribee River is considered to be an accurate proxy for the volume of groundwater inflow in the mine workings.

The size of model cells used at Berrima (50 m x 100 m) are double the area of the model cells used within the Hume Coal Mine Lease (50 m x 50 m). It is therefore appropriate to use a drain conductance value that is half the magnitude of the conductance value at Berrima.

This approach for calibration is endorsed by the NSW Government independent peer reviewer, Hugh Middlemis who states:

> 'this is a good example of a best practice method that minimises non uniqueness issues and supports a model Class 2, confidence level' (Hydrogeologic 2017).

DoI Water Response: Berrima mine occupies a much smaller footprint and therefore a smaller groundwater catchment; the implication with the Hume Coal mine project area, with a greater groundwater catchment area, is that relatively far greater volumes and perhaps rates of water are potentially available to the Hume Coal voids in a fractured rock environment. Without the specific mining plan details being applied to a fit for purpose Hume Coal model, using the Berrima mine inflows is tenuous and doesn't provide a high degree of confidence.

It is agreed that the proposed Hume Coal Project occupies a larger footprint than Berrima mine. This is one factor that is likely contributing to the greater volume of groundwater take that is simulated by both Coffey (2016) and HydroSimulations (2018) groundwater models in comparison to Berrima mine.

Data from the Berrima mine was adopted and considered in the development of both the conceptual and numerical model for the Hume Coal Project. The Berrima mine is within the same geological unit as the Hume Coal mine, and is broadly similar, but some aspects of the geological settings are slightly different between Hume and Berrima, and the mining method is different. There was full pillar extraction at Berrima and consequential fracturing of overlying strata, but at Hume mine design will ensure stable roof and no intended fracturing. Therefore, there are differences in hydrogeological characteristics (recharge, mine inflow, discharge etc), however the data and information from the Berrima mine, particularly the drain conductance and inflow measurements, can still be used to assist with model calibration and provide a better understanding of hydrogeological impacts.

The differences explain that although the drain conductance can be up-scaled, the up-scaling of the model results from Berrima to Hume is not linear in terms of inflow and drawdown.

The NSW Government peer reviewer, Hugh Middlemis, determined that the conductance values applied at both Hume and Berrima to be appropriate and states that the use of the Berrima inflow data is:

> 'a best practice approach that reduces model non-uniqueness problems'

DoI Water Response: 'Without the specific mining plan details being applied to a fit for purpose Hume Coal model, using the Berrima mine inflows is tenuous and doesn't provide a high degree of confidence.'

An appropriate level of mine plan details have been provided to undertake modelling to the a level of adequacy for impact assessment as determined by The NSW Government peer reviewer, Hugh Middlemis.

DoI Water Response Berrima is a much older mine closer to steady state in terms of groundwater inflows, with decades of dewatering behind it and lowered water levels providing a lower gradient to flow. To use inflows from Berrima is inapplicable to a greenfield site like Hume Coal which will likely not reach the same degree of equilibrium for several decades. The Hume Coal mine has a larger volume of water immediately available to it than Berrima. In the initial years, inflows into Hume Coal mine would be far larger than the Berrima mine after decades of dewatering.

MODFLOW Drain cells passively take water from the model at a rate determined by the conductance value and head difference between the groundwater level defined in the drain cell and the groundwater level in surrounding model cells.

When head is above the reference elevation of a drain cell, flow into the drain (out of the groundwater system/ groundwater model) increases linearly with increasing head above the reference elevation of the drain. The current state of a groundwater system (depressurised at Berrima, elevated at Hume) does not influence the conductance term of the drain cells.

The simulation of an older mine such as Berrima with '*decades of dewatering behind it and lowered water levels providing a lower gradient to flow.'* will result in lower rate of inflow due to lower hydraulic gradients.

The higher hydraulic gradients that are currently present in the Hume Coal Mine Lease will be a significant factor contributing the higher rates of inflow simulated in both the Coffey (2016) EIS model as well as the HydroSimulations (2018) groundwater modelling.

It is important to note that the difference in mining technique (collapsing pillar extraction at Berrima vs non collapsing first workings at Hume) means that Hume mining has far less impact on overlying strata than Berrima and are therefore unlikely to be '*inflows into Hume Coal mine would be far larger than the Berrima mine after decades of dewatering.'*

DoI Water Response: Geological heterogeneity almost ensures that hydrogeologically, the sites are incomparable in how water flows into a resulting mine void when comparing the two mine sites. There is uncertainty with regards to the presence, extent or differences between the thickness of the Narrabeen Group over the Hume and Berrima sites and the effect this has on potential recharge to the mine voids. DoI Water has recommended detailed clarification about the details of all aquifers, aquitards and faults above both mines to allow full assessment of the hydrogeology and its eventual proper inclusion in the model.

The similarities and differences between the Berrima mine and the proposed Hume Coal mine (geology, hydrogeology, data, mining method, position in landscape etc) have been considered in great detail over many years by hydrogeologists and modellers working on the project. The DoI Water claim that the sites are 'incomparable' is surprising, considering both mines are adjacent to one another and are in a similar part of the Southern Sydney Geological Basin. There are some definite similarities and some definite differences, but to disregard all data would be remiss.

Geological and hydrogeological data has been provided in the EIS and the RTS documents to a level that is deemed fit for the purpose of the groundwater assessment.

Question 8 - What does the error statistic SRMS of 10.7% tell you about the model accuracy?

DoI Water Response: DoI Water continues to have concerns about the calculation of the SRMS error statistic at over 10%. It is good practice to also apply the error statistic to individual aquifers, as opposed to averaging it across all the model layers and assess the aquifers separately to gain a deeper insight.

There is no recommendation for this to be conducted in the AGMG, and no precedent for the subdivision of the error statistic to apply to individual aquifers. This has never been required previously for groundwater modelling projects conducted by HydroSimulations.

The statement that *'It is good practice to also apply the error statistic to individual aquifers, as opposed to averaging it across all the model layers'* is new to Hydrosimulations and other groundwater modellers within industry are not aware of this new requirement.

DoI Water Response: The error statistic provides an aggregated measure of the calibration but does not indicate the spatial or temporal distribution of the error. The error statistic should be less than 5% for a model destined for the purpose stated earlier.

Section 5.4.5 of the Australian Groundwater Modelling Guidelines cautions against the proposal of target values for calibration statistics unless it is known that a model can be developed to achieve the target value. Recommendations of the strict SRMS error statistic for groundwater models on specific projects (particularly mining projects) appears counter to the advice provided in the Australia Groundwater Modelling Guidelines and is not recommended for this project or others.

DoI Water Response: DoI Water considers the model to be unacceptably calibrated as a direct consequence of the unsuitability of indicators/elements referred to in our reply to the first question from the IPC. DoI Water does not therefore consider the model (the improved Modified EIS USG-T model nor MEAN K model) to be fit for the purpose of assessing drawdown impacts resulting from mining, to an adequate level of certainty for decision taking purposes for this project.

A visual analysis of the calibration hydrographs concludes that the vast majority of bores are uncalibrated. A residual of far less than 2 m for the majority of the bores would be regarded as more acceptable and should be achievable using PEST pilot points and spatially varying hydraulic parameters within reasonably possible ranges as has been recommended as a result of reviews of the modelling work to date.

The assertion by DoI Water that residuals within 2 m should be required for a majority of bores is disagreed with. Groundwater models provide one head value for each model cell and therefore both topographic relief and the thickness of the layer contribute to the model prediction aligning with the observed heads to within 2 m. Forcing the model to calibrate to heads will potentially render the model results less representative. Section 4.2 within GEOTLCOV25281AB-ACB (Coffey, 2016) further details sources of uncertainty within groundwater level targets.

Guiding principle 7.4 within **Section 7.4 – Relation of model calibration to model uncertainty** (Page 98) of the AGMG states that '

> 'Analysis of uncertainty should recognise 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."

Greater confidence should be placed on differential predictions such as drawdown impacts (2 m extent and at registered bores) and baseflow impacts on water courses, rather than on the absolute outputs like groundwater elevations at observation and landholder bores. Head matches at calibration sites do not need to be perfect in order for a groundwater model to provide reliable predictions and be fit for purpose.

DoI Water Response: The calibration statistics provided require a deeper exploration and explanation to determine the consistency of the weighting applied to model parameters. It is uncertain why the large dataset private bores were also not used within PEST to obtain a base case calibrated model.

Private bores within the model domain remain either unmetered, or usage data is not recorded by the NSW Government. Therefore, the actual extraction from landholders bores is unknown.

Groundwater level observations upon construction at landholder bores are subjective due to the often unknown rates of extraction, unknown screeded interval, and unknown quality of the water level data (ie was the bore fully recovered following drilling and air lifting).

The accuracy of screen information, bore depth and even bore location further complicate the use of these sites as groundwater level targets within a groundwater model.

Question 9 Do you have concerns with the make good strategy for affected bore owners?

<u>DoI Water Response:</u> no clear policy on how make good should be achieved, DoI Water recommends that where impacts are known or likely, users should have pre-agreed make good measures in place before mining commences.

Hume Coal propose that make good measures will be in place with individual landholders prior to impacts occurring. Landholders predicted to experience greater than 2 m of drawdown in their bore as a result of the mine have been notified several times. Individual negotiations for make good measures are to be staged with 16 bores needing to be negotiated in the first 5 years of mining. Therefore, agreements will be in place in the years preceding the impact at the bore occurring. This strategy is practical and logical and aligns to how other mines (ie Tahmoor) practically manage their mining related drawdown on landholder bores.

a) Do you think the affected irrigation bore owners can obtain an equivalent water supply from the strata below the Hawkesbury sandstone?

<u>DoI Water Response:</u> Whilst it might be possible for affected landholders to obtain a similar supply from strata beneath the Hawkesbury Sandstone under undisturbed conditions, the availability of groundwater during and following mining is not known.

Hume Coal understand and have committed to investigations into deeper formations. It also understands that more than one bore may be required to replace a single bore (or several measures) may be required to ensure that sufficient volume is made available. Hume Coal also acknowledges that the volume needing to be provided may be historical use, or may include proposed growth in use up to full licence volume. The make good strategy includes all of the above commitments and that investigation and negotiations are part of the agreed make good strategy that Hume Coal have already committed to and proposed for the project.

b) What yields and water quality are likely from the deeper formations?

<u>DoI Water Response:</u> Typically bores that penetrate through the Hawkesbury Sandstone are lower yield and poorer quality. The Southern Highlands district in which the proposed mine is located is typically quite productive in terms of bore water supplies, due to a combination of influences including the structural setting, the recharge zone location and enhanced permeability of the Hawkesbury Sandstone.

The Illawarra Coal Measures unconformably underlying the Hawkesbury Sandstone tend to host groundwater that contains dissolved constituents derived from the coal seams and include other layers that are tighter, more massive, and with higher fines content.

Hume Coal acknowledge that the Hawkesbury Sandstone is the main water bearing formation in the area and that deeper formations are not as commonly utilised and may be of slightly poorer quality and lower yield. The location of the proposed Hume Coal mine in the recharge zone means that although slightly poorer in quality, there is actually a very close similarity in the freshness of the Triassic Hawkesbury Sandstone to the underlying Wongawilli Seam and Illawarra Coal Measures, which show a slightly increased but similar salinity signature (Figure 8).

Should lower yields be encountered, then drilling can include a combination of more than one bore; larger diameter bores; and or deeper bores with greater volumes of available head can be undertaken.

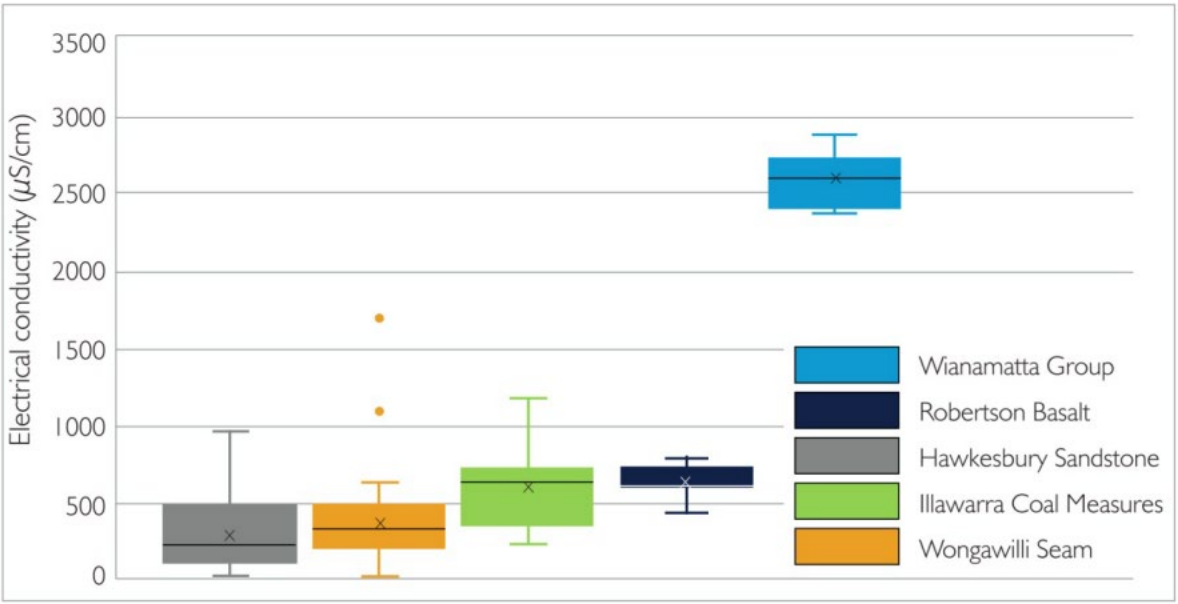

Figure 8 Box plot of EC of major groundwater

DoI Water Response: it is not clear how the proposed mining will impact the availability or quality of the deeper geological formations. In particular, the development of localised failure planes, the repressurisation of mined voids and the possible activation of major geological structures arising as a result of the proposed mining could all affect both yield and quality of the Hawkesbury Sandstone and the underlying coal measure formations in unforeseen ways.

There are no changes in groundwater quality or the aquifer properties predicted for the formations that underlie the mine coal seam. It is not predicted, and is highly unlikely that any changes (such as reactivation of major geological structures) will occur to formations underling the mine will occur as a result of mining.

c) Do you consider the direct supply of water should be included in the make good options?

DoI Water Response: Due to the significance of impacts on groundwater resulting from this project there is the requirement for make good provisions to apply according to the NSW AIP. The intent of this is for the affected party to have a comparable water supply made available, or other suitable arrangements, however how this is to be achieved is not specified. Direct supply of water may be a valid option in some circumstances however DoI Water notes there are likely to be practical constraints or barriers to providing large volumes of water to a large number of impacted users. In this case initial information indicates a third may require additional operating costs, a third may require deepening of bores and a third may require an alternate supply. Specific detail on these requirements is awaiting further individual bore assessments and development of viable make good measures. Therefore, DoI Water recommends viable measures need to be developed to address the make good provision requirement. The measures used are likely to vary and for example for some high yield irrigation bores, the ability to provide a viable make good option is yet to be confirmed.

Hume Coal have provided a detailed make good strategy that openly and transparently discusses the mining related drawdowns on each individual bore and commits to make good in accordance with the AIP. It also openly and transparently discusses and commits to providing comparable water supplies for affected landholders.

Options for the supply of water to affected bores have been discussed in detail in the make good strategy and it is recognised that each landholder will have a differing view of how and what will suit them. For example, while some users will prefer a new bore, others may prefer financial compensation. The make good strategy prepared by Hume Coal is based around the need for a high degree of flexibility and pragmatism for these negotiations. Hume Coal have deliberately not proposed hard wired strategies, or a ‘one size fits all’ approach. The make good strategy proposed by Hume Coal allows for flexibility and offers a series of pragmatic and logical measures for make good at the individual landholder level.

It is noted that to date Hume Coal have negotiated over 20 access agreements with landholders, and the process is proving to be highly successful in these early stages. It is also noted that although the number of bores affected by more than 2 m is considered high, the median level of drawdown for all bores is only 6 m. It is also noted that in the first 5 years of mining, only 16 bores are predicted to be affected by more than 2 m.

Negotiating and finalising 16 agreements with these landholders is achievable. The ‘make good’ negotiations are an ‘opt in’ arrangement whereby landholders have access to mitigation measures if they wish to take it up. However, should one landholder not wish to participate, it will not jeopardise the rights of others or the ability of the project to proceed. The proposed make good strategy for Hume Coal is similar to mitigation measures made available noise impacts and follows a practical means to proceed.

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