Water Research Laboratory | School of Civil & Environmental Engineering

NSW DPE State Significant Development Proposal No. 7172: Hume Coal Project

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11 February 2018

UNSW SYDNEY Australia's Global University

Outline

Overview:

- ➢ Key WRL Review Findings

Background:

- ➢ Project SEARs
- ➢ Water management in NSW
- ➢ Groundwater Values
- ➢ Hawkesbury Sandstone

Key Assessment Issues:

1. Joints, fractures and structures
2. Interpretation of geological and geophysical logs
3. Interpretation of field hydraulic conductivity data
4. Model calibration claims:
    a. sensitivity to specific storage (Ss)
    b. transient calibration and confidence level
5. Numerical model uncertainty analysis
6. NSW Government owns the water resource and responsible for its management but relevant technical field data, geological model and groundwater modelling files are not available to DI Water to assist with management of the resource.

Summary of WRL Review Findings:

- The predictive model is biased towards predicting slow flow through the HS rock matrix, not fast flow at structures.
- The predictive model will under-predict magnitude and timing of drawdown at many surrounding groundwater works.
- The predictive model may under-predict the rate at which groundwater may flow into the mine workings.
- If the project does proceed, to correct errors of past practice, the requirement to make-good an alleged drawdown impact must not be negated by the absence of a numerical model impact prediction nor simply because an alleged drawdown impact is observed during periods of below average rainfall. Groundwater needs to be used during periods of below average rainfall. Groundwater levels decline when groundwater capture exceeds recharge. Adding a large underground mine to a catchment increases groundwater capture because the entire mine void may fill with water.
- Hume Coal's model calibration and model confidence level classification (Class 2) claims are over-stated, e.g.
  - While a transient model calibration was attempted, the supporting field observation data and MODFLOW modelling workflow did not allow for a successful transient calibration.
  - Key geological, geophysical and hydrogeological field observation data are not adequately represented in the model. For example, horizontal and vertical hydraulic conductivity estimates are not integrated with geological and geophysical log data to provide upscaled K_h and K_v values to honour in the model calibration objective function.
  - Joints, fractures, faults and other geological structures that significantly influence groundwater flow are not represented in the numerical model. Homogenous hydrogeological conditions assumed in each model layer.

Project SEARs relating to groundwater

‘*An assessment of the likely impacts of the development on the quantity and quality of the region’s surface and groundwater resources…*’

‘*An assessment of the likely impacts of the development on aquifers*’

References environmental planning instruments, guidelines and policies including:

- *Australian Groundwater Modelling Guidelines 2012*
- *NSW Aquifer Interference Policy 2012* (which requires complex, peer reviewed modelling giving consideration to the modelling guidelines)

Administrative Issue: Model peer reviewed in accordance with Murray Darling Basin Groundwater Modelling Guidelines 2001.

Background: Water management in NSW

Groundwater and surface water resources are connected – must be managed together

NSW Government is responsible for managing water resources for current and future generations (enshrined in policy and statutory instruments)

Water Sharing Plans:

- Macro-scale instruments to prevent over-abstraction at the catchment-scale
- Does little to protect existing water users from local-scale impacts caused by nearby water use

Aquifer Interference Policy:

- Micro-scale instruments to prevent and/or manage impacts at the local-scale
- Requires development proponents to build computer model(s) to predict groundwater impacts
- <u>Does not specify minimum acceptable levels of work to understand and represent a resource</u>

Groundwater values and project risks

Highly valued in Southern Highlands: (Pritchard et al. 2004)

Groundwater provides:

- ecosystem services, water supply security during drought

Primary producers value-add to water:

- Significant capital investment in groundwater works
- Requires security of groundwater supply:
  - return on investment, production during drought

Groundwater mismanagement can result in:

- Lost economic production: less revenue for NSW
- Lost income: financial challenges for primary producers
- Sunk costs: decommissioning of bores, pumps and infrastructure
- Capital costs: sourcing and establishing alternative water supplies
- Management costs: Resolving 'unanticipated' impacts

Pritchard, S., Russell, G. and Hehir, W. (2004). A review of the status of the groundwater resources in the Southern Highlands, NSW: ensuring the sustainability of the water source New South Wales. Dept. of Infrastructure, Planning and Natural Resources

Hawkesbury Sandstone (HS)

The principle groundwater aquifer in the Sydney Basin

A dual porosity aquifer material:

- Joints, defects and other structures are common place
- Some groundwater flows slowly through the rock pores, but
- much more water flows quickly in contact with the joints, defects and other structures
- Vertical hydraulic conductivity (K_v) is typically:
  - higher than horizontal (K_h) at sub-vertical joints & structures
  - lower than horizontal (K_h) at clay / shale interbeds

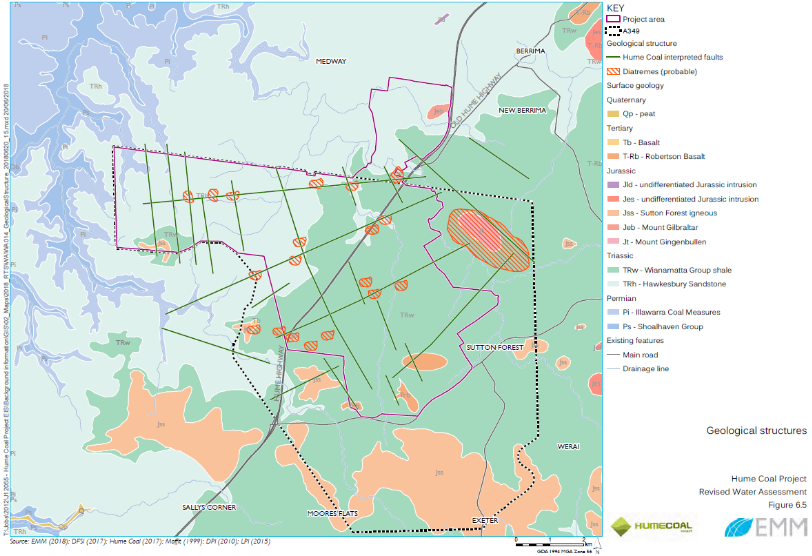
High yielding groundwater works in HS intersect joints, fractures and regional structures.

Dale, M. (2015) Contaminant flow in groundwater in Hawkesbury Sandstone – Experience from Major Basement Excavations, Australian Geomechanics Society Sydney Chapter Symposium November 2015

Issue #1

Joints, fractures and structures ignored:

- ➢ Numerous structures observed during desktop and field investigations
- ➢ Has a significant influence on groundwater flow but not represented in any numerical impact assessment model
- ➢ Hawkesbury Sandstone modelled as a homogenous slab of layered rock



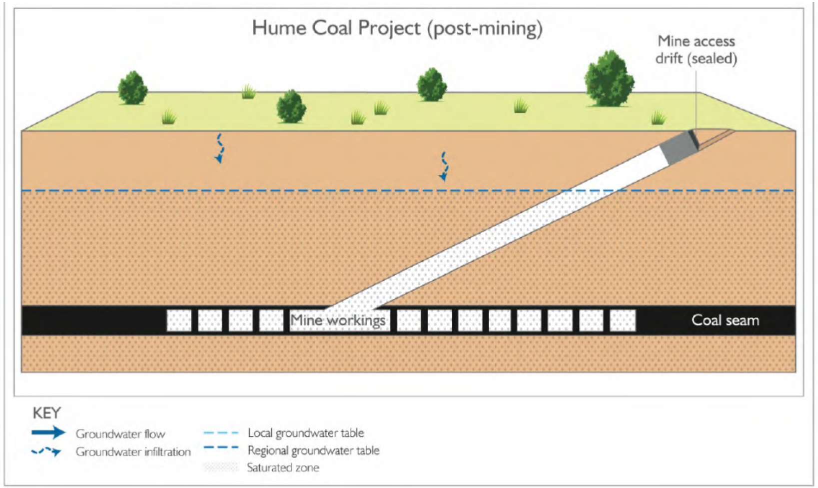
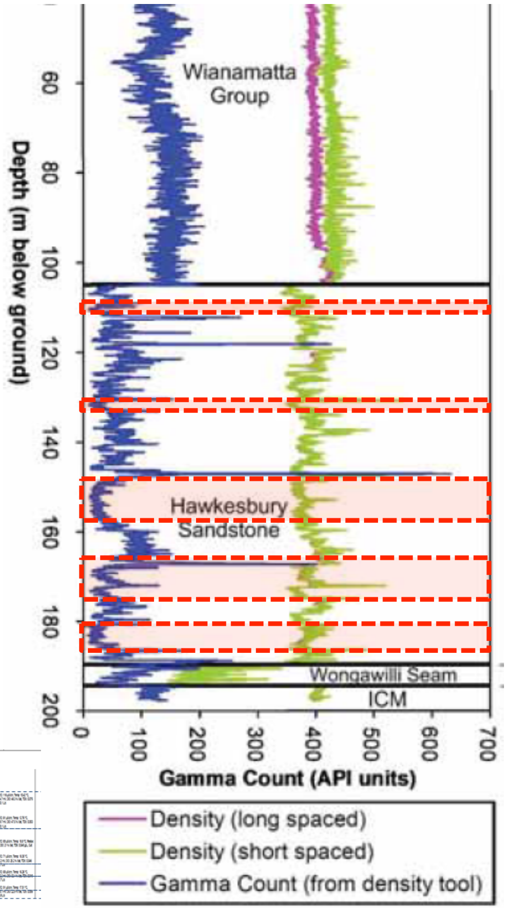


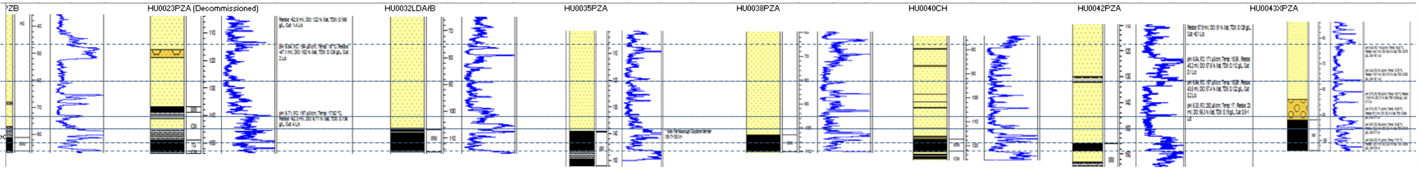
Figure 8.2 Schematic representation of Berrima Colliery and Hume Coal Project (post-mining)

Issue #2

Numerical model layer conceptualisation:

- Extensive downhole gamma log data provides a clear evidentiary basis for subdividing the HS sequence into zones of higher and lower permeability
- WRL review of EIS geological log data finds:
  - Hawkesbury Sandstone in direct contact with coal seam in 80% of logs
  - Average thickness of layer 8 Narrabeen Group Rocks is about 0.4m not 2 m.
  - No geological basis for assigning model layers 6 to 10 the same hydrogeological properties because these layers represent different geological units (e.g. Hawkesbury Sandstone, Narrabeen Group, Farnborough Claystone and Wongawilli Group)





Further details:
WRL2017018_L20180920 (Section 3.2)
WRL2017018_L20170623 (Section 3.5)

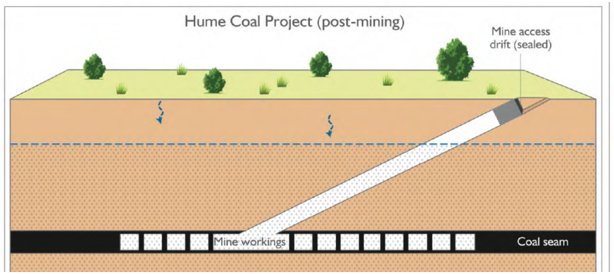
Issue #3

Interpretation of field hydraulic conductivity data:

- Ignored representative field-based determinations of high horizontal hydraulic conductivity (K_h) made from pumping tests and packer tests in nearby groundwater wells intersecting joints, fractures and structures.
- Specific yield assigned towards lower bound of literature values (i.e. drainage from sandstone pores with high clay content)
- Modellers' assumed K_v always 10 to 100 times lower than K_h (not realistic where sub-vertical joints and structures exist)

Predictive groundwater flow model limitations:

- Defects and structures ignored: predict slow flow through the HS rock matrix.
- Unrealistic geology and hydrogeology = unrealistic prediction
- Timing and magnitude of drawdown impacts at surrounding groundwater works intersecting joints, fractures and structures will be under-predicted
- May under-predict the amount of groundwater flowing into the mine workings
- Cannot be used reliably as the basis for make-good arrangements to establish whether drawdown at a nearby groundwater works is unrelated to mining.



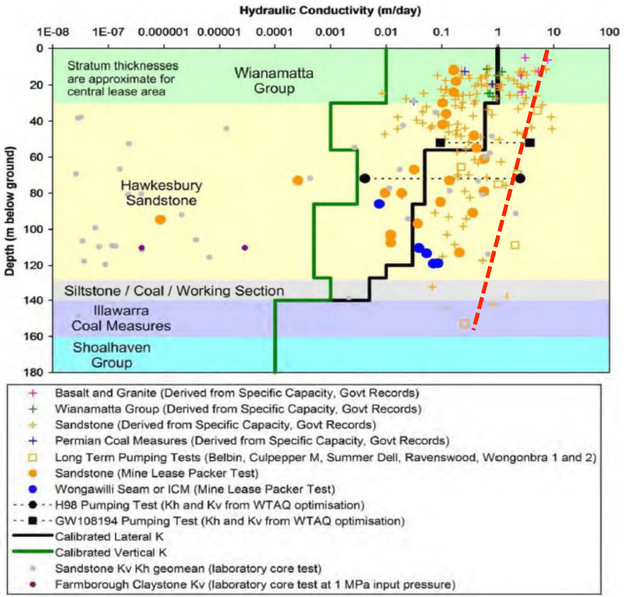


Figure 9.7 Comparison of measured versus calibrated hydraulic conductivity (from Coffey 2016a)

Issue #4

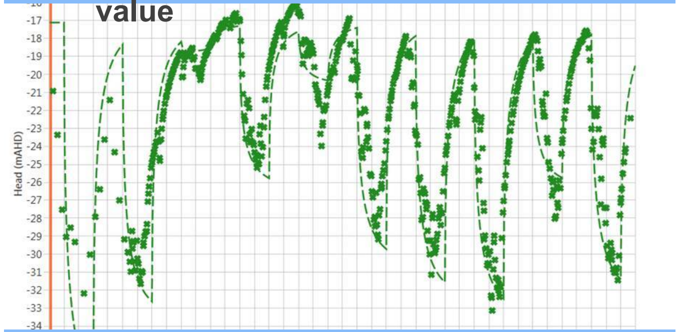
Model calibration not sensitive to Ss:

- ➢ Model essentially insensitive to aquifer Ss values (RTS, page 26, Vol. 2D)
- ➢ Ss values stated to be consistent with interpretations from pumping test data

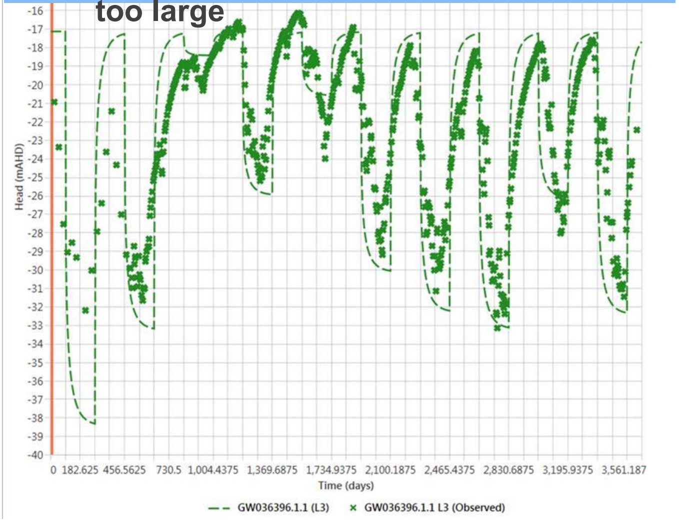
Limitations:

- ➢ Drawdown predictions in groundwater systems are sensitive to the Ss value.
- ➢ The available observation data, model stress periods and calibration objective functions were insufficient to support a transient model calibration.
- ➢ Aquifer test interpretation sheets not published for review by NSW Government
- ➢ When modelled Ss values are consistent with aquifer test data but the K_h and K_v values are ignored in preference of lower rock matrix values (Issue #3) then the aquifer hydraulic diffusivity must be modelled incorrectly. Therefore, the model will under-predict the speed at which drawdown moves out into the surrounding formation through joints, fractures and structures. Consequently, impacts will occur at groundwater works prior to the EIS model predicting them.

Example aquifer model with calibrated Ss value



Specific Storage one order of magnitude too large



Issue #5

$$\boxed{\frac{dh}{dt}} Ss = K.\boxed{\nabla h^2} + \boxed{R} - \boxed{D}$$

Rate of pressure decline (drawdown)

Pressure levels through space

Recharge (e.g. rainfall)

Natural discharge (baseflow, transpiration)
Aquifer Interference (Pumping, seepage into mines)

Hume Coal model transient calibration claims:

- Hydraulic conductivity and Ss calibrated to observations at Berrima Mine, therefore model is Class 2 confidence level classification as described in the Australian Groundwater Modelling Guidelines.

Limitations:

- No time series plots or tables of observed and modelled Berrima mine groundwater levels and inflows / outflows were provided as evidence (perhaps because observation data of pressure declines and mine inflows from start of Berrima mine are limited to non-existent).
- Model calibration reported to be insensitive to Ss (refer Issue #5)
- No intermittent pumping stresses in the calibration model (Model Stress Period = ½ year) and K values from pumping test interpretation ignored.
- Modelled groundwater recharge rate is 1.8% of rainfall with 1.5% being baseflow to streams (Coffey, 2016a). Boral's model of Berrima mine applied 1% to 4% of rainfall and 8% over the colliery (David, 2015a; PSM, 2016).
- Strictly, the model confidence level classification is Class 1.

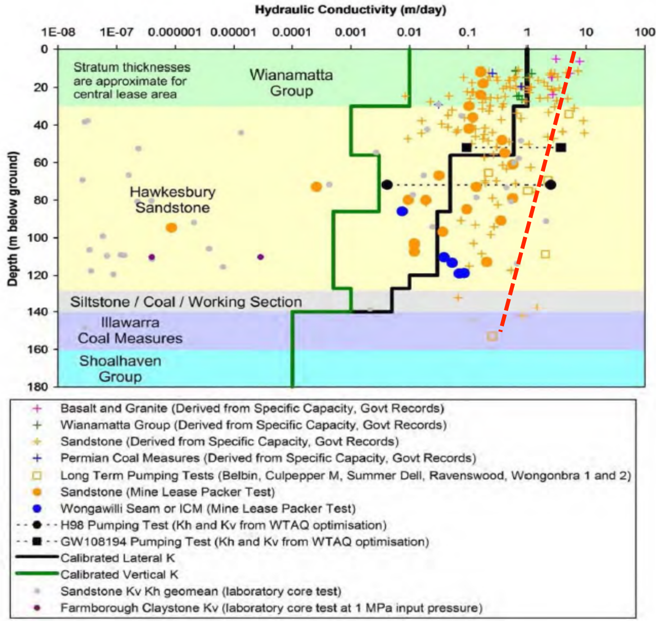
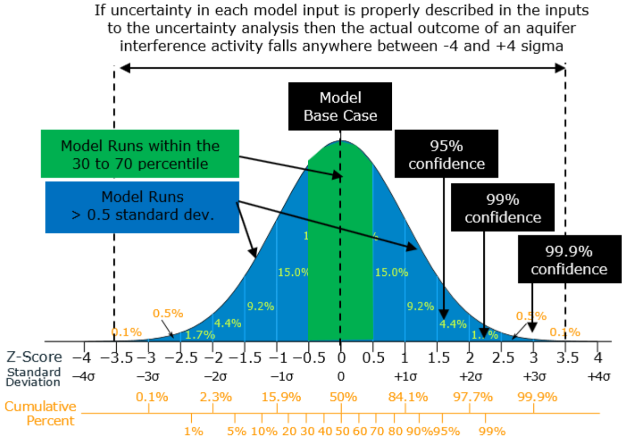


Figure 9.7 Comparison of measured versus calibrated hydraulic conductivity (from Coffey 2016a)

Issue #6

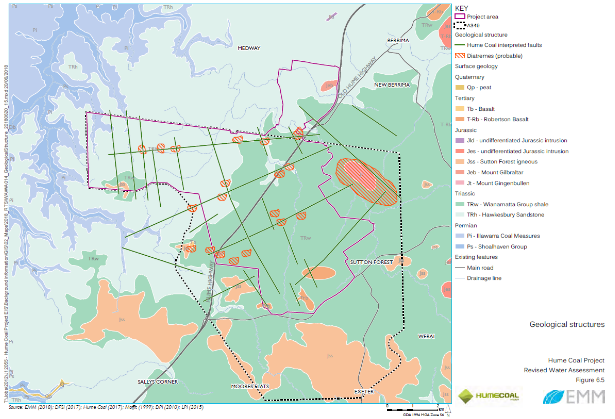
Uncertainty analysis approach:

- Monte-Carlo simulation approach
- Statistical distributions developed to describe the possible range of Kv, Kh, S_s, S_y values in each numerical model layer
- Modellers' dismissed all outputs outside 33 – 67 percentile of model base case



Limitations:

- Standard scientific practice: present results for 95% to 99% confidence interval
- Initial model inputs biased towards low K_h and K_v (i.e. matrix values)
- Monte-Carlo approach: Model input parameters not calibration constrained (No alternative geological conceptualisation considered, e.g. effect of structures)
- Draft IESC advice on uncertainty assessment (Middlemis and Peeters, 2018):
  "geological model uncertainties become crucial in situations where groundwater models that are history-matched to head and discharge data for the historical pumping or climate record are then used for extrapolation beyond that conditional calibration base. In such 'out of range' simulations, the geological structure uncertainty may often be the dominant source, and thus alternative hydrogeological conceptualisations should form part of the uncertainty assessment"



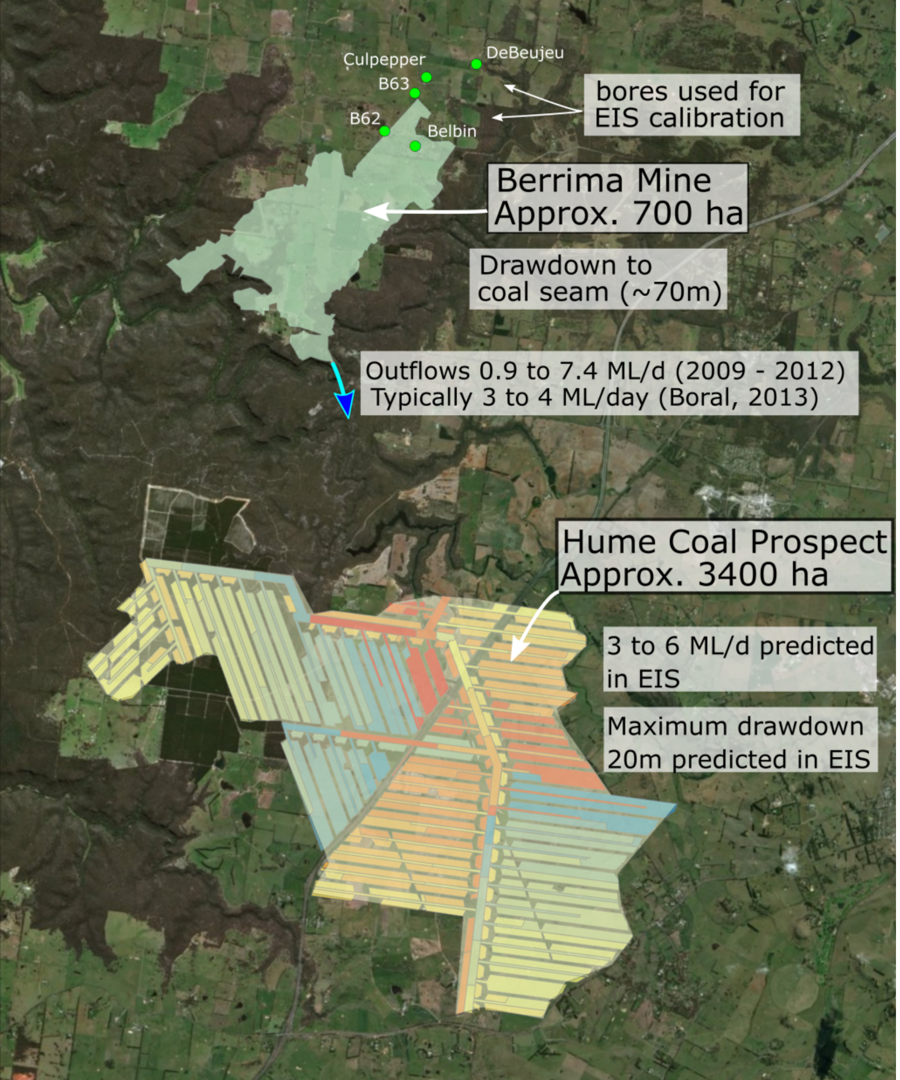
NSW DPE State Significant Development Proposal No. 7172: Hume Coal Project

Comments on mining effects: groundwater

Dr. Steven Pells

Principal, PSM

12 February 2019



Hume Coal EIS Groundwater Model was calibrated to Berrima Mine:

- inflows to the larger mine comparatively less?
- drawdown for the larger mine significantly less?

Information in the EIS is insufficient to answer these questions.

1. Flows at Berrima reasonably represented
2. Drawdown at Berrima is not presented

approximate match to 5 bores from 2011 to 2013 at it northern extremity.

Why the difference?

EIS claims groundwater impacts mitigated by proposed form of mining.

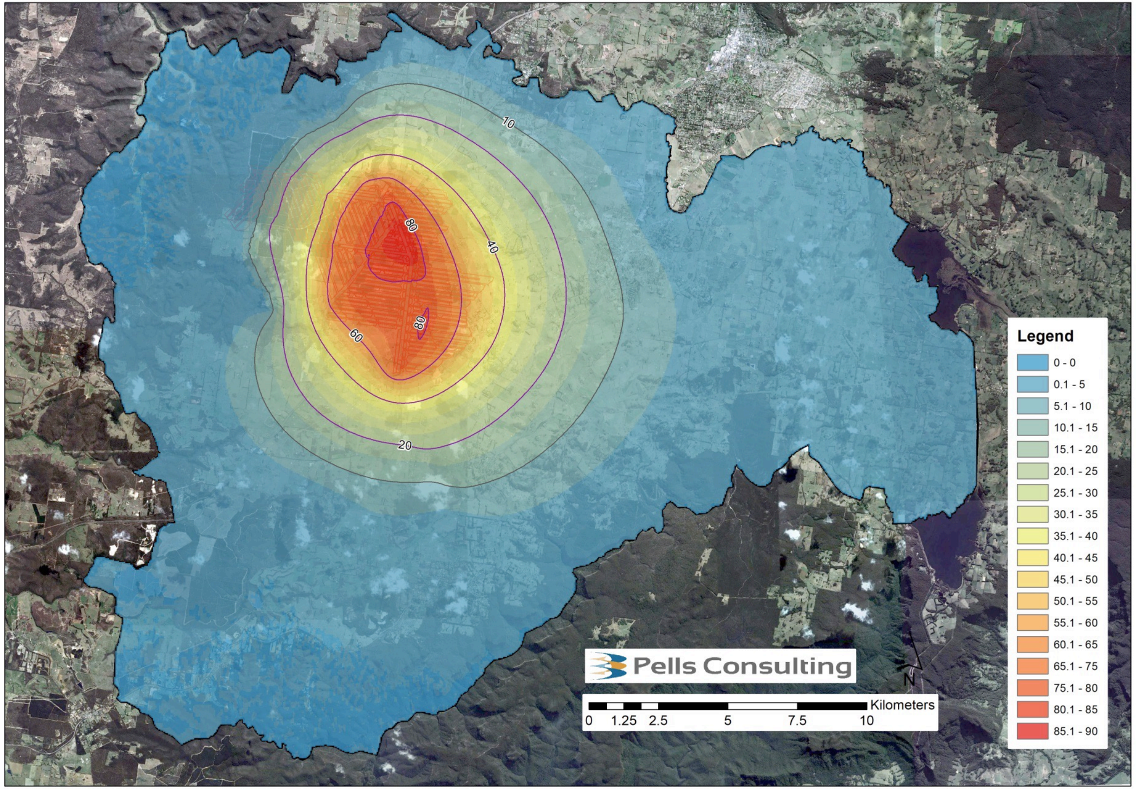
I examined this claim with a numerical model:

A) method of mining did not result in mitigation of impacts.

B) smaller impacts in EIS reflect modelling conceptualisation

1. Dismissal of sandstone aquifer
2. ‘drain conductance’ control
3. low conductivity of coal measures in and above the workings - continuity of a thin claystone seam above proposed workings.

Numerical prediction of drawdown, Pells Consulting 2017



Note that this model:

- Represents the current Hume Coal mine plan
- Represent 'plugs'
- Does NOT assume 'goafing'
- Was peer reviewed
- Geology as per Austen and Butta (1982)
- Hydrogeology as published by Lee (2000)
- Predicts drawdown to the seam, as observed at Berrima

Numerical prediction of drawdown, Pells Consulting 2017

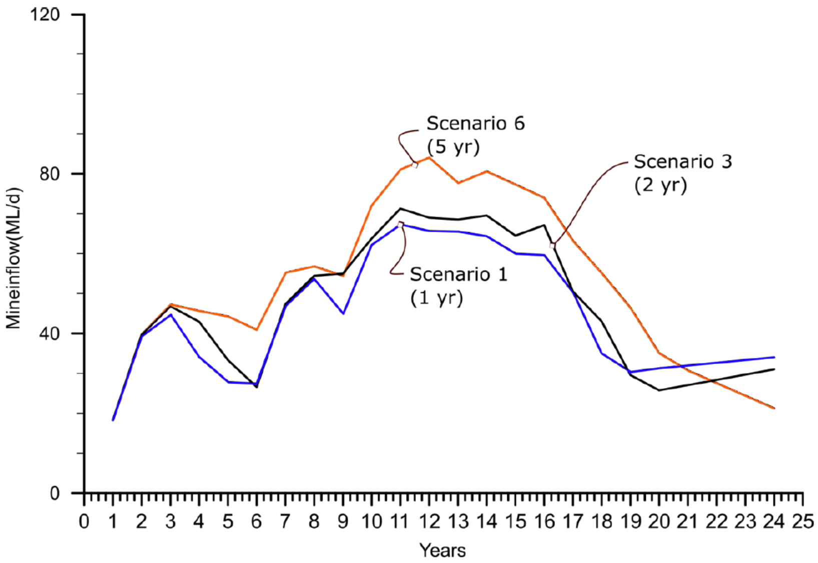
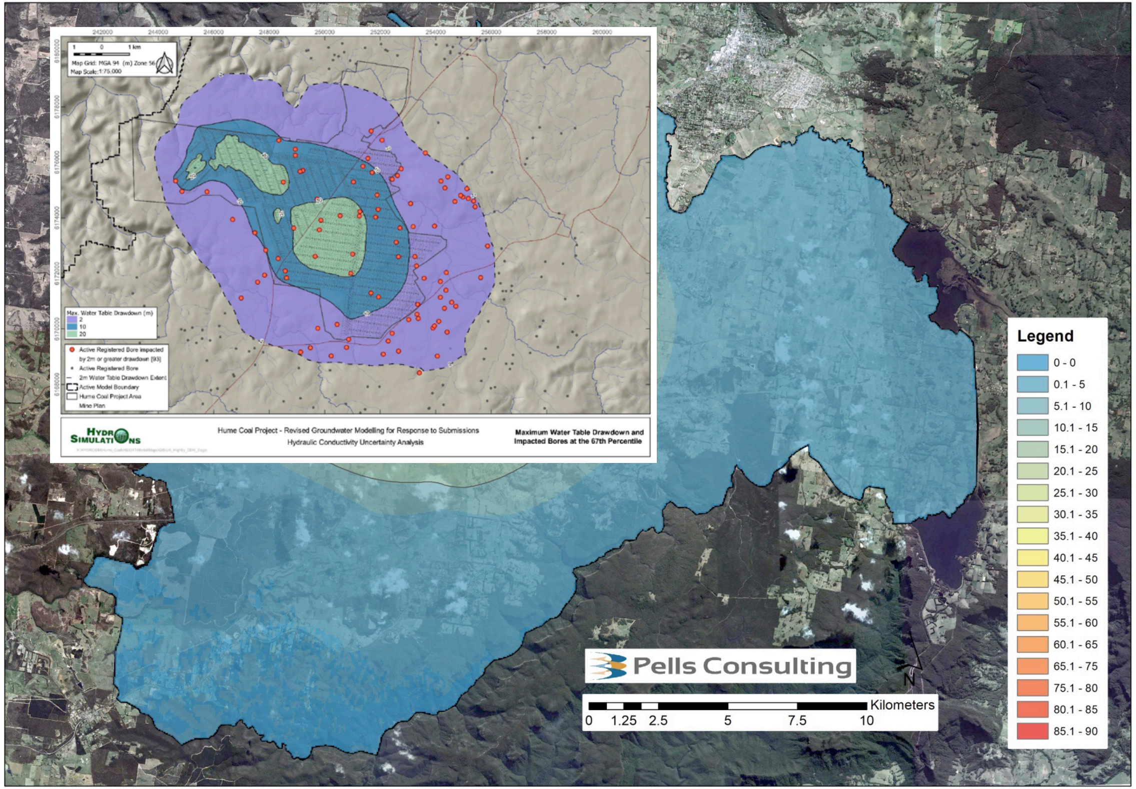


Figure 5.5 – Predicted inflow, Scenarios 1, 3 and 6 showing the effects of time to place panel bulkheads

Note that this model:

- Represents the current Hume Coal mine plan
- Represent ‘plugs’
- Does NOT assume ‘goafing’
- Was peer reviewed
- Geology as per Austen and Butta (1982)
- Hydrogeology as published by Lees (2000)
- Predicts inflows relatively compatible to those observed at Berrima

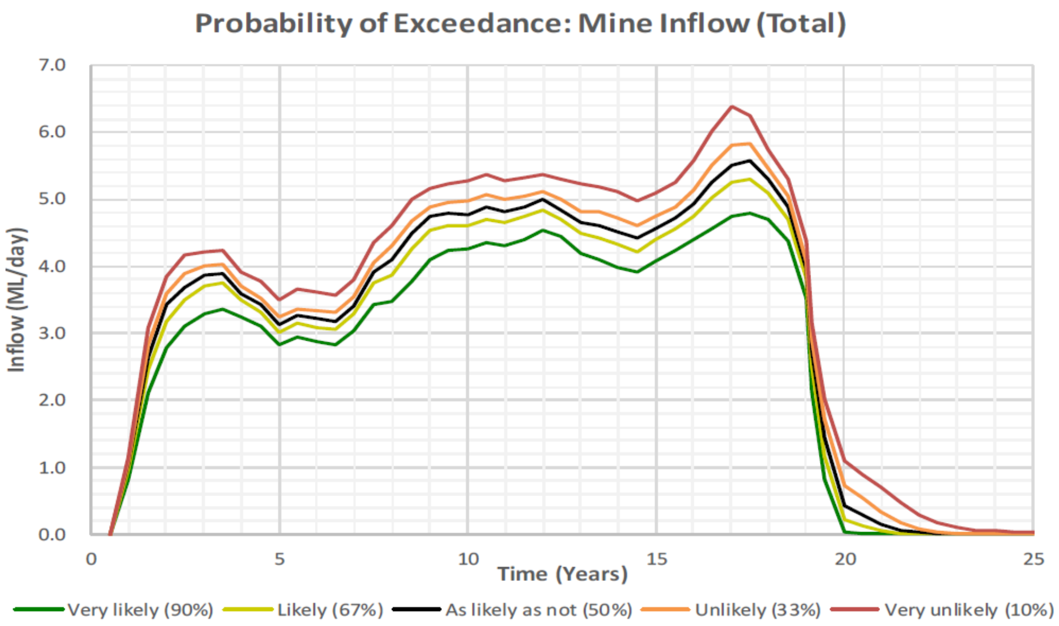
Numerical prediction of drawdown, Hume Coal EIS



Note that this model:

- Predicts only 20m drawdown

Numerical prediction of drawdown, Hume Coal EIS



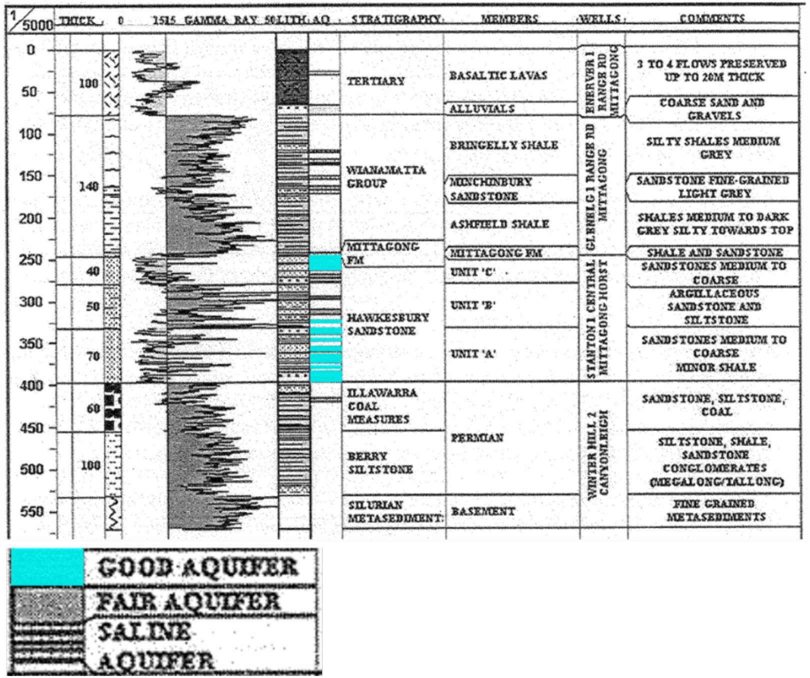
Note that this model:

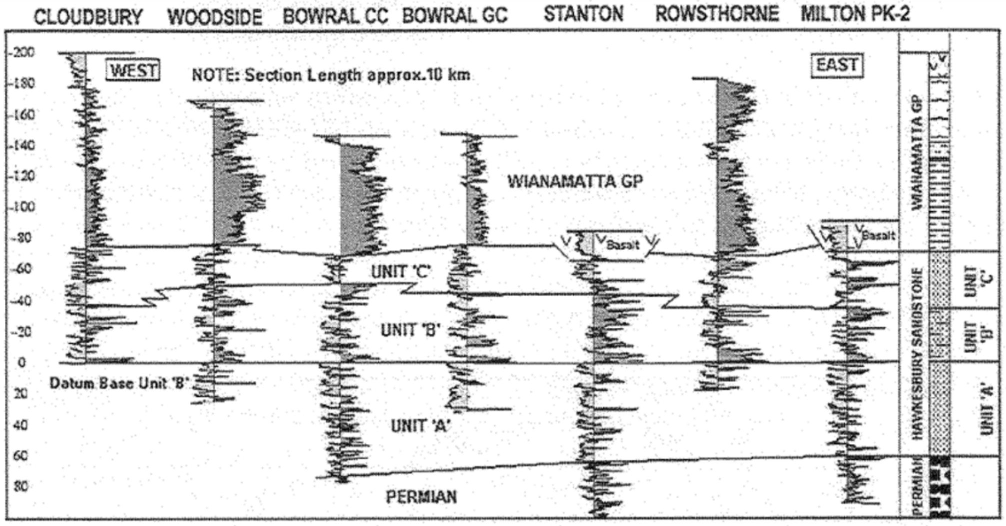
- Predicts inflows similar to Berrima Mine, despite being:
  - 7 times larger
  - A new mine

Why the difference in predicted impacts?

Reason 1: Conceptual model

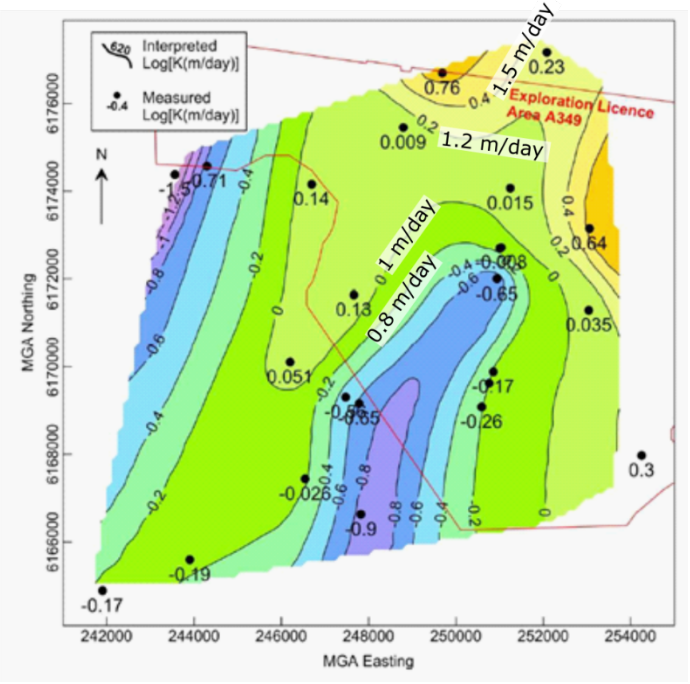
Lee, 2000 "*Hydrogeology of the Hawkesbury Sandstone in the Southern Highlands of NSW in Relation to Mesozoic Horst-Graben Tectonics and Stratigraphy*"

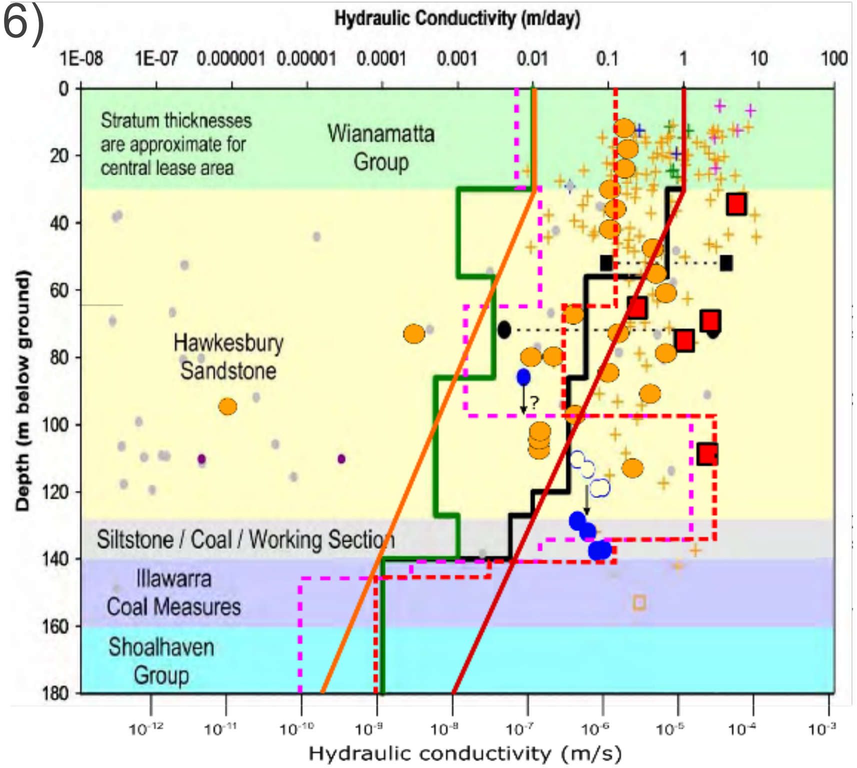




Reason 1: Conceptual model

Hume Coal EIS (Coffey 2016, Figure 5.6)





Reason 1: Conceptual model

Multiple lines of evidence suggest the presence of a high-yielding formation above the mine - an ‘aquifer’ in its true sense

This has not been represented in the EIS model

… at all

Reason 1: Conceptual model

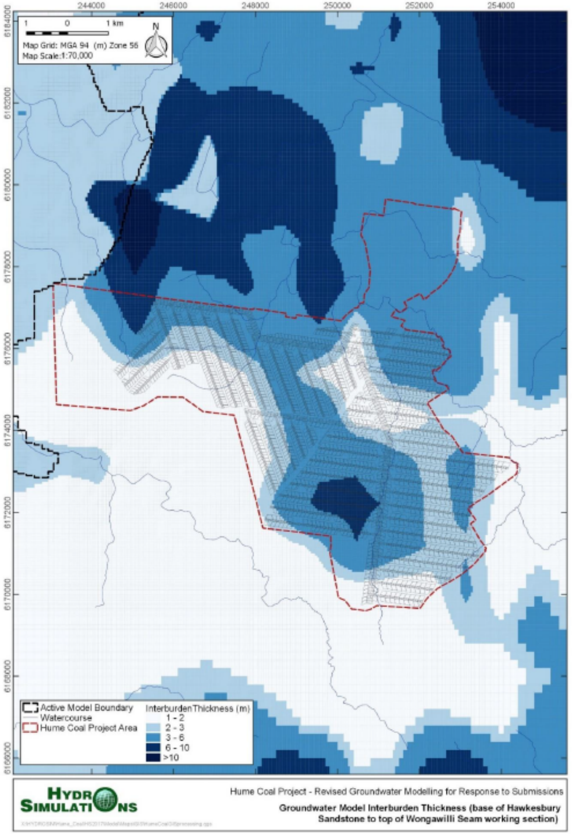


Figure 3 Groundwater model 'interburden' thickness

McElroy and Bryan (1980):

> 200 borehole records from the pre-1985 investigations

direct contact between the Hawkesbury Sandstone and the Wongawilli Coal Seam in > 90% of the bores.

… TENUOUS

Reason 2: Outlet control

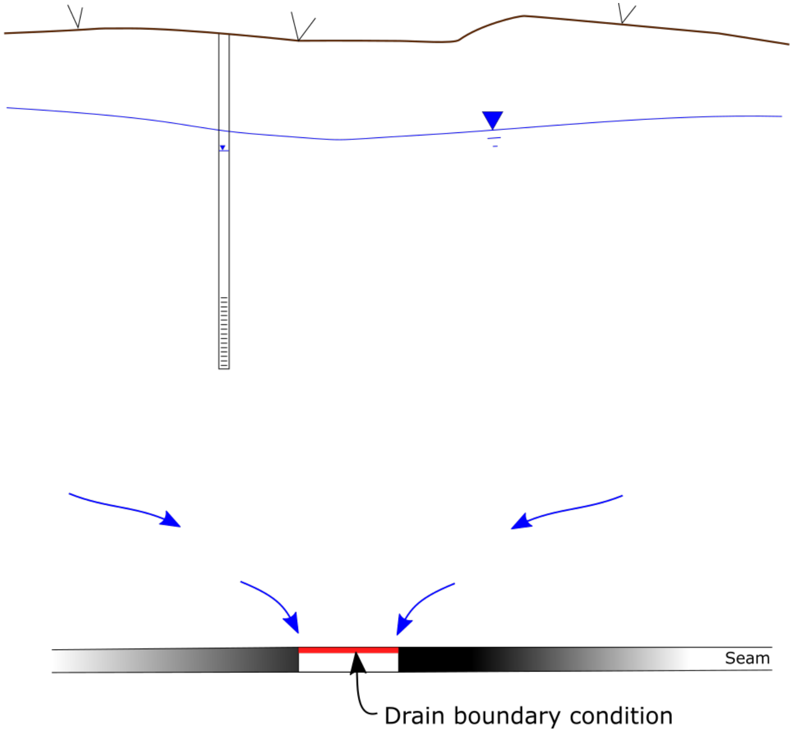
Predicted flows to the workings are represented as outlet controlled within the EIS.

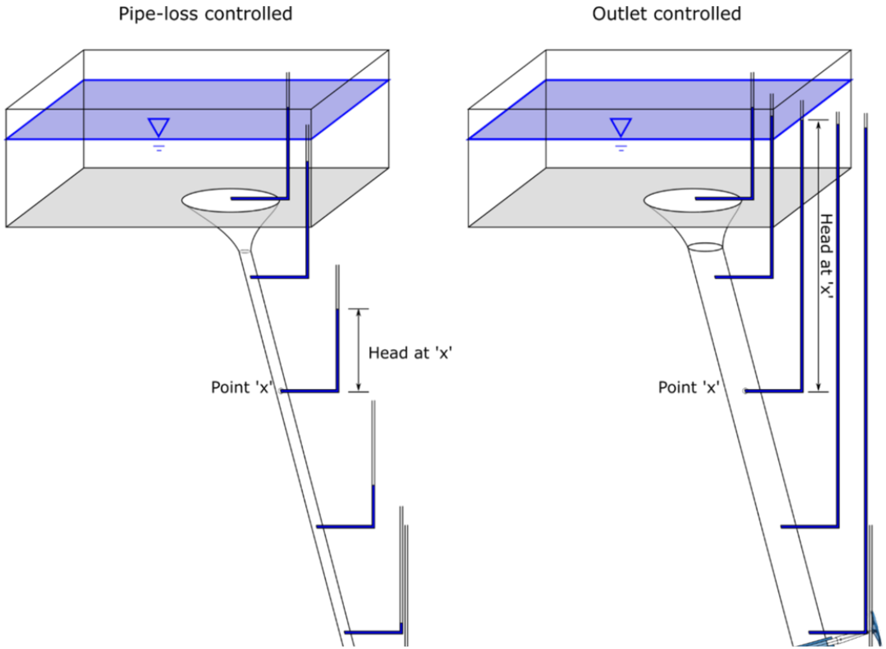
A ‘drain’ boundary condition, with ‘conductance’ of 0.05 to 0.1 m^2/day.

This controls inflows to the mine.

The following observations are important:

Reason 2: Outlet control





Reason 2: Outlet control

These two examples have equivalent discharge, but no drawdown for the outlet controlled case …

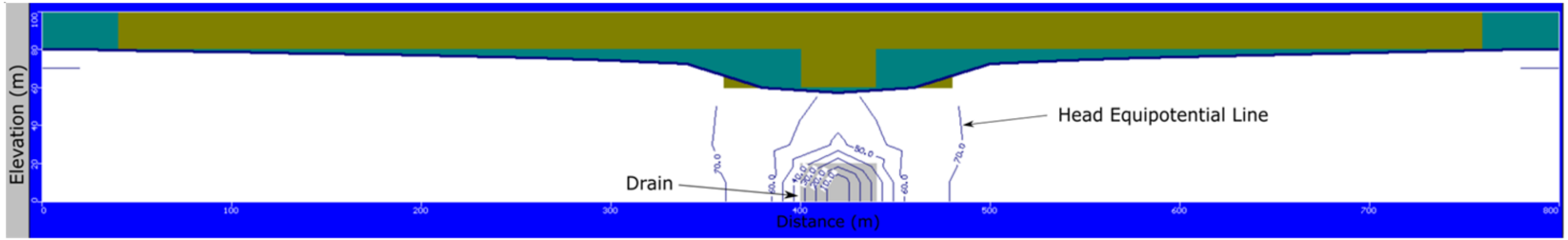


Figure B4 – Model 1 output cross-section

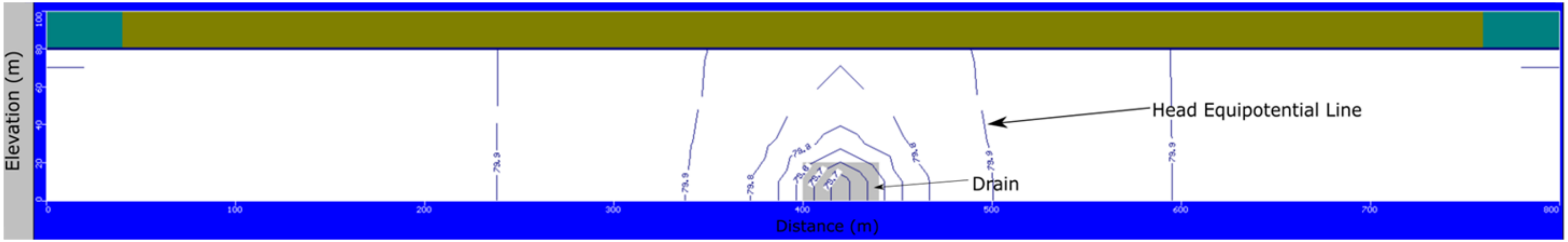


Figure B5 – Model 2 output cross-section

Reason 2: Outlet control

1. This degree of outlet control does not represent reality
2. This is not standard practice

   - It is common to use a large number (eg 1000 m^2/day) to remove outlet control

   - previous models of Berrima Mine (1000 and 5000 m^2/day)

3. Outlet controlled systems under-predict drawdown

   - Is this why drawdown is small compared to Berrima?

4. It is analogous to backfilling mine with clay

   - This is dismissed in responses in the EIS, but without fact or calculation

5. Is not a suitable calibration parameter when multiple layers of drains are used

   - The location of drains is not presented in the EIS

6. Despite being the control, it is not included in sensitivity testing

Summary

Based upon review of the Hume Coal Model, comparison to my model, and consideration of Berrima Mine, I argue that the EIS for Hume Coal:

- Significantly under-estimates inflows
- Significantly under-estimates drawdown

I have shown in submissions, through test and calculation, that:

- The ‘pine-feather’ mine does not account for the smaller predicted impacts.
- Under-prediction of impacts are due to conceptualisation in modelling:

1. Dismissal of sandstone aquifer
2. ‘drain conductance’ control
3. low conductivity of coal measures in and above the workings - continuity of a thin claystone seam above proposed workings.