Vickery Coal Project

Environmental Impact Statement

ATTACHMENT 7

PEER REVIEW LETTERS

Resource Strategies

WHITEHAVEN COAL

KALF AND ASSOCIATES Pty Ltd
Hydrogeological, Numerical Modelling Specialists

VICKERY COAL PROJECT

PEER REVIEW OF HERITAGE COMPUTING GROUNDWATER ASSESSMENT

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Background Summary

This report is the Kalf and Associates Pty Ltd (KA) peer review commissioned by Whitehaven Coal Limited for the Heritage Computing Pty Ltd (HCPL 2012) Vickery Coal Project Groundwater Assessment report.

Whitehaven Coal Limited proposes to mine coal in an open cut mine at the former Vickery Coal Project site over a 30 year mine life. The coal seams within the mining zone are contained within outcropping to subcropping Permian Maules Creek Formation (sandstone, siltstone, conglomerate, coal seams). These porous/fractured rocks and upper weathered profile "island" is abutted in a southerly to westerly direction by lower elevation alluvial sediments of the Namoi River and in a northerly direction by a predominately ancient tributary creek drainage system alluvium. The topography along the northern alluvial flats is also somewhat higher than those adjacent to the Namoi River.

Naturally occurring groundwater in the Permian strata to be mined is for the most part of low quality, slightly alkaline to alkaline with brackish salinity in the coal seams in the range 3,800 to 5300 μS/cm. The Maules Creek Formation overburden and interburden sedimentary strata groundwater is slightly brackish to saline with salinity in the range 2500 to 16,600 μS/cm[1]. Permeability is low to very low and therefore groundwater contained in these strata has limited groundwater potential across and immediately surrounding the proposed mining area.

The Namoi River alluvium at depth has sediments with much higher permeability that contain much better quality groundwater suitable for irrigation (less than 1000 μS/cm). The shallower alluvial sediments in the near vicinity of the subcropping Maules Creek Formation are affected either by the ingress of lower quality Permian strata groundwater emerging from the north western edge of hard rock strata or the bores in this area with higher salinity (2900 to 5000 μS/cm) are partially tapping this Formation at depth.

The alluvium sediments to the north generally have groundwater salinity in the range 1000 to 2500 μS/cm.

Modelling of the groundwater system during mining operations indicates low to moderate inflow to the open cut mine in the range 0.3 ML/day to 1.7 ML/day. A proportion of this inflow would be evaporated from the mine pit. Drawdown created by the mine will not extend beyond the elevated Permian rock "island" across the mine area to any measurable degree. Consequently there will not be any drawdown influence on alluvial bore water levels located in the vicinity of the mine boundaries according to the modelling results. There could however be drawdown influence greater than 2m in two privately owned local bores that are tapping groundwater in the subcropping Maules Creek Formation (i.e. bores WL1 and SK1).

Presence of the mine pit during operations would divert much of the brackish Permian strata groundwater immediately surrounding and beneath the pit from intruding into the adjacent alluvial sediments. Model analysis however has indicated that this groundwater diversion would only decrease baseflow in a local section of the Namoi River immediately adjacent to south-west mine boundary by less than 0.2 L/sec. A local storage (Blue Vale) proposed

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[1] 16,600 μS/cm based on GES (2012) Figure 2.5 bore TR7 in Maules Creek Formation. Similar salinity magnitude is known to exist in this Formation elsewhere in the Gunnedah Basin.

would increase the baseflow in this section of the River by about five times that rate. Any change in river salinity however due to these changes would be too small to be measured.

The final mine voids will for all time act as a permanent 'sink' with groundwater inflow balanced by evaporation. Increasing salinity of void water due to evaporation is a natural outcome over time but would be of no consequence as the system would not allow any such void storage water to migrate into the surrounding strata or therefore to the surrounding alluvium.

Drawdown assessed due to other mines in the region indicates no significant cumulative drawdown influence on the Namoi Alluvium.

KA is in agreement with the key issues presented in the HCPL report as summarised above.

Peer Review Assessment

Previous Studies and Reviews

There have been previous assessments of the original Vickery Coal Mine by Coffeys and Partners in 1982, 1984 and 1986.There are also a number of coal mines in the region that have been assessed for their influence on the groundwater system. These include Tarrawonga 10km north and Rocglen 5km east from the Vickery site reported on by HCPL (2011) and Douglas and Partners (2010). References are given in the HCPL groundwater assessment report (2012).

During mid-October 2012 KA conducted a preliminary review of the draft HCPL hydrogeological and modelling report for the Vickery Coal Project. In that review a range of changes, comments and suggestions were made for report modification. The current review is based on the final report submitted by HCPL.

The current review is based on an assessment of the HCPL modelling report, its findings and associated data and a supplementary groundwater field investigation report supplied (GES 2012). A model audit was not included.

Hydrogeological and Modelling Description

The hydrogeological description of the region and modelling work described in the HCPL report (2012) is detailed and has been conducted and presented in a professional manner in my opinion.

The initial part of the report sets out the scope of work; proposed mine development; government legislation and policies.

The Hydrogeological Regime section provides a detailed description of previous studies, the investigation program; weather and climate; topography and drainage; the various geological strata, sediments and structures; groundwater occurrence, users and monitoring; ecosystems; hydraulic properties; recharge; groundwater quality and yields; strata potentiometric levels; mining operations.

The Numerical Groundwater Model section covers groundwater conceptualisation; model software; description of modelling objectives; model extents, layers and hydraulic properties; boundary conditions; steady state and transient calibration and predictive simulations. It also includes model sensitivity; water balance; predicted pit inflow; cumulative influence; groundwater recovery; mining influence on surface water.

A final section presents groundwater management and mitigation measures.

Modelling Guidelines

This review report uses as a basis the new Australian Groundwater Modelling Guidelines (National Water Commission 2012). It should be noted that while this set of guidelines contains relevant procedures and items for the HCPL modelling work, it does not specifically cover open cut coal mining *per se*. Where no guidelines are available specific comments are made regarding the adequacy or otherwise of the approach used for modelling the groundwater system at the Project area based on the author's experience, previous reviews or available reported field evidence. The completed Peer Review guideline checklists for this modelling work are presented in Appendix A.

Model Conceptualisation, Design and Simulation Methods

The model conceptualisation is considered suitable and described in detail in the HCPL report. The model is comprised of 14 model layers representing the various rock strata including layering of individual coal seams.

Use is made of the variably saturated computer modelling code MODFLOW-SURFACT and trial and error to calibrate the model. A parameter estimation code was not used for this project and while not essential this could have provided additional facility to analyse sensitivity more fully. Nevertheless the modelling results obtained are considered to be acceptable at this pre-mine stage given the overall statistical fit of model calibration and measured groundwater levels.

Boundaries chosen for the model are considered suitable. They include the western Mooki Thrust (fault) and very low permeable rocks east as no-flow and also general head boundaries south and west in the two shallow layers and no-flow in the deeper layers. The Namoi River and major creeks in the region are represented as 'River cells' in the upper layer with bed leakage co-efficients representative of the underlying clayey sediments. The other creeks across the site are ephemeral and have no important alluvium and have been set as non-leakage river cells and therefore act as drains. Gross recharge was applied in the model as a variable percentage of rainfall over different geological zones as well as evapotranspiration.

Initial hydraulic parameters used were based on previous investigation reports in the region by various consultants including those parameters derived by GES (2012).

Calibration

Both steady state and transient simulations have been conducted. Steady state results are considered acceptable. Transient calibration is limited to recharge events because this is essentially a pre-mine site with apparently no previous monitoring. The calibration has provided a new set of hydraulic parameters derived for each model layer within various geological zones including rainfall recharge. The hydraulic parameters derived are plausible and simulation of the measure water levels is acceptable.

The overall calibration performance statistics of 2.8% RMS and 2.6% SRMS obtained is a very good result although of course not necessary unique.

The water balance derived from the transient calibration gives rainfall recharge as 19.8 ML/day but evapotranspiration at only 1.9 ML/day which would appear to be low but is due to the potential evapotranspiration set at 150mm /annum. The modeller has indicated that this maximum is based on Bureau of Meteorology research data.

Sensitivity, Uncertainty and Model Constraints

Uncalibrated sensitivity analysis was conducted during the transient calibration phase, which showed that horizontal permeability of the coal layers was the most important parameter. No further details are provided in the report or any uncertainty issues discussed. Again this is in part because no mining stress has been monitored at the site.

The model constraints and limitations are adequately outlined in the report.

Model Predictions and Cumulative Influence

Drawdown created by the mine will not extend beyond the elevated Permian strata “island" across the mine area to any measurable degree. Consequently there will not be any drawdown influence on alluvial bore water levels located in the vicinity of the mine boundaries according to the modelling results. There could however be drawdown influence greater than 2m in two privately-owned local bores that are tapping groundwater in the subcropping Maules Creek Formation beneath colluvial and soil profile.

The Vickery model grid was extended to include the Tarrawonga and Rocglen mines. However, the Tarrawonga and Rocglen mines are situated some 10km and 5km respectively from the Vickery site. Hence it would not have been necessary to include them in a 'cumulative' model assessment in my opinion particularly given the localised Vickery site drawdown predicted by the groundwater model.

Because of Vickery model grid limits in the Tarrawonga region, the Tarrawonga mine drawdowns determined previously and independently by HCPL have been used and applied using Principle of Superposition to determine the regional drawdown influence. Based on this analysis the HCPL (2012) report concludes *"... no interaction with the effects from the Tarrawonga Coal Mine"*. In addition there is no significant combined drawdown influence predicted with the Rocglen mine in the alluvium. Computed drawdown is 1m or less in this region that can be considered to lie within model error bounds. I agree with these assessments and using the superposition procedure in assessing cumulative drawdown influence.

The climate change issue as discussed in the report and how it has or will affect rainfall is highly controversial and uncertain. No correlation or climate model has so far been successful in relating such change to rainfall patterns. Rainfall events are however known to correspond closely to ENSO[2] events that apply to the Australian Eastern States. However, these events are related more to changing weather than climate and occur in unpredictable sequences. Therefore any groundwater model predictions made assuming long-term periods of "drying" or "wetting" are also bound to be highly uncertain.

Mitigation and Monitoring Plans and Trigger Levels

There is agreement with the groundwater monitoring proposed as set out in Section 6.3 in the HCPL report (2012 - Table A-22). No specific trigger levels or criteria are presented in

[2] ENSO - El Nino/La Nina Southern Oscillation.

the report. This should based on significant deviations of time based monitoring hydrograph water levels compared to model simulated hydrographs at selected bore sites rather than default specific level or levels at a given time. A 20% deviation between measured and model computed hydrographs for example has been used in other projects.

Conclusions and Considerations

This peer review has assessed the adequacy of the hydrogeological data and the development of a numerical model for predicting the local and regional effects of open cut mining at the Vickery Coal Project site. The hydrogeological description, conceptualisation, model design, simulations and reporting have been conducted in a professional manner and described in detail.

Groundwater in the Permian coal bearing strata contains brackish to saline groundwater that is slightly alkaline to alkaline and therefore has limited groundwater potential.

The groundwater model has been set up in a suitable manner and various boundary conditions applied are considered to be acceptable.

Steady state and transient calibrations of the bore water levels has yielded a very good fit to the measured data. The transient simulation is limited because this is essentially a “pre-mine” site. The derived model hydraulic parameters are considered plausible.

The modelled mine inflow range is considered to be plausible when compared to existing mines in the area.

The model predicts substantial drawdown will be restricted within the more elevated Permian hard rock strata with no measurable drawdown, or cumulative drawdown likely to affect bores within the adjacent Namoi and tributary creek alluvial sediments based on the modelling results.

Voids created during mining and after decommissioning will for all time act as a permanent 'sink' with groundwater inflow balanced by evaporation. Increasing salinity of void water due to evaporation is a natural outcome over time but would be of no consequence as the system would not allow any such void water to migrate into the surrounding strata or therefore to the surrounding alluvium.

The plan of monitoring and mitigation as set out in the report is considered suitable. Trigger levels should be based on measured time based hydrograph deviation from model predicted hydrographs at bores yet to be selected.

Because the transient calibration is currently limited to recharge rather than mining stress the model simulations should be assessed after two years mine operation and recalibrated using the measured water levels over that period.

The model is considered to be "fit-for-purpose" for mining impact assessment at the Vickery Coal Project.

References

Groundwater Exploration Services Pty Ltd (GES) 2012. *Groundwater Field Investigation Program in support of the Vickery Coal Project Environmental Assessment. July 2012.*

Heritage Computing Pty Ltd (HCPL) 2012 *Vickery Coal Project – Groundwater Assessment, Report prepared by Drs N. Merrick and M. Alkhatib. Report HC2012/15. October 2012.*

National Water Commission 2012 *Australian Groundwater Modelling Guidelines. Report compiled by SKM and NCGRT and various authors. Waterlines Report Series No 82. June.*

Appendix A - Peer Review Checklists

Peer review checklists

NA - Not Applicable

Question	*Yes/No*
1. Are the model objectives and model confidence level classification clearly stated?	Y
2. Are the objectives satisfied?	Y
3. Is the conceptual model consistent with objectives and confidence level classification?	Y
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Y
5. Does the model design conform to best practice?	Y
6. Is the model calibration satisfactory?	Y
7. Are the calibrated parameter values and estimated fluxes plausible?	Y
8. Do the model predictions conform to best practice?	Y
9. Is the uncertainty associated with the predictions reported?	N
10. Is the model fit for purpose?	Y

Review questions	*Yes/No*	*Comment*
1. Planning		
1.1 Are the project objectives stated?	Y	
1.2 Are the model objectives stated?	Y	
1.3 Is it clear how the model will contribute to meeting the project objectives?	Y	
1.4 Is a groundwater model the best option to address the project and model objectives?	Y	
1.5 Is the target model confidence-level classification stated and justified?	Y	Class 2 with aspects of Class 3.
1.6 Are the planned limitations and exclusions of the model stated?	Y	
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Y	
2.2 Is the aquifer system adequately described?	Y	
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Y	
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Y	
2.2.3 aquifer geometry including layer elevations and thicknesses	Y	
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Y	
2.3 Have data on groundwater stresses been collected and analysed?	Y	
2.3.1 recharge from rainfall, irrigation, floods, lakes	Y	
2.3.2 river or lake stage heights	Y	
2.3.3 groundwater usage (pumping, returns etc)	Y	indirectly
2.3.4 evapotranspiration	Y	
2.3.5 other?		
2.4 Have groundwater level observations been collected and analysed?	Y	

2.4.1 selection of representative bore hydrographs	Y	
2.4.2 comparison of hydrographs	Y	
2.4.3 effect of stresses on hydrographs	Y	
2.4.4 watertable maps/piezometric surfaces?	Y	
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	NA	
2.5 Have flow observations been collected and analysed?	N	Pre-mine site
2.5.1 baseflow in rivers	Y	predicted
2.5.2 discharge in springs	NA	
2.5.3 location of diffuse discharge areas?	Y	
2.6 Is the measurement error or data uncertainty reported?	N	
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	N	
2.6.2 spatial variability/heterogeneity of parameters	Y	
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	N	
2.7 Have consistent data units and geometric datum been used?	Y	
2.8 Is there a clear description of the conceptual model?	Y	
2.8.1 Is there a graphical representation of the conceptual model?	Y	Model layer x sections
2.8.2 Is the conceptual model based on all available, relevant data?	Y	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Y	
2.9.1 Are the relevant processes identified?	Y	
2.9.2 Is justification provided for omission or simplification of processes?	Y	
2.10 Have alternative conceptual models been investigated?	N	
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Y	
3.2 Is the choice of numerical method and software appropriate	Y	MODFLOW-SURFACT
3.2.1 Are the numerical and discretisation methods appropriate?	Y	
3.2.2 Is the software reputable?	Y	
3.2.3 Is the software included in the archive or are references to the software provided?	N	
3.3 Are the spatial domain and discretisation appropriate?	Y	
3.3.1 1D/2D/3D	Y	3D
3.3.2 lateral extent	Y	
3.3.3 layer geometry?	Y	
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Y	
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	Y	
3.4 Are the temporal domain and discretisation appropriate?	Y	
3.4.1 steady state or transient	Y	Steady state /transient pre-mine. stage
3.4.2 stress periods	Y	

3.4.3 time steps?	Y	
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Y	
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Y	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Y	Drawdowns
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Y	
3.5.4 Are lateral boundaries time-invariant?	Y	
3.6 Are the initial conditions appropriate?	Y	Steady State derived.
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	-	GW modelling steady state
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	N	Steady state heads pre-mine are suitable
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	
3.7 Is the numerical solution of the model adequate?	Y	
3.7.1 Solution method/solver	.	PCG Newton
3.7.2 Convergence criteria	.	0.001m
3.7.3 Numerical precision	.	Single
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	Y	
4.1.1 Groundwater head data	Y	
4.1.2 Flux observations	N/A	
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	N/A	
4.2 Does the calibration methodology conform to best practice?	Y	For trial and error
4.2.1 Parameterisation	Y	
4.2.2 Objective function	NA	
4.2.3 Identifiability of parameters	Y	
4.2.4 Which methodology is used for model calibration?	.	Trial and error
4.3 Is sensitivity of key model outcomes assessed against?		
4.3.1 parameters	Y	
4.3.2 boundary conditions	Y	
4.3.3 initial conditions	.N	
4.3.4 stresses	.Y	recharge
4.4 Have the calibration results been adequately reported?	Y	
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Y	
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Y	
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Y	
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?		Steady state only
4.5.1 spatially	.Y	
4.5.2 temporally	Y	But not complete. Transient to be done when stress

		applied to coal seams
4.6 Are the calibrated parameters plausible?	Y	
4.7 Are the water volumes and fluxes in the water balance realistic?	Y	evapotranspiration seemingly low
4.8 has the model been verified?	N	Partially but not entirely feasible until mining commences
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Y	
5.2 Is predictive uncertainty acknowledged and addressed?	N	
5.3 Are the assumed climatic stresses appropriate?	Y	
5.4 Is a null scenario defined?	.	
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Y	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	NA	
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	NA	
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	N	Not feasible at present
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Y	
5.6 Do the prediction results meet the stated objectives?	Y	
5.7 Are the components of the predicted mass balance realistic?	Y	
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	NA	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	NA	
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?	N	
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Y	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	N	
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	NA	
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	N	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	N	
6.3 Are the sources of uncertainty discussed?	N	
6.3.1 measurement of uncertainty of observations and parameters	N	
6.3.2 structural or model uncertainty		
6.4 Is the approach to estimation of uncertainty described and appropriate?	N	

6.5 Are there useful depictions of uncertainty?	N	
7. Solute transport	NA	Not Applicable
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?		
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?		
7.3 Is the choice of numerical method and software appropriate?		
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?		
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?		
7.6 Are the solver and its parameters appropriate for the problem under consideration?		
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?		
7.8 Has an assessment been made of the need to consider variable density conditions?		
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?		
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?		
7.11 Is the calibration based on meaningful metrics?		
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?		
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?		
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?		
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?		
8. Surface water–groundwater interaction		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Y	
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Y	
8.3 Is the groundwater model coupled with a surface water model?	N	
8.3.1 Is the adopted approach appropriate?	Y	
8.3.2 Have appropriate time steps and stress periods been adopted?	Y	
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	Y	