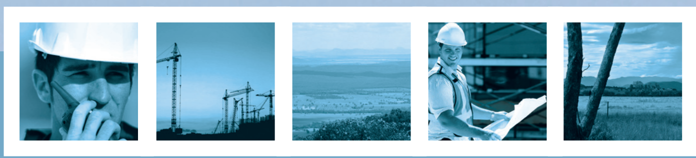
APPENDIX M



Addendum - Peer Review of the Maules Creek Coal Project Groundwater Impact Assessment

HERITAGE COMPUTING

HERITAGE COMPUTING REPORT

PEER REVIEW OF THE MAULES CREEK COAL PROJECT GROUNDWATER IMPACT ASSESSMENT

FOR

ASTON RESOURCES LIMITED

By

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1.0 INTRODUCTION

This report provides a peer review of the groundwater impact assessment of open cut mining for the Maules Creek Coal Project. The mine is to be situated about 18 km to the north-east of Boggabri in NSW.

The hydrogeological assessment is based on field investigations and a regional numerical groundwater model developed by Australasian Groundwater & Environmental Consultants (AGE) Pty Ltd.

The groundwater modelling forms an important component of the environmental assessment for the project. The main purpose of the modelling is to assess potential impacts on groundwater levels on the Project Site and in the surrounding area where private bores are situated, and also to assess potential interception of alluvial groundwater recharge in aquifer systems associated with Maules Creek to the north and Bollol Creek to the south. The model also provides an assessment of likely groundwater inflow to the open cut pit as the mine progresses in time.

2.0 SCOPE OF WORK

The agreed scope of work for the review consisted of the following tasks:

- Attend a kickoff/conceptualisation meeting in Brisbane;
- Maintain an overview of AGE's modelling progress at all stages of model development;
- Review a model study plan after the conceptualisation stage;
- Attend a meeting in Brisbane after model calibration;
- Assess the model component in the draft final report by means of the MDBC peer review checklists;
- Review the full groundwater assessment draft report;
- Prepare a report that outlines the key findings from the review; and
- Provide phone/email advice as required.

This report addresses the penultimate dot point (above) by outlining the key findings from the review. As indicated in the second dot point (above), this review was conducted as a progressive review.

The reviewer has been engaged in all phases of the groundwater assessment since October 2010. Peer review was conducted progressively at key milestones:

- Model conceptualisation;
- Model calibration;
- Model prediction; and
- Final reporting.

The reviewer participated in meetings with the modelling team and project managers in Brisbane on 21 October 2010, 8 December 2010 and 27 January 2011.

3.0 MODELLING GUIDELINES

The review has been structured according to the checklists in the Australian Flow Modelling Guideline (MDBC, 2001). This guide, sponsored by the Murray-Darling Basin Commission, has become a *de facto* Australian standard. This reviewer was one of the three authors of the guide, and is the person responsible for creating the peer review checklists. The checklists have been well received nationally, and have been adopted for use in the United Kingdom, California and Germany.

The modelling has been assessed according to the 2-page Model Appraisal checklist in MDBC (2001). This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis.

The effort put into a modelling study is often dependent on timing and budgetary constraints that are generally not known to a reviewer.

4.0 EVIDENTIARY BASIS

The primary documentation on which this review is based is:

1. *Australasian Groundwater & Environmental Consultants Pty Ltd, 2011, Maules Creek Coal Project Groundwater Impact Assessment. February 2011. Version 7. 85p + Drawings + 3 Appendices.*

Apart from background knowledge of the area, no other documentation has been referenced in doing this review.

As a progressive review has been conducted, comments have been offered progressively by the reviewer on a series of draft AGE reports and model outputs.

5.0 PEER REVIEW

In terms of the modelling guidelines, the Maules Creek Coal Project model is categorised as an *Impact Assessment Model* of medium complexity, as distinct from an *Aquifer Simulator* of high complexity.

The Australian best practice guide (MDBC, 2001) describes the connection between model application and model complexity as follows:

- Impact Assessment model - a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies; and
- Aquifer Simulator - a high complexity model, suitable for predicting responses to arbitrary changes in hydrological conditions, and for developing sustainable resource management policies for aquifer systems under stress.

An Impact Assessment model is the appropriate level of complexity for an Environmental Assessment.

The appraisal checklists are presented in Tables 1 and 2 (at the back of this report). The current review has been based entirely on a written report, with no reference to electronic model files.

6.0 DISCUSSION

6.1 THE REPORT

The Model Report (Document #1) is a substantial, high quality document of 85 pages in the main body of the report plus 29 drawings and three appendices. To an external reader with no prior knowledge of the study area, the report is very good as a standalone document without need of supporting documents.

The objectives of the groundwater study and the scope of work to address those objectives are articulated clearly in Section 3.0 (Scope of Work). The specific objectives of the modelling study are stated in Section 9.1.

In Section 10.11, the findings of the modelling study are reported succinctly in the context of the objectives. This reviewer considers that the objectives have been met satisfactorily and the findings are well substantiated.

There is ample coverage of the modelling component of the study, with full disclosure of (uniform) aquifer/aquitard parameterisation.

6.2 Data Analysis

While substantial hydraulic testing has been undertaken on coal seams in the Project area and neighbouring areas, assessment of interburden permeabilities is limited.

There is a substantial record of groundwater level variations (hydrographs) in government alluvial bores. However, there is limited hydrographic information available within the coal measures within the Project Boundary and for neighbouring mining operations. Hydrographs are presented for three vibrating wire installations that have piezometers at either one or two depths within the Project Boundary. Data acquisition commenced in September 2010. The lack of monitored sites and the shortage of the measurement record have limited model calibration to steady-state analysis. Transient calibration could have been done on alluvial hydrographs, in principle, but these datasets are affected by private pumping which is not on public record.

The vibrating wire installations would have benefitted from having more piezometers installed on the one string. The marginal cost is low, and vertical head profiles would provide a strong calibration target, especially during mining. Nevertheless, the quantification of vertical head difference between two depths provides some control for model calibration.

A good correlation has been demonstrated between alluvial hydrographs and rainfall trends.

Sufficient "snapshot" water levels are available for production of a regional water level map. This shows clearly the dominant directions of groundwater flow.

6.3 Conceptualisation

The conceptualisation of the local hydrogeology is sensible and is discussed in detail, in terms of geology and key recharge/discharge processes. Excellent graphics are provided in support of the conceptualisation (Figures 21, 22, 23).

Due to the number of coal plies, the stratigraphic division into model layers required a compromise. The plies were lumped into layers having aggregate thicknesses and placed at the base of a significant seam. This is a sensible compromise. The consequences of this action are well understood and are addressed in the report.

6.4 MODEL DESIGN

The model has been built with MODFLOW-SURFACT in DOS mode with only incidental use of a commercial Graphic User Interface. This combination is unusual, as it limits transferability of models, but it does allow model refinements not available through other means.

The use of MODFLOW-SURFACT is supported over standard MODFLOW as it is a more powerful version which is better able to handle desaturated conditions caused by mining.

One limitation that both MODFLOW versions have for coal mining simulations is that they do not permit time-varying material properties (without frequent stops and starts). AGE has adopted the stop-start approach, which is the acceptable best practice approach. It is noted that MODFLOW-SURFACT has introduced a time-varying facility recently, and this is likely to become a better approach after it is fully tested.

Discretisation in space is appropriate. Model cells are a minimum 50 m square, maximum 500 m square, over a 30 km (east-west) by 40 km (north-south) area. Finer discretisation is applied in the area to be mined. The model has 12 layers.

The broad model extent isolates the boundaries from likely impacts and reduces the need for accurate representation of boundary fluxes which are set as no-flow for most layers except for prescribed heads in the alluvial Gunnedah Formation. Final predicted drawdowns verify that the adopted boundary conditions have had no undue effect.

The mining operation has been simulated appropriately by MODFLOW "drain" cells in each layer of the open cut excavation.

Watercourses are handled properly using the "river" (RIV) MODFLOW package.

Where uncertainty exists, a deliberately conservative approach has been adopted for the modelling. This is good practice. In particular, faults have not been included. Such faults and seam discontinuities are likely to limit the predicted extent of drawdown effects.

6.5 CALIBRATION

Calibration has been performed for steady-state conditions only, as insufficient data were available for transient calibration. The latter could have been done for alluvial hydrographs, but essential information on private groundwater abstraction is not available in the public domain. However, the alluvial system was adopted from a well calibrated government model. The only deficiency of the government model is that it assumes no interaction with hard rock. The Maules Creek model had to adopt a leakage coefficient (or equivalently a vertical permeability) at the sediment-rock interface. This was informed through steady-state calibration against long-term average alluvial groundwater levels. This is considered sufficient by the reviewer.

Several lines of evidence are provided in support of steady-state calibration in the form of a scatter plot, performance statistics, and a water level contour map for comparison with best-estimate field contours. Steady-state calibration is quite good, with satisfactory performance statistics: 5 % scaled RMS and ~6 m absolute RMS.

The inferred hydraulic conductivity magnitudes are consistent with aquifer tests and previous modelling, and the inferred rainfall recharge rates are plausible.

6.6 PREDICTION

Predictions are based on transient simulation for 21 years of continuous mining followed by 1000 years of recovery after the cessation of mining. Project-specific and cumulative effect simulations are performed.

The report presents continuous plots of mine inflow with time, and also of intercepted lateral groundwater flow normally destined for the alluvial system. Drawdown maps are offered at 5 year intervals.

All runs are performed properly and the findings are defensible.

Predicting mine inflow magnitude is always difficult in a "greenfields" application. The plausibility of the prediction (average 1.6 ML/day) would have benefitted from knowledge of measured or estimated mine inflows at the shallower neighbouring Boggabri and Tarrawonga mines. It is understood that reliable mine inflow estimates are not available, but they are expected to be less than 0.5 ML/day.

6.7 Sensitivity Analysis

A sufficient sensitivity analysis has been reported. Perturbations of 50% are applied to rain recharge, specific yield, coal seam horizontal permeability, specific storage and Gunnedah vertical permeability. This is sufficient for bracketing the range of uncertainty for the first three parameters. For the latter two, an order of magnitude or half order of magnitude perturbation would normally be applied. The -50% perturbation gives a half order of magnitude change, but +50% is a multiplier of 1.5. This means that reduced specific storage and Gunnedah vertical permeability are assessed adequately, but increased values could be tested at higher levels.

Steady-state calibration statistics are reported for each sensitivity run. Calibration performance is affected significantly only by higher rain recharge. This suggests that the adopted rain recharge is confined to a small range of uncertainty (or that the ratio of rain recharge to surficial permeability is well defined). The mass balance elements are well defined except for rain recharge perturbation.

6.8 Uncertainty Analysis

Sensitivity simulations in predictive mode provide a way of quantifying the uncertainty in predicted outcomes.

Mine inflow rate was found to be sensitive to coal seam permeability, resulting in an average of 1.6 ± 0.5 ML/day. For other property perturbations, the uncertainty was found to be much smaller.

The interception of alluvial flow was found to be sensitive to specific storage, resulting in an average of about 0.35 ± 0.2 ML/day. It has been remarked already that specific storage can reasonably vary by more than 50% without affecting a (transient) calibration. Hence, the real uncertainty in alluvial groundwater interception could be higher. However, higher interception occurs only with a lower specific storage value, and this has been tested adequately by a half order of magnitude change. The value for this parameter should be refined when model recalibration is done after proposed mining commences. This reviewer agrees with the AGE recommendation for model updates every five years, to guide adaptive management.

7.0 CONCLUSION

The Maules Creek Coal Project groundwater model has been developed competently and is regarded as “fit for purpose” for addressing cumulative impacts from three mines, for estimating indicative dewatering rates, and for assessing regional potential groundwater impacts.

Model predictions are expected to be conservative for two main reasons:

- Exclusion of structural controls that are likely to cause some compartmentalisation of effects in reality and to limit the drawdown extent towards alluvial aquifers; and

- Probable overestimation of mine inflow.

Model predictions of mine inflow are likely to be overestimated for two main reasons:

- Aggregation of coal plies into a thicker coal seam at a lower depth; and

- No allowance for the time taken for spoil to reach saturation.

The stated objectives of the modelling study have been addressed satisfactorily; namely:

- Estimation of mine inflow to the open cut void for 21 years;

- Prediction of drawdown magnitude and extent;

- Prediction of alluvial groundwater losses;

- Prediction of impacts on stream baseflows and other groundwater users; and

- Identification of risks that might necessitate mitigation measures or controls.

It is considered that the model would benefit from refinement through transient calibration when sufficient hydrographic data become available in the Permian formations. As recommended in the AGE report, transient calibration should be performed after the first five years of mining.

Drawdown predictions indicate that the Project will not have significant impacts external to the mined area. This conclusion is well substantiated.

The model anticipates no change in baseflow at the neighbouring creeks. This conclusion is well substantiated.

There is a prediction of reduced average lateral recharge of groundwater in the alluvial system, in the order of 50 ML/a. This estimate is sensitive to the adopted specific storage values which cannot be calibrated properly until transient calibration becomes possible. Even allowing for uncertainty in specific storage, this volume of water is less than 1% of rain recharge over the model area. It is likely that Aston Resources can offset this volume by acquiring existing water licences.

8.0 REFERENCES

Australasian Groundwater & Environmental Consultants Pty Ltd, 2011, Maules Creek Coal Project Groundwater Impact Assessment. February 2011. Version 6.

MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: http://www.mdbc.gov.au/nrm/groundwater/groundwater_guides/

Table 1. MODEL APPRAISAL: Maules Creek Coal Model

Q.	QUESTION	Not Applicable or Unknown	RATING				COMMENT
1.0	THE REPORT						
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good	Scope of Work Section 3.0
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes		Impact Assessment Model, medium complexity. Executive Summary includes the relevant statement.
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good	Tabulated for steady state calibration. Presented as time-series graphs for the prediction model. Also tabulated for 10% sensitivity runs.
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good	Subject to stated limitations.
1.5	Are the model results of any practical use?			No	Maybe	Yes	
2.0	DATA ANALYSIS						
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good	Includes a field program packer tests; 8 piezos; 4 VW piezo nests (x2); water samples. No prior information on vertical head profiles.
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good	For 1992 Coffey northern area and recent contours developed using shallow steady state targets (Permian/Quaternary mix).
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good	Rain residual mass analysis is done. Steady stream stage based on ground elevation minus estimated incision.
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good	Private gw abstraction from alluvium not available in the public domain.
2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good	Strong correlation of groundwater hydrographs with rainfall trends, shown by residual mass analysis. Quantified vertical head gradients in new VWP holes. One faulty VWP.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes	
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes		Inconsistency in some TDS/EC values; some ratios are very low (<0.6) for a bicarbonate water. Two anomalous TDS.

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3.0	CONCEPTUALISATION						
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	Yes	
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	Adequate	Very Good	Section 9.2.
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good	Figure 21 for during-mining situation. 3D geometry shown in Figures 22 and 23 – removal of alluvium is illustrative.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No		Sensible stratigraphic division. Plies lumped into layers having aggregate thicknesses – an acceptable compromise.
4.0	MODEL DESIGN						
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes	Extensive.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good	Generally no-flow at distant borders, and fixed heads in Layer 2 (Gunnedah Fm.). Not clear if flow boundary has been applied to Narrabri Fm. (Layer 1) – probably no flow, as applied in deep layers. Could have had spatially varying fixed head in alluvium from NOW model. Streams are RIV cells (often = DRN). Mining by DRN cells.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes	MODFLOW-SURFACT in DOS mode (no GUI). Time varying material properties handled by start-stop simulation.

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Table 2. MODEL APPRAISAL: Maules Creek Coal Model

Q.	QUESTION	Not Applicable or Unknown	RATING				COMMENT
5.0	CALIBRATION						
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good	Several lines of evidence: scattergram for steady-state; performance statistics for steady state (%RMS and absolute RMS); residual at each bore; water table contour map. Presumably used PEST – not stated.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good	Drawing 14 compared with "observed" contour map (Drawing 11).
5.3	Is the model sufficiently calibrated against temporal observations?	N/A	Missing	Deficient	Adequate	Very Good	Steady-state calibration only.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes	Consistent with aquifer tests. Rain recharge rates are consistent with district knowledge and prior modelling. Should not report Ss for Layer 1.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good	4.9% SRMS and 5.7mRMS; maximum residual 14m. SRMS is very good and meets the MDBC guideline.
5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good	Geological complexity. Mixed water levels from many years.
6.0	VERIFICATION						
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good	
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A	Unknown	No	Maybe	Yes	
6.3	Are there good reasons for an unsatisfactory verification?	N/A	Missing	Deficient	Adequate	Very Good	
7.0	PREDICTION						

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7.1	Have multiple scenarios been run for climate variability?		**Missing**	Deficient	Adequate	Very Good	No climate variability is simulated. Steady average rain is applied – appropriate for the model purpose.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	**Adequate**	Very Good	Single mine plan – with and without two neighbouring mines. Irrigation gw abstraction excluded. Appropriate for the model purpose. Two final void options are modelled.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	**No**	Maybe	Yes	21 years prediction based on steady state calibration and prior/textbook storage properties.
7.4	Are the model predictions plausible?			No	Maybe	**Yes**	Mine inflow <4 ML/day; average <2 ML/day. Consistent with prior model estimates, but conservatively high. No accurate knowledge of current mine inflow at Boggabri and Tarrawonga, but Tarrawonga is believed to be <0.1 ML/d and Boggabri <0.5 ML/d.
8.0	SENSITIVITY ANALYSIS						
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	**Adequate**	Very Good	Done for rain recharge, specific yield, specific storage, Gunnedah Kz, coal seam Kx, for 50% perturbation. This will bracket likely uncertainty for the first two and the last, but not for Specific storage (Ss) and Kz. Values are lowered by half order of magnitude (multiplier 0.5), which is adequate, but higher values should use a multiplier of 3 or 5 instead of 1.5.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	**Very Good**	RMS and SRMS are reported.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	**Very Good**	Water budget items are reported.
9.0	UNCERTAINTY ANALYSIS						
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	**Yes**	Range in average and maximum mine inflow is reported for sensitivity analysis. Recovery time is investigated for 2 spoil recharge rates.

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