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FROM: Dr Noel Merrick

RE: **Groundwater Peer Review – Drayton South Coal Project**

OUR REF: HC2015/16

1. Introduction

This report provides a peer review of the groundwater assessment undertaken for open cut mining for the Drayton South Coal Project (the Project). The groundwater assessment has been done by Australasian Groundwater and Environmental (AGE) Consultants Pty Ltd for Anglo American Coal (Anglo American). The Project is located about 10 km north-west of Jerrys Plains in the Upper Hunter Valley (NSW).

The groundwater assessment is based on field investigations and a regional numerical groundwater model. The groundwater modelling forms an important component of the environmental impact statement 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, and also to quantify the incidental capture of streamflow and alluvial groundwater associated with the Hunter River and Saddlers Creek as required by the NSW Aquifer Interference Policy (AIP). The model also provides an assessment of likely groundwater inflow to the open cut pits as the mine progresses in time.

The scope of work was limited to a peer review of AGE's groundwater report and completed model.

An earlier peer review was undertaken by Heritage Computing Pty Ltd (now trading as HydroSimulations) in March 2013 on the Groundwater Impact Assessment for the previous application and previous mine plan. The NSW Planning Assessment Commission (PAC) refused the previous Project application. Anglo American has now reduced the extent of the previous mine plan to adhere to the setbacks required by the PAC.

2. Documentation

The previous review was based on:

1. *Australasian Groundwater & Environmental Consultants Pty Ltd, 2012, Drayton South Coal Project Groundwater Impact Assessment. October 2012. 138p (Text) + 114p (Figures and Appendices).*

The current review is based on:

2. *Australasian Groundwater & Environmental Consultants Pty Ltd, 2015, Drayton South Coal Project EIS Groundwater Impact Assessment. March 2015. 135p (Text) + 82p (Appendices).*

The Groundwater Assessment for the current application references two intervening AGE reports, namely the groundwater assessments for the Preferred Project Report and Retracted Mine Plan report completed as part of the previous application. As these reports are not directly relevant to the current application they have not been examined by the reviewer.

The Groundwater Assessment has 22 sections:

1. Introduction
2. Project description
3. Objectives and scope of work
4. NSW water regulation
5. Previous hydrogeological studies
6. Regional setting
7. Geology
8. Groundwater monitoring network
9. Hydrogeological regime
10. Conceptual model
11. Groundwater model generation and calibration
12. Predicted impacts during mining
13. Predicted impacts post mining
14. Sensitivity analysis
15. Cumulative impact
16. Drayton Mine voids - tailings and rejects disposal
17. Water allocations
18. Comparison of predictions to minimal impact considerations
19. Groundwater management
20. Comparison of impacts between the previous application mine plan and the current EIS mine plan
21. Conclusion
22. References.

The Appendices to the Groundwater Assessment contain:

A. Monitoring bore construction logs
B. Groundwater level monitoring hydrographs
C. Numerical groundwater model
D. Steady-state calibration heads
E. Transient calibration hydrographs
F. Summary of batch trials results
G. AIP assessment framework

3. Guidelines

The review has been conducted in accordance with the principles of the Australian Groundwater Modelling Guidelines issued by the National Water Commission (NWC) in

June 2012 (Barnett *et al*., 2012[1]) and structured according to the checklists in the Murray Darling Basin Commission Groundwater Flow Modelling Guideline (MDBC, 2001[2]).

In terms of the MDBC 2001 modelling guidelines, the 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 NWC 2012 guide has replaced the model complexity classification by a "model confidence level". The AGE report gives (in Appendix C) a thorough defence of the model's Class 2 classification (the middle category) in terms of data, calibration, prediction and key indicator checkpoints. A Class 2 model would be suitable for "prediction of impacts of proposed developments in medium value aquifers" and for "providing estimates of dewatering requirements for mines and excavations and the associated impacts".

The review checklists are presented in **Table 1** (at the back of this report). The checklists address the following components of a groundwater assessment based primarily on modelling:

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 current review has been based entirely on written reports, with no reference to electronic model files.

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1 Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). Australian Groundwater Modelling Guidelines. Waterlines report 82, National Water Commission, Canberra.

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

4. Discussion

Comments on The Report

A feature of the Groundwater Assessment report [Document #2] is that much of the detail on groundwater responses and groundwater model development and calibration has been shifted to Appendices. Although some useful information no longer appears in the main text, a sufficient summary is presented there to aid readability of the report as a near-standalone document. The main report includes a summary of the model calibration performance and several water balance tabulations for steady state and transient simulations, with particular accounting for baseflows to the major streams.

However, apart from one example of vibrating wire piezometer (VWP) responses [Figure 12], showing an upwards vertical gradient, there is no cause-and-effect analysis of the groundwater hydrographs [in Appendix B] to inform conceptualisation. Comment should have been offered on the hydrographs at bore RBD1 which appears to show a mining response in the Blakefield Seam but not in the Whynot Seam.

Other observations:

1. Comprehensive Executive Summary.
2. Good summary of the Aquifer Interference Policy and minimal harm considerations.
3. Good report structure and high quality graphics.
4. Project objectives are articulated clearly.
5. Although evapotranspiration (ET) is included in the conceptual model [Figure 14], it is not a component of the numerical model. This process would normally be included in the numerical model if there is evidence of depth to water being within a few metres of ground surface anywhere close to the planned mining operations. The reviewer is of the opinion that it is not sufficient to subtract this component from the incident rainfall in adopting a figure for net rainfall recharge.
6. "mAHD" should be used instead of "mRL" [Figure 16; Figure C3; all figures in Appendix E].

Comments on Data Analysis

1. No cause-and-effect analysis of groundwater hydrographs other than for bore RD1221 [Figure 12].
2. Groundwater hydrographs are given in Appendix B, but mostly at uninformative scales.
3. Geology is well known except towards the corners of the model extent outside the Project Boundary (as the mine's geological model is focused on the mining lease area).
4. Substantial previous field investigations undertaken since 1998 and sufficient new work installed and undertaken as part of the original Environmental Assessment (10 standpipe piezometers; 5 vibrating wire piezometer nests with 4-6 piezometers in each).
5. Water level monitoring since 1998. Useful information on vertical hydraulic gradients is apparent but not emphasised, other than one example in Figure 12.
6. A regional groundwater head pattern (and inferred flow direction) is given in Figure 13. The locations of data points controlling the contour pattern should be included on the figure so the reader can infer overall reliability of interpolation and extrapolation.
7. There is no comment on whether Hunter River floods might reach the Project Site. If so, this is another potential source of aquifer replenishment. Ignoring flooding is consistent with a conservative assessment of drawdown impacts.

8. There is no comment on whether Saddlers Creek is prone to flooding, but one instance of a flow of 1,000 ML/day is cited. If so, this is another potential source of aquifer replenishment. Ignoring flooding is consistent with a conservative assessment of drawdown impacts.
9. Groundwater abstraction is not included as a stress on the aquifer system, due to lack of metering and difficulty in access to private records. This is not a critical factor in the assessment.
10. No mention of BoM "actual evapotranspiration".

Comments on Conceptualisation

1. Valid and sufficient.
2. Excellent conceptual model graphic [Figure 14 and Figure C11].
3. The conceptual model graphic Includes ET but there is no ET quantification in the model as it is said to be "simulated by assigning a slightly reduced rate of recharge" [Section C1.2.5.3]. Specific inclusion of ET as a process could allow reductions of ET to be interpreted as impacts on GDEs.

Comments on Model Design

1. Almost entirely in Appendix C. No change has been made to the original EIS model except for storage properties, the mine plan and the final landform.
2. MODFLOW-SURFACT software is appropriate.
3. A van Genuchten model is adopted for variable saturation, as the pseudo-soil function failed; van Genuchten parameters are not reported.
4. Cell size 50m to 500m.
5. 168 rows; 155 columns; 17km x 22km.
6. About 470,000 model cells - a manageable size.
7. 18 layers. 5 separate coal seam layers (thickness is the aggregate of the ply thicknesses). 5 deeper seams combined with overburden to form 5 model layers. The model stratification is appropriate as separate consideration is given to the Whybrow, Redbank Creek, Wambo, Whynot and Blakefield seams. There is a single surficial layer to represent either alluvium or the regolith.
8. Southern boundary limited to the southern extent of the Hunter River Alluvium. Effects might propagate beyond this limit, but modelling results support the original decision.
9. Western boundary marked by Mt Ogilvie fault on assumption of significant throw associated with truncation. However, there is a possibility that the coal seams roll over the fault; in this case drawdowns could propagate farther to the west.
10. As Saddlers Creek is represented as a drain, it can never be a source of recharge in the model. This leads to a conservative estimate of drawdown, which might in fact be offset by occasional replenishment episodes.

Comments on Calibration

1. Primarily steady-state but supported by transient calibration over 17 years without further amendments to hydraulic conductivity, changing storage parameters only.
2. Sufficient evidence for good steady-state calibration in the form of a scattergram, performance statistics, a table of residuals and groundwater head contours.
3. Steady-state performance: 7.6 %RMS; 13 mRMS; 95 calibration targets. The performance has been affected by inclusion of lower-quality data from open holes.

4. Transient performance: 14 %RMS; 18 mRMS. When inconsistent vibrating wire piezometer (VWP) records are excised, performance improves to 5.8 %RMS. It is not unusual for poor matches to VWP measurements. This is more indicative of inherent errors in VWP readings than a deficiency of the model.
5. No residuals map to assess whether there is a spatial bias in the calibration performance.
6. It is unclear whether layers other than layer 1 have spatially variable hydraulic conductivity. Section C2.2 suggests variability in layer 1 only. However, Table C3 has ranges for each layer, but this might be due only to increasing depth.
7. Adopted/calibrated hydraulic and storage properties are generally in accord with field measurements and expectations. However, some Kv values are very low: e.g. 4.6×10^{-9} m/d; 2.6×10^{-10} m/d. The specific yield (Sy) values in the deeper hard rock layers appear to be low (0.001 to 0.05 percent).
8. Storage properties are not well resolved due to lack of significant natural fluctuations in groundwater hydrographs.

Comments on Verification

1. Traditional verification has not been done. This is not an issue as it is not a compulsory step in the modelling process (Barnett *et al*., 2012).

Comments on Prediction

1. Proper procedures have been followed for transient tracking and representation of the mine plan. A time-slice approach has been followed.
2. Usefully, Document #2 compares critical predictions with those in the original EA.
3. The prediction model outputs have been interrogated thoroughly in accordance with the minimal impact considerations of the AIP. Especially for quantification of possible water quality impacts.
4. Pit inflow estimates are less than half for this reduced mine plan.
5. The prediction outputs have been used to partition water takes between different water sources for licensing purposes.
6. A very long recovery simulation (1,000 years) has been conducted.
7. For the final void, the adoption of a unit value is appropriate for specific yield and storage coefficient.
8. The cumulative groundwater level and flux impacts of neighbouring mines have been assessed by discussion of the findings of previous (approved) modelling studies rather than independent simulation. This is a sufficient and sensible approach to the difficult and demanding requirements for cumulative impact assessment.

Comments on Sensitivity Analysis

1. Sensitivity analysis has been conducted for horizontal (Kh) and vertical (Kv) hydraulic conductivity, rainfall recharge fraction, and the two storage properties (Sy, Ss).
2. An appropriate one order of magnitude perturbation has been applied to hydraulic conductivity and specific storage, with a factor of two for other less critical properties.
3. The calibration performance is reported for sensitivity runs in Table 26. This enables the plausibility of model outputs to be assessed and indicates the uncertainty in the impacts predicted for extreme scenarios. As an order of magnitude perturbation in hydraulic conductivity decalibrates the model, by roughly doubling the SRMS

statistic, the associated predictions should be dismissed as indicative of likely limits to predicted impacts.
4. Sensitivity is tested on pit inflow, rock-alluvium flux and drawdown extent.

Comments on Uncertainty Analysis

1. The uncertainty in the model findings is illustrated sufficiently through the outputs of the sensitivity simulations. The impacts for extreme scenarios are indicative only and are not considered reliable in all cases as the model has been decalibrated for some property perturbations.
2. It is agreed that a conservative approach has been adopted in the case of uncertain assumptions.

Additional Comments

1. Figure 7 (detailed stratigraphy) should be given a vertical elevation scale.
2. Page 94, Paragraph 4 is ambiguous. It is not clear whether 555 mg/L is the average salinity or 1% of the average salinity.
3. In Appendix E, the water levels for VWP nests should be illustrated on the one graph to show comparison of actual and simulated hydraulic gradients.

5. Conclusion

Although model calibration performance statistics are acceptable (when excluding often inconsistent VWP records), many of the hydrographs do not match well. None of the field hydrographs appear to have demonstrable climate or mining effects, but the scale of graphical presentation makes assessment difficult.

The impacts of importance are stipulated in the Aquifer Interference Policy, especially drawdown impacts on groundwater dependent ecosystems and private bores, water quality departures from beneficial use, and salinity increases in nearby reliable surface watercourses. In addition, the volumetric takes of water are to be determined (and partitioned where necessary) for licensing purposes.

The groundwater assessment includes three tables (Tables 31, 32, 33) that address the minimal harm considerations for Saddlers Creek alluvium, Hunter River alluvium and Permian coal measures. Each consideration is addressed in full. This reviewer concurs with the finding that no Level 2 impacts have been identified, apart from a possible shift from "marginally saline" to "saline" for groundwater in the Permian coal measures far into the future when there might be an increase in salinity from final void leakage. It is noted that the Aquifer Interference Policy includes no formal definition of beneficial use categories.

It is the reviewer's opinion that all objectives have been met satisfactorily. The stated project objectives have been addressed in full in terms of the requirements of the Aquifer Interference Policy. There has been a thorough examination of the pertinent outputs and uncertainties of the modelling simulations. In particular, a thorough quantification of water salinity impacts has been made.

Furthermore, it is the reviewer's opinion that the Drayton South Groundwater Model has been developed competently and is “fit for purpose” for addressing the potential environmental impacts from the proposed open cut mining operations and for estimating indicative dewatering rates.

Yours sincerely,

Dr Noel Merrick

Table 1. MODEL APPRAISAL: **DRAYTON SOUTH**

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
1.0	THE REPORT								Good Executive Summary and very good AI Policy summary.
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	Adequate	Very Good			
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	Yes				Impact Assessment Model, medium complexity. Class 2 confidence.
1.3	Is a water or mass balance reported?		Missing	Deficient	Adequate	Very Good			Steady-state and transient calibration water budgets. Prediction : inflow and river-aquifer components..
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	Very Good			
1.5	Are the model results of any practical use?			No	Maybe	Yes			All objectives are addressed satisfactorily.
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	Very Good			Substantial history plus new work. Geology well known except at model corners.
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	Adequate	Very Good			Interpolated contours are shown in Figure 13. Source data points should be posted.
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	Adequate	Very Good			Lack of stream gauge information. Estimated stages from DEM. No consideration of flooding as potential recharge source (conservative approach).
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	Adequate	Very Good			Groundwater abstraction is not included but should be minor. Could refer to BoM "actual ET". Main streams are included.

2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	Very Good			Minimal cause-and-effect analysis in main report. One VWP example illustrates upwards vertical gradient. Hydrographs compared with residual mass in Appendix B without comment but plot scales are too broad to show responses to climate. No obvious pumping effects (not stated). One possible mining effect (at RBD1) but not discussed.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	Yes			76 hydrographs. Sy and Ss varied manually; retained steady-state K values.
2.7	Have consistent data units and standard geometrical datums been used?			No	Yes				mRL used on many figures instead of mAHD.
3.0	CONCEPTUALISATION								ET is in the conceptual model but not included in the numerical model as a separate process. Reduced recharge surrogate.
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			Detailed flux pairs identified.
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	Adequate	Very Good			Figure 14 and Figure C11in Appendix C.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	No				
4.0	MODEL DESIGN								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	Yes			Limited southern extent to far side of Hunter River alluvium. Limited western extent to fault line. Full model grid is shown with geology underlay to define BCs (Figure 15). No change in extent from original EIS model.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	Adequate	Very Good			Appear to be no-flow cells on boundaries. No GHB control. No change from original EIS model.

4.3	Is the software appropriate for the objectives of the study?			No	Maybe	Yes			Modflow SURFACT & PMWIN & custom code. Van Genuchten has been used for variable saturation, but parameters are not stated. Pseudo-soil was attempted but failed.

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
5.0	CALIBRATION								
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			Scattergram for 95 target water levels (median = steady-state). Table of observed, simulated and residual water levels.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Head contours. No spatial residual map to see where calibration is good or bad.
5.3	Is the model sufficiently calibrated against temporal observations?	N/A	Missing	Deficient	Adequate	Very Good			Done using steady-state K and manual adjustment of Sy and Ss on 76 hydrographs.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Some uniform, some distributed (PEST analysis). Min, max & median given. Spatial distributions are disclosed. Ss & Sy are not well resolved due to lack of natural variation. %Rain OK.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Steady-state 7.6 %RMS , 13 mRMS. Transient 14 %RMS, 18 mRMS; 5.8 %RMS excluding VWPs.
5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good			VWP trends are inconsistent with nearby standpipes.
6.0	VERIFICATION								
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			Insufficient data . This is not a compulsory step (Barnett et al., 2012).
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								
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	Very Good			Average conditions. No climate change scenario but rain recharge sensitivity analysis could serve the same purpose.
7.2	Have multiple scenarios been run for operational /management alternatives?	N/A	Missing	Deficient	Adequate	Very Good			One mine plan. Final void. Recovery for 1000 years. No integrated modelling of cumulative impacts but results borrowed from two previous models. Three tailings/rejects scenarios.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	No	Maybe	Yes			27 years projected from steady-state calibration. Transient calibration for 17 years (1998-2014).
7.4	Are the model predictions plausible?			No	Maybe	Yes			Consistent with earlier modelling and experience with neighbouring mines. Peak pit inflow much lower with revised mine plan than before. Spoil Sy now 0.2.
8.0	SENSITIVITY ANALYSIS								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	Very Good			Done for Kh, Kv, recharge%, Sy, Ss.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	Very Good			Baseline SRMS doubled for order of magnitude change to K. Extreme results are for a decalibrated model, and should be rejected. Smaller perturbation should be explored to find where model ceases to be calibrated, to give likely uncertainty range for predictions.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	Adequate	Very Good			For pit inflow, drawdown extent and rock-alluvium fluxes.
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	Yes			Conservative approach. Also sensitivity analysis for impacts.
	TOTAL SCORE								PERFORMANCE: %