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23/01/2015

Att. L. Briggs AO, J. Woodward PSM, J. Murrell

Re: Proposed Watermark Coal Mine – Review of Shenua Coal Response to PAC Assessment

I have conducted a further review of reported groundwater impacts associated with the Shenhua Watermark Project. This review is subsequent to my report dated 14/08/2014 (MER, 2014a) and specifically addresses the response provided by the proponent Shenhua Watermark Coal P/L (SWC) to the PAC report dated August 2014.

In summary, my earlier report identified a number of serious concerns relating to groundwater modelling undertaken by Australian Groundwater and Environmental consultants (AGE) on behalf of SWC for the Environmental Impact Statement. Those concerns were based upon a detailed inspection of the data files underpinning the model wherein AGE adopted a model design that included the vadose zone[1] with parameterisation based entirely on conjecture. In addition, the model domain was considered to be poorly discretised for vadose zone simulations while the representation of open cut mining operations employed an unconventional use of 'drain' type boundary conditions[2]. Other concerns were associated with the incorrect methodology for determining the elevation of the water table from model output data, and unexplained erratic behaviour of calculated pit seepage rates.

Consequently I was unable to accept the reported model outcomes in the EIS as either accurate or meaningful. A number of additional groundwater models were recommended in the hope that AGE might resolve the various issues and uncertainties that I had identified.

A response to my review was submitted by the proponent to the Department of Planning and Environment (DPE) in October 2014[3]. My assessment of that response is as follows.

1. Overview of AGE response to the PAC assessment

The response provides discussion of fourteen model simulations (identified as scenarios 0 to 13) including the four additional simulations requested in my previous report. There are two more scenarios identified as scenarios 14 and 15 that are only discussed in AGE 2014c but are represented for completeness. The various models are summarised in Table 1 below which is based upon Table 1 in AGE 2014b[3]. For simplicity I have employed descriptors generally in line with my previous report rather than adopting the AGE descriptors. Here I identify the following:

1. **Simulation type** defines whether the Surfact groundwater model code has been run as a ***vadose zone*** model or as a ***pseudo soil*** model. The pseudo soil option requires four parameters associated with the flow system material properties to be prescribed . These are the horizontal and vertical hydraulic conductivities (Kh, Kv), the elastic storage (Ss) and the specific yield or drainable porosity (Sy). These parameters were assessed by field and laboratory testing as part of the Watermark EIS groundwater studies. Vadose zone modelling requires prescription of a further three parameters – the air entry (α), desaturation rate (β) and residual saturation (Rs).

[1] The vadose zone is the unsaturated zone above the water table
[2] a boundary condition is a mathematical assignment that constrains the groundwater flow system
[3] Appendix A of Hansen Bailey, 2014

MER 2014a highlighted both an absence of any measured values for the above noted three parameters and the assignment of the same three parameter values to all layers in the model, as underpinning highly questionable model outcomes[4]. In the proponent's response, AGE[5] notes that '*the drain boundary condition is the dominant influence on the simulated water levels, not the unsaturated zone parameters*'. The flawed nature of this statement was clearly demonstrated by simple vertical section modelling provided in my previous report[6] where significantly different water table elevations resulted from different values of the air entry parameter (α). AGE[7] also notes that the vadose zone option was employed '*due to its ability to aid model convergence*' to a solution while the '*selection of uniform saturated zone properties was based primarily on model stability*'[8]. These statements reflect a somewhat naive understanding of groundwater numerical modelling and the process by which a model solution is derived – solution accuracy should not be compromised for a desire to expedite the process.

Inclusion of the vadose zone in the EIS groundwater model (and subsequent models) using a suite of parameters having no factual basis has in my view, resulted in meaningless model outcomes.

2. **Drain control** defines whether the reference elevation for this boundary condition has been assigned in an ***unconventional*** manner and has been set below the base of the drain cell[9], or whether the reference elevation has been assigned in a ***conventional*** manner within a drain cell. Results of simulations requested in MER 2014a and conducted by AGE[10] clearly demonstrate the fallacy of setting the reference elevation below the base of a drain cell as was done in the EIS model – model outcomes are profoundly different.

   AGE notes that unconventional assignment is a procedure normally adopted in their modelling process '*to introduce conservatism to model predictions*'[11]. This stated strategy of conservatism was not mentioned in the EIS and no reference material can be found in support of the use of unconventional reference elevations for a mine pit or any other type of simulation. I therefore regard the so-called conservatism intent as lacking any scientific integrity and the EIS (and subsequent) model results that are based upon improper assignment of drain controls, as meaningless.

3. **Spoils recharge** has either been included during simulation of the active mining phase (**recharge**) in each of the mine pits (see Figure 1 for pit locations) or excluded from the model (**no recharge**). In order to simplify my initial review of groundwater impacts (MER,2014a), I requested a model simulation where spoils recharge was excluded from the model and drain cells in all pits remained active over the entire mine life (the WST model – Scenario 3). This simply means that each pit is simulated as free draining without allowing a rise in the spoils water table above the excavated pit floor. Adopting a sustained free draining simulation is considered to be a plausible worst case scenario.

   By including rainfall recharge during the active mining phase (EIS model), there are complex water exchanges between model cells resulting in pit groundwater levels that recover during the first months following respective pit closures at rates that are questionable and unsupported by observations elsewhere. For example, AGE[12] predicts a recovery rate of 29m in just 84 days. Such a rapid rate of recovery in a mine pit from rainfall recharge has the potential to mitigate drawdown impacts regionally.

4. **Assessment worth** defines whether the model scenario provides an outcome that is considered to be meaningful in predicting the likely future impacts of mining on the regional groundwater systems. Basically any model that simulates the vadose zone or is based upon unconventional

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[4] see MER 2014a pages 3 and 4
[5] see the answer to Question 3, page 2 of AGE 2014a
[6] see Mer 2014a Figures 3 and 4
[7] see AGE 2014b, page 1
[8] see AGE 2014b, page 19.
[9] see MER 2014a page 5 and Figure 5
[10] see AGE 2014b Section 2.1.2
[11] see AGE 2014b Section 3. para 1
[12] see the answer to Question 6, page 8 of AGE 2014a

drain controls is considered to be flawed and therefore meaningless. Consequently scenario 3 and its variants (scenarios 6, 7 and 11) are considered to be the only models that contribute in a meaningful way to the assessment of groundwater related impacts for the Watermark project.

Overview by Kalf and Associates

In October 2014, Dr Kalf from Kalf and Associates (KA) undertook a review of the additional modelling carried out by the proponent (AGE 2014b). Dr Kalf also considered my earlier report to the PAC (MER 2014b) and sought clarification of my findings in relation to the EIS model.

Dr Kalf found that the reported model outcomes were highly questionable, especially in view of the discretisation of the model domain and the selection of the air entry parameter (α). His independent assessments led him to the view that the EIS modelling held little validity and that the pseudo soil option is the preferred approach.

Dr Kalf found that the only models offering a meaningful outcome for impact assessment purposes were scenarios 3, 6, 7 and 11. Scenario 3 was considered to be useful in establishing an upper limit for drawdown while scenarios 6 and 7 explored model sensitivities.

Table 1: Summary of groundwater models

Scenario	Simulation type	Drain control	Spoils recharge	Assessment worth
0	vadose zone	unconventional	no recharge	meaningless
1	vadose zone	conventional	no recharge	meaningless
2	pseudo soil	unconventional	no recharge	meaningless
3	pseudo soil	conventional	no recharge	meaningful
4	vadose zone	n/a	recharge	meaningless
5	pseudo soil	n/a	recharge	meaningful simulation of recovery
6	pseudo soil	conventional	no recharge	meaningful simulation - faults removed
7	pseudo soil	conventional	no recharge	meaningful simulation – increased storage
8	vadose zone	unconventional	no recharge	meaningless
9	vadose zone	conventional	no recharge	meaningless
10	vadose zone	conventional	recharge	meaningless
11	pseudo soil	conventional	recharge	meaningful simulation ? (optimistic recharge)
12*	vadose zone	unconventional	recharge	meaningless
13*	vadose zone	conventional	recharge	meaningless
14**	vadose zone	conventional	recharge	meaningless - faults removed
15**	vadose zone	conventional	recharge	meaningless - conductive faults

* Model variants developed to address UNSW submission, **Models only discussed in AGE 2014c

Review of likely drawdown impacts

The Eastern Pit will be mined down to an elevation of about 225 mRL. Since the nearest alluvial lands to this pit host a water table at an elevation of about 265 mRL, the mine pit will generate a groundwater sink with a maximum head difference of about 40 m. Southern Pit will be mined down to an elevation of 195 mRL. The alluvial lands to the south of this pit host a water table at an elevation of about 290 mRL resulting in a groundwater sink with head difference of about 95 m. Western Pit will be mined down to an elevation of about 245 m resulting in a groundwater sink with only a small head difference with respect to the alluvial lands. Southern pit is considered to be the pit most likely to induce the highest drawdowns in the alluvial systems.

The groundwater modelling reported in the EIS and subsequent modelling undertaken by the proponent reflects a distorted understanding of the modelling process. The inclusion of the vadose zone as a means of accelerating solution times, the absence of measured vadose zone properties, the failure to correctly determine the water table surface in vadose zone simulations, and the improper use of drain boundary conditions to simulate mining, have all contributed to meaningless outcomes. As indicated in Table 1, meaningful outcomes are only associated with models based upon the pseudo soil option. These include scenario 3 and its variants (scenarios 6, 7 and 11).

Scenario 3 simulates mining operations at the three pits with free draining spoils until the cessation of mining in the Western pit at year 30 (see Figure 1 for proposed mining areas). This free draining condition means that the Eastern pit remains dewatered within the model for about 13 years after cessation of operations in that pit (recovery is inhibited) while Southern pit remains dewatered for about 6 years after cessation of operations in that pit. As noted above, a maximum impact regime could reasonably be associated with this scenario.

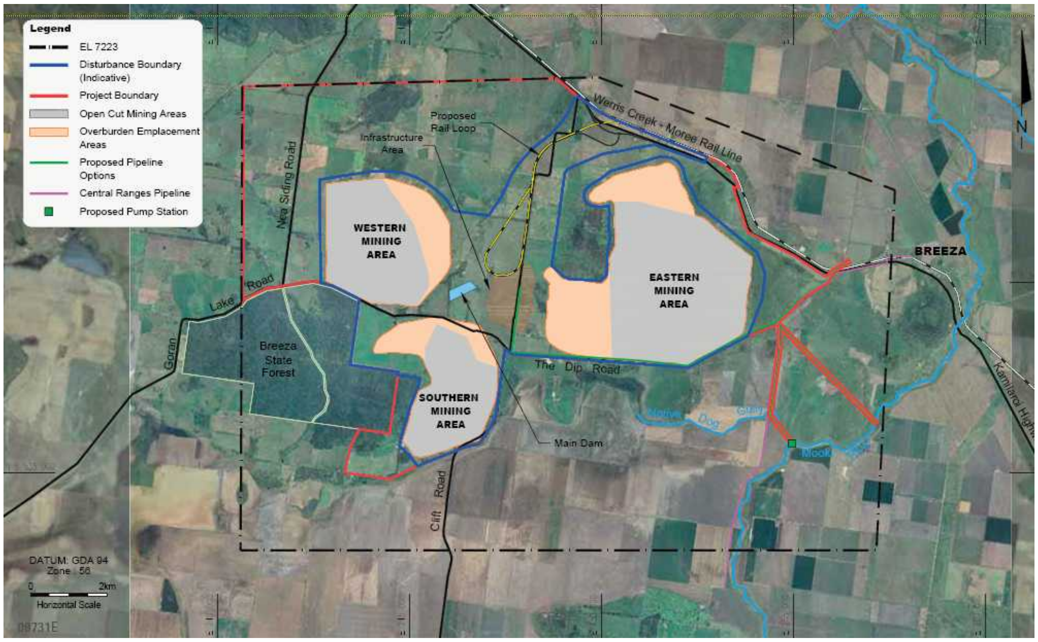

Figure 1: Project area and pit locations (from EIS Figure 9)

The modelled drawdown of the water table after 30 years for scenario 3 is shown on Figure 2[13]. Drawdown impacts surrounding Eastern pit are generally minimal due to:

- the elevated terrain on which the pit is situated;
- the generally poor water transmitting properties of the rock mass (Permian coal measures);
- and the small penetration of the water table at the deepest part of the pit relative to water table elevations in the alluvial lands (about 40 m).

Drawdown surrounding Southern pit is more extensive with the 1.0 m contour migrating approximately 1.5 km southward from the pit crest. Drawdown of 0.5 m is predicted to extend to the nearest private pumping bore (GW015505) about 2 km from the pit crest as indicated by the red dot[14]on Figure 2. Drawdown associated with Western pit is relatively minor due to shallower mining below the water table.

Scenario 3 includes numerous faults that transect the project area and apparently compartmentalise the groundwater flow system[15]. Scenario 6 is a variant of scenario 3 which removes the faults and their compartmentalising effect, from the model. The modelled drawdown of the water table after 30 years for scenario 6 is shown on Figure 3 where impacts to the east of Eastern pit remain minimal while drawdowns to the south of Southern pit are slightly more expansive than scenario 3.

In assessing the veracity of these drawdown predictions it is important to understand the key factors that govern the drawdown impacts. These are the hydraulic conductivities and storage parameters prescribed throughout the model, together with the net recharge to the flow system.

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[13] Originally supplied in AGE 2014b as Figure 2.15. However that figure only represented 27.6 years due to solver problems encountered by AGE. An updated plot for 30 years was supplied on request.
[14] See Table 2.9 in AGE 2014b
[15] see Section 8.4.7 in AGE 2014a and Section 3.3.2 in AGE 2014c

Extensive field testing including pumping, slug, recovery and packer tests, has been undertaken by the proponent to establish the range in hydraulic properties associated with the different lithologies. Laboratory tests on selected core samples have also been conducted to establish rock matrix hydraulic conductivities and bulk porosities. Assignment of representative properties throughout the flow model is addressed in the EIS. Inspection of model data files suggests properties are generally consistent with previous studies in the region and with findings from the field testing programme.

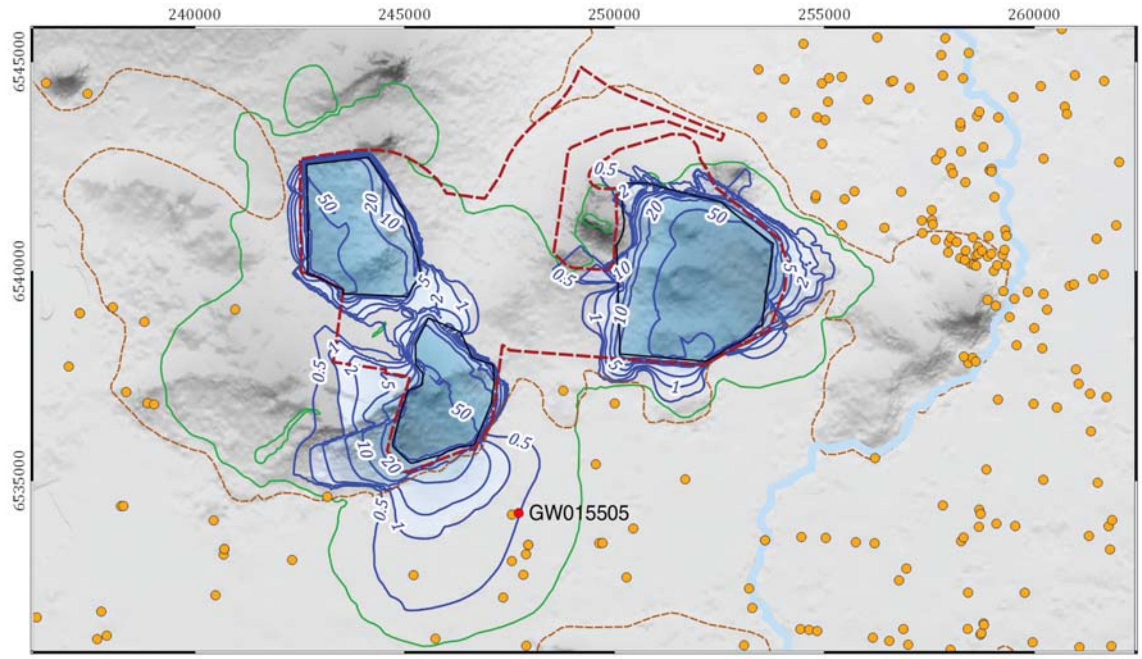

Figure 2: Assessed drawdown for Scenario 3 (from AGE 2014b Figure 2.15)

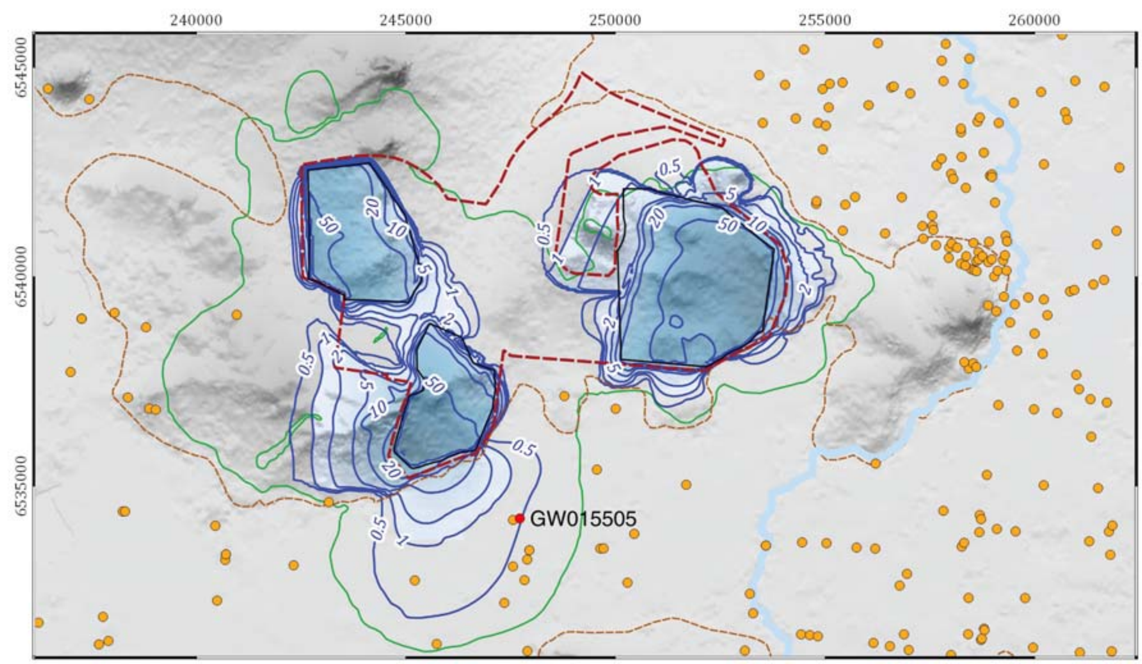

Figure 3: Assessed drawdown for Scenario 6 - faults removed from the model

Calibration of the pseudo soil model has been conducted for pre-mining conditions and is reported to generate 3% (SRMS) error[16]. It is based upon water table monitoring in the unconsolidated Narrabri and Gunnedah Formations which have been routinely stressed by irrigation pumping and rainfall recharge. Fundamentally, the calibration process has involved adjustment of hydraulic properties and rainfall and river recharge until the model was able to simulate the measured water table elevations with an acceptably low error margin. However it is important to note that the Permian hardrock systems have only been weakly stressed (no irrigation pumping). Accordingly the hydraulic properties of these systems could be varied in some parts of the model over a reasonably wide range without significant change in the calculated (pre-mining) water table or the correlation error. The correctness of the hardrock parameterisation can only be determined when the hardrock systems are significantly stressed by development of an open cut pit below the water table and the model is re-calibrated.

Pit seepage

Pit influx estimates derived from computer modelling using drain type boundary conditions assume that groundwater is instantly released from porous matrix storage in the (blast fragmented) rock and directly contributes to the pit water make. This is generally not the case for low conductivity Permian strata. Instead the stored groundwater slowly drains from the fragment matrix with significant losses attributed to evaporation.

Estimates of pit influx attributed to groundwater seepage for scenario 3 are below 0.4 ML/day over the life of the mine[17] with the first 20 years below 0.2 ML/day. Actual influx is likely to be much lower if evaporative losses from the waste rock are considered. A reduced estimate of groundwater seepage may have impact on the site water balance. However this is unlikely to significantly affect operations since the proponent proposes to make up shortfalls through external sources under appropriate Water Access Licences and within relevant Water Sharing Plan constraints[18].

Pit closures

Further assessment of pit closures has been undertaken by the proponent with a steady state recovery simulation being generated using the pseudo soil option (Table 1 - recovery scenario 5). Results indicate a long term outcome with elevated water tables (above pre-mining levels) in Eastern and Southern pits, and a depressed water table and pit lake in Western pit.

Emplaced spoils in all pits will generate a leachate from rainfall infiltration/percolation and saturation as the water table rebounds. Geochemical impacts associated with re-wetting (and oxidation) appear to be low with overburden-interburden spoils and coal rejects expected to be non acid forming and exhibiting low sulphur content and excess acid neutralising capacity[19]. Both runoff and seepage infiltration through spoils are predicted to exhibit neutral to weakly alkaline pH with moderate salinity.

An initial runoff-leachate salinity has been estimated at 5000 mg/L reducing in the longer term as the more soluble salts are flushed from the system. The equivalent salt load released into the landscape from Eastern and Southern pits post mining has been estimated at 1.0 and 5.6 kg/Ha/day respectively. The relatively low load for Eastern pit is expected to have '*low and insignificant impact on the surrounding environment'*[20]. It is important to note that progressive reshaping and rehabilitation of the Eastern pit during the first 17 years of mining will permit comprehensive monitoring of runoff salinity and retention of early high salinity flushes within the mine water system if required. Monitoring data will also facilitate more accurate estimates of long term salinity with more focused management of runoff. The predicted higher salt load for runoff from Southern pit may ultimately require longer term management.

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[16] see AGE 2014b Figure 2.14, page 20. SRMS=Scaled Root Mean Squared error
[17] see AGE 2014b Figure 2.17, page 24.
[18] See WRM 2013, page 41 in Appendix S of Hansen Bailey, 2014
[19] Appendix W of Hansen Bailey, 2014
[20] Appendix T of Hansen Bailey, 2014 Section 10.12.2 page 276

Conclusions

After consideration of the additional modelling and the responses to questions put to the proponent in respect of certain attributes of these models, I believe the maximum drawdowns in the water table during and at the completion of mining are best represented by scenario 3 (see Figure 2). Close inspection of these drawdowns shows the impacts are modest in areas close to the mine pits and diminish with increasing distance from the pit crests. A maximum drawdown of 2 m permitted by the Aquifer Interference Policy does not encroach upon any private water supply borehole; drawdown of 0.5 m is likely to extend southward to the nearest private pumping bore (GW015505) about 2 km from the pit crest. These relatively low drawdown impacts are considered to be acceptable and manageable.

As with any greenfield site, it is important to ensure that a comprehensive groundwater monitoring system is in place prior to any penetration of the water table. Since Eastern pit is scheduled as the first active pit, there will be a reasonably long period of time in which the water table movements and pore pressures can be monitored. Such monitoring must include vertical arrays of pressure sensors installed in boreholes that are located at varying distances from the pit crests to facilitate accurate vertical profiling of the water table and pore pressures. This will enable the ‘bulk’ hydraulic properties of the Permian strata to be assessed and provide a means of validating model predictions.

In view of the many issues associated with the EIS model, I strongly recommend that vadose zone modelling be discarded in favour of the pseudo soil approach and that recalibration of the groundwater model be undertaken at intervals not exceeding three years. A future model should be significantly reduced in area and the vertical discretisation increased by introducing additional layers. Peer review should be conducted by a suitably qualified person.

I also recommend the modelled drawdowns generated by scenario 3, underpin any trigger-action-response plan. Re-assessment of impacts associated with the proposed Southern pit, should be undertaken at least 5 years prior to entry at that pit. If model re-calibration indicates the potential for adverse impacts at this time, then pit design may need to consider reduced penetration of the water table.

Yours sincerely

Mackie Environmental Research Pty. Ltd.

C. Mackie

(Attachment 1)

References:

AGE, 2014a. Letter addressed to Shenhua Australia, dated 22/07/14, and provided to the PAC as the response to questions raised by Mackie Environmental Research.

AGE, 2014b. Appendix A in Hansen Bailey 2014. Response to Planning Assessment Commission Review Report. Prepared for Shenhua Watermark P/L, October 2014.

AGE 2014c. Watermark Project. Response to submission from University of New South Wales.

Hansen Bailey 2014. Response to Planning Assessment Commission Review Report. Prepared for Shenhua Watermark P/L, October 2014.

Kalf and Associates Pty. Ltd., Shenhua Watermark Coal Project – Adequacy review of groundwater assessment Stage 1. Prepared for Dept. of Planning and Infrastructure, December 2012

Mackie Environmental Research (MER) 2014a. Proposed Watermark Coal Project – Environmental Impact Assessment. Report prepared for Planning Assessment Commission, (letter and attachments dated 14/08/2014).

Mining and Petroleum Gateway Panel – Shenhua Watermark Coal Project Advisory Report

NSW Planning and Environment – State Significant Development Assessment Watermark Coal Project (SSD-4975), May 2014

NSW Planning and Environment – Addendum: State Significant Development Assessment Watermark Coal Project (SSD-4975), November 2014

Planning Assessment Commission (PAC) 2014. Watermark Coal Project Review Report, August 2014

Watermark Coal Project – Environmental Impact Statement, February 2013 (main volume) authored by Hansen Bailey P/L;

Watermark Coal Project – Environmental Impact Statement (Appendix S) Surface Water Impact Assessment, February 2013 authored by WRM Water and Environment P/L;

Watermark Coal Project – Environmental Impact Statement (Appendix T) Groundwater Impact Assessment, January 2013 authored by Australian Groundwater and Environmental Consultants P/L;

Watermark Coal Project – Environmental Impact Statement (Appendix W) Geochemical Assessment of Overburden/Interburden and Coal Rejects Materials, February 2013 authored by RGS Environmental P/L;

ATTACHMENT 1

Questions arising from the review of Appendix A in Response to Planning Assessment Commission Review Report. Prepared for Shenhua Watermark P/L, October 2014:

Comment 1: EIS modelling adopted the unorthodox method of setting drain elevations to the base of the pit (model layer 10) rather than the base of respective cells. AGE notes that this procedure was intentionally employed in order to 'introduce conservatism to modelling predictions, and to aid model stability for the recovery'.

Question 1: Can AGE provide reference material (journals, texts etc.) that supports the correctness of this methodology and the stated conservatism?

AGE Answer: There are many ways to represent the process of mining within a numerical model. The approach adopted for the project was based on our experience, not any literature or texts. The approach adopted lowered the reference elevation within each layer within the pit, conservatively increasing the hydraulic gradient and drawdown around the pit. The additional scenarios conducted for the PAC have shown the EIS approach was conservative, and is considered appropriate given the productive groundwater regime within the region.

At the end of mining the approach to setting the reference elevation at the base of the pit was adopted to ensure the head in each layer within the void was below Layer 10. Using the alternative approach where the reference elevation is set at the base of each layer, we were concerned that higher heads could occur within void at the end of mining, (as shown in Figure 2-3). This head does not represent a water table, or a potentiometric surface as it is below the base of the layer, and therefore when using the van Genuchten approach more represents the matric suction. The EIS model represented the open void with a high hydraulic conductivity and storage. The EIS approach was adopted to minimise the potential for layers with matric suction heads above the floor of the pit to become artificially saturated, or 'create water' where the 'matric suction surface' was above the base of the underlying layer.

Comment 2: Contrary to the reported specific yield value of 0.1 (10%) applied to spoils emplacements (see Table 2.2 in AGE 2014a and Table 10.1 in EIS), inspection of supplied data files indicates a value of 0.05 (5%) or half the stated value.

Question 2: Should the value in the data files be 0.1 as reported or should it be 0.05? If the latter is correct, why was this value selected?

AGE Answer: There is an error in the EIS report (Table 10.1), which has been transferred into table 2.2 of the PAC report. All models have used a specific yield value of 0.05 (5%) for the spoil. The project is a 'truck and shovel' not a dragline operation, which is expected to result in more compaction of the spoils during mining, which is why this value was adopted.

Comment 3: Figure 2.3 in AGE 2014b shows potentiometric heads associated with the unorthodox use of drain cell reference elevations (blue lines describing layer 2 and layer 10). It is stated that 'Clearly, groundwater drawdown impacts using drain cell reference elevations to the base of the pit floor (layer 10) results in conservative predictions as the potentiometric heads are dragged below the base of each layer in the cells surrounding the pit'.

Question 3: Do these 'potentiometric' head profiles on Figure 2.3 represent the water table?

AGE Answer: No, the heads in layer 2 represent the 'matric suction surface' as described above as the groundwater surface is below the base of the layer. The potentiometric surface of layer 10 is more representative of the true water table.

Comment 4: Figure 2.15 shows drawdowns for Scenarios 3 and 11 (Table 1 in AGE 2014a). Drawdown in the Western pit for Scenario 11 extends westward a greater distance than for Scenario 3.

Question 4: Are the two plots (Scenarios 3 and 11) generated for the same mining year. If so, what is the reason for the increased impact shown on Scenario 11 for the Western pit compared to Scenario 3. If not, can the proponent please supply the correct plot(s).

AGE Answer: This is due to the convergence issues which caused the model to fail to reach a solution at stress period 112 (as described in Table 2-7). In our email (dated 17/12/2014) outlining the details of the model files we noted we have since been able to make the model run for the additional 7 stress periods required to reach the western margin of the west pit, but this has negligible change to the impacts.