Mackie Environmental Research Pty. Ltd.
ABN 62077235164

4 Ross Place
Wahroonga NSW 2076

Telephone: **(02) 94875061**
Facsimile: **(02) 94896809**

Department of Planning
GPO Box 39.
Sydney 2001

14/08/2007

Att. M. Moore

Dear Michael

Re: Moolarben Coal Project - Groundwater assessments

Further to your instructions, we have reviewed additional material supplied by Moolarben Coal Project (MCP) to the Department of Planning (DoP) in relation to groundwater studies. The material comprises two reports referenced below as PDA 2007a and PDA 2007b. These reports provide data, numerical modelling and further consideration of groundwater related impacts in respect of proposed underground mining at Moolarben.

1. Background information

MCP lodged an Environmental Assessment report (EA) with DoP in September 2006 in respect of a proposal for open cut and underground coal mining near Ulan. In that same month, an Independent Hearing and Assessment Panel (IHAP) was constituted by the Director General to assess subsidence, groundwater and noise related impacts. As part of that process, and following rigorous review and interactions with the proponent, a number of significant concerns were raised by the IHAP in respect of groundwater. Subsequently, MCP met with the IHAP and DoP to more fully comprehend the nature of those concerns which are outlined below. MCP then prepared a Preferred Project Report (PPR) for consideration by DoP. That report together with the EA provided the 'data set' for the IHAP report which was submitted to the Director General, in February 2007. Concerns and findings in relation to groundwater were summarised as follows.

IHAP Concerns:

- loss of water supply from springs and bores located throughout the region;
- leakage and flow losses from the Goulburn River and tributary systems, resulting from sustained depressurisation of underlying strata;
- depressurisation/dewatering of the Triassic aquifer systems that host The Drip and other groundwater dependent ecosystems.

IHAP Findings:

- the IHAP determined that there is a potential for measurable depressurisation of groundwater systems within the Triassic aquifers overlying the proposed UG4 underground mine area. The extent to which this is likely to occur had not been adequately demonstrated by numerical modelling of the aquifers;
- the IHAP lacked confidence in the computer numerical models used to predict impacts. The validity of those predictions depended on how well the models approximated field conditions. The Panel noted that field conditions appeared to be poorly represented with respect to a number of model design elements;
- the IHAP was unable to comprehend with sufficient certainty, the magnitude and extent of impacts likely to prevail upon aquifer systems as a result of longwall mining operations. Consequently the Panel had serious reservations concerning the development of an underground

mine until such time as impacts were predicted with increased certainty and were found to be acceptable;

- In respect of open cut mining, the Panel considered the impacts on aquifer systems were likely to be limited in magnitude and extent. The Panel did not identify any major groundwater related impediment to open cut mining.

In summary, the main concerns were identified as (1) poor characterisation of the Triassic aquifer system which hosts the Goulburn River and The Drip in areas adjacent to and just north of proposed longwall operations, and (2) aquifer numerical modelling that inadequately translated the mining process into a computer based representation for impact assessments. These factors combined to realize significant uncertainties in the assessment of impacts.

2. Review of additional material provided by MCP subsequent to the IHAP

PDA 2007a was submitted to DoP in April 2007. That report summarises previous information submitted to the IHAP in respect of the Triassic aquifer systems (with some additional data), and presents results of an amended groundwater model identified as model MC1.6.

2.1 Triassic aquifer systems

The Triassic sediments are eroded and absent in the southern parts of the proposed Moolarben underground UG4 area but are present in the central and northern parts of the area. The sediments dip to the north-east at a shallow angle and as a result, they exhibit a gradual increase in thickness in that direction with the lower part of the sediments dipping below the regional water table. The underlying Permian strata exhibit a thickness of about 90 to 100m above the target Ulan coal seam. These strata also dip to the north-east below the regional water table. Any dewatering impacts within the Permian strata that are induced by mining, could affect the overlying Triassic strata.

Hydrogeologic characterisation of an aquifer system is especially important if calculations relating to groundwater storage and flow are to be undertaken. In this regard there are 3 fundamental properties of the strata that need to be determined – the hydraulic conductivity (or permeability), the compressible storage, and the drainable porosity. The method of determination typically includes borehole testing and core testing. The properties of strata can also be inferred through observation of water level movements in boreholes but this methodology is subject to some uncertainty.

PDA undertook testing of numerous boreholes in Permian sediments throughout the area and reported findings in the EA (MCP 2006a). Very limited information was provided in the EA in respect of the Triassic sediments. Some additional testing was subsequently undertaken at 3 piezometers installed in the Lower Triassic strata, and findings were reported in the PPR (MCP 2006b).

Since the IHAP report, only a small amount of new information has been advanced. New information relates to core inspections and limited core testing of Triassic strata which is reported in PDA2007a. Importantly, the core testing supports the likelihood of very low intergranular hydraulic conductivity in the vertical direction. No new measurements relating to compressible storage or drainable porosity have been provided.

2.2 Re-modelling of impacts

There are significant differences between impact modelling presented in the EA and PPR, and recent modelling efforts presented in PDA 2007a and 2007b.

Impact modelling presented in the EA utilised a code known as Modflow to represent underground longwall mining. Modelling in the PPR utilised a variation of that code known as Modflow Surfact which is more amenable to simulations of underground mining but is cumbersome for sequential panel extraction simulations where hydraulic properties within a subsidence regime, are changed. In both the EA and the PPR, the modelling effort reflected a poor translation of longwall mining into a computer based simulation. In particular, the failure regime that commonly occurs above extracted longwall panels was limited to about 20% of the height of 122 m predicted by MCP subsidence consultants in the PPR, and hydraulic properties of goaf were changed in a manner that artificially introduced substantial volumes of groundwater into the model(s). These and other shortcomings acted to dilute the potential impacts of mining on shallower groundwater systems and led the IHAP to conclude that uncertainties within the models were sufficiently great, that model predicted outcomes could be unrealistic.

2.2.1 New model MC1.6

PDA 2007a presents an amended model identified as model MC1.6 that employs the Modflow Surfact code. Additional model layers have been included to improve representation of the subsidence regime, panel layouts have been amended, hydraulic properties have been applied to a greater height above extracted panels, and more localised assessment of leakage interactions with the Goulburn River have been provided. .

Calibration of the MC1.6 model against Ulan Coal Mines Limited (UCML) historical mine water influx and strata depressurisation, has been conducted. This has resulted in changes to vertical conductivity, horizontal conductivity, and compressible storage of certain strata when compared to earlier models. The fact that the MC1.6 model has been 'calibrated' to arrive at similar outcomes to models previously presented in the EA and PPR, perhaps illustrates the non uniqueness of groundwater modelling.

The MC1.6 model calculated depressurisation of strata resulting from the proposed UG4 underground mine, is significantly different from representations in the EA and PPR. Previous modelling noted negligible impact within both Triassic and underlying Upper Permian strata, with modest impacts predicted within the deeper Lower Permian strata. In contrast, the revised MC1.6 model exhibits dewatering of the Lower Triassic and Permian strata over most of the UG4 subsidence zone with a partly saturated area remaining in the north-eastern corner (see Figures 3.20, 3.21, 3.22 in PDA 2007a). The Upper Triassic is generally dry over the UG4 area both prior to and following mining.

The marked increase in impacts demonstrated by the MC1.6 model is attributed to the inclusion of an increased height of the free draining part of the subsidence zone above extracted longwall panels. Depressurisation of Triassic strata is predicted to extend northwards towards the Goulburn River where about 0.5m drawdown in aquifer pressures is noted by the end of proposed longwall mining. Importantly, groundwater flow towards the river appears to be sustained within the Triassic rocks. That is, the water table is predicted to remain above the river bed level.

2.2.2 Sensitivity analysis using MC1.6

PDA 2007a also reports findings of a sensitivity analysis conducted on model MC1.6 that adopts a free draining subsidence regime to a height of at least 122m above the Ulan Seam. However analysis was only undertaken for simulation of UCML operations prior to MCP underground mining and was rejected as unrealistic on the basis of poor calibration against observed groundwater pressures at UCML.

2.2.3 Shortcomings of Model MC1.6

We conducted an assessment of Model MC1.6 in view of the shortcomings identified in previous modelling efforts. As part of that assessment we identified a number of design elements that continued to 'blur' an appreciation of the potential impacts of underground mining. Those elements were brought to the attention of PDA and included:

- representation of the failure regime to a height of about 80 to 90m above extracted panels. MCP subsidence consultant advised the IHAP that 122m was the maximum likely height of connected cracking. A precautionary approach adopting a failure regime to this height therefore seemed appropriate;
- hydraulic properties of the goaf/failure zone were prematurely changed in a manner that artificially introduced groundwater into the model and may have acted to reduce the rate and extent of strata depressurisation;
- reporting of groundwater seepage to mined panels was conducted in manner that seemed to under represent model seepage by 10% or more.

PDA opted to undertake further modelling.

2.3 New model MC1.9

Model MC1.9 is reported in PDA 2007b. This model extends the free draining regime above mined panels to a height of at least 122m. The model also removes premature changes in hydraulic properties associated with that same regime that might otherwise dilute the impacts of depressurisation. Accounting for groundwater seepage to mined panels, remains the same as in all previous models and under represents the average seepage (as a continuum) by 10% or more.

The model was again re-calibrated to UCML operations before conducting simulations of the proposed UG4 panel extractions. PDA noted that while calibration against UCML historical mine water make could be achieved, the regional drawdowns predicted by the model tended to be more excessive than those observed and reported by UCML. PDA further notes that these drawdowns could be more satisfactorily matched by generally reducing the hydraulic conductivity of strata but this would mean adopting regionalised values beyond the range considered to be credible by PDA.

Results of modelling suggest significantly increased drawdown in the Lower and Upper Triassic aquifers as would be expected for an increased height of the subsidence failure regime. Indeed these aquifers are effectively dewatered above the UG4 area.

Depressurisation of Triassic strata extends northwards towards the Goulburn River where about 0.5m drawdown is predicted. Similar to model MC1.6, a groundwater flow gradient towards the river appears to be sustained.

3. Overview of likely impacts

The revised models MC1.6 and MC1.9 are considered to be more representative of the longwall mining process than earlier models presented to the IHAP. Based on the information provided in PDA 2007a and 2007b reports, the predicted groundwater related impacts are considered plausible.

3.3.1 Potential impacts on The Drip

PDA 2007a notes the seepages that constitute The Drip are discharges from perched aquifer horizons within the Triassic strata on the northern side of the Goulburn River. Those perched systems are sustained by percolation of rainwater from surface. Current model predictions suggest the likely depressurisation in Triassic strata will be relatively minor and of the order of 0.5m in the area surrounding The Drip. This low level of drawdown could reasonably be replenished by rainfall. Additionally, PDA 2007a notes that the river gorge that hosts The Drip, effectively isolates the shallow Triassic strata on the northern side from the same strata on the southern side and that groundwater flow is maintained towards the river from both sides.

These explanations and predicted depressurisation suggest the Drip is unlikely to be adversely impacted by proposed UG4 mining operations.

3.3.2 Potential impacts on the Goulburn River

Interaction with the Goulburn River has been examined by PDA in increased detail for river reaches in proximity to the underground UG4 mine. Three reaches have been examined – a western reach extending upstream from the confluence with Ulan Ck., a northern reach extending downstream from the confluence with Ulan Ck., to a point below The Drip, and an eastern reach extending downstream from The Drip for a distance of 3 km..

Water balance calculations for the MC1.6 model are presented by PDA as cumulative contributions to/from the river resulting from mining operations at Ulan, Moolarben and Wilpinjong. Results indicate that a loss of 0.75ML/day in base flow will occur within the northern and eastern reaches by the end of underground mining in 2021. This loss could be largely attributed to MCP due to the proximity of the UG4 underground operations to the identified reaches. For the western reach, PDA has provided calculations that indicate the expected loss is only of the order of 0.001 ML/day.

Water balance calculations for the MC1.9 model are markedly lower. Those results indicate that a loss of 0.28 ML/day in base flow will occur by the end of underground mining in 2021. However PDA reports this model as less representative than the MC1.6 model.

We note that the Goulburn River retains an embargo with respect to river water extraction (losses) and hence the Department of Water and Energy (DWE) is unlikely to accept a loss to base flow of the magnitude indicated by modelling, without an appropriate offset strategy. PDA2007a reports that an offset would be invoked using UG4 mine dewatering discharge subject to appropriate water quality treatment. PDA further notes (pers.comm, August 2007) that if mine dewatering discharge is depleted and therefore unavailable for treatment and release into the Goulburn River, then base flow impacts would continue to be offset by ‘importing groundwater drawn from bores remote from the underground mine in other parts of the Moolarben lease area’. PDA also notes that any continuing base flow losses to the Goulburn River post mining would be offset by the purchase and relinquishment of appropriate groundwater licenses.

We concur that losses to river base flow could be expected and that losses attributed to MCP would steadily rise from zero at the commencement of underground mining, to a maximum rate at the end of mining or at some time thereafter . The magnitude and rate of change of these losses would need to be verified during early years of mining and an appropriate offset strategy developed in consultation with DWE.

2.3.3 Mine water supply

Water supply for the open cut and underground operations is reliant upon the installation of a substantial borefield situated on the eastern boundary of the UG4 longwall panel footprint. Simulation of the borefield in model MC1.6 indicates mine water demand could be met from the borefield with a surplus in supply during years 1 to 16 (large surpluses in years 1 and 13 to 15). In contrast, model MC1.9 predicts variable surpluses in years 1 to 4, large deficits in years 5 to 12 and large surpluses in years 13 to 16.

The marked reduction in surplus years (and increase in deficit years) indicated by Model MC1.9 is attributed to be a reduction in the permeability of certain strata in that model. While PDA favours Model MC1.6 outcomes, it is quite possible that strata permeabilities are indeed lower than predicted and as a result, there may be insufficient water available from the borefield over the planned mine life. Under these circumstances it is understood that MCP may seek to import mine water from UCML operations where a surplus apparently prevails.

2.3.4 Potential impacts on bore water supplies

A small number of private water supply bores are vulnerable to loss of yield as a result of depressurisation of Triassic and Permian strata in the UG4 area. These bores are identified as the Imrie and Elward bores.

MCP has provided a commitment to restore, replace or compensate for any affected water supplies.

4. Concluding remarks

In summary, we have reviewed groundwater reports made available to us subsequent to the IHAP report.

We consider the uncertainty identified by the IHAP in respect of Triassic aquifer system characterisation has been partially reduced through core testing which although limited, does suggest the intergranular permeability of that strata, is very low. Any significant groundwater flows would most likely be constrained to joints and fractures which appear from field observations, to be relatively sparse.

We consider the uncertainty relating to groundwater model predictions to be reduced through the use of a more robust model code than was adopted in earlier (EA) models and through the improved representation of the subsidence failure regime and more localised assessment of potential impacts on the Goulburn River.

We conclude that:

- impacts on Triassic aquifers will be governed largely by the geometry of the subsidence failure regime and connected regional jointing but associated depressurisation is unlikely to adversely affect The Drip;
- any surface cracking above longwall panels has the potential to connect to underground goaf. A rapid response programme needs to address repair of those cracks that transgress surface drainages;
- a small number of local bores tapping water supply in the Triassic aquifer(s) may be yield affected. MCP proposes to repair, replace or compensate for any affected supplies;

- likely losses to base flow in the Goulburn River remain uncertain and may be as high as 0.75 ML/day. Improved estimates need to be generated through a combination of flow monitoring, piezometry, and model validation-calibration checks during early years of underground mining;
- MCP proposes to offset river base flow or leakage losses through release (to the river) of mine water or pumped bore water treated to an acceptable quality. Purchase and relinquishment of existing licenses has also been identified as an option. DWE will need to carefully consider these strategies before issuing appropriate licenses.
- mine water supply from the borefield and from seepage to underground operations should be sufficient to meet mine water demand if strata hydraulic properties at a regional scale are consistent with expectation (Model MC1.6). Continuous and accurate monitoring of all aspects of water management would need to be documented in a site water management plan.

Based on recent modelling (model MC1.6) and information supplied by PDA we see no outstanding groundwater related issues that might impede development of underground mining. However we do recommend a precautionary approach to development that encompasses rigorous monitoring of the groundwater regime.

Consent conditions in relation to groundwater, would need to include recommendations made by the IHAP in respect of subsidence and open cut mining, extended to include underground mining operations and formalised within a groundwater monitoring plan. We suggest:

- the existing piezometric monitoring regime is enhanced to provide a network of additional multi level piezometers (for pore pressure measurement) around the proposed longwall panels in order to assess strata depressurisation and to understand and quantify potential base flow or leakage losses to the Goulburn River. This network should provide advance warning of impacts and facilitate the determination of action trigger levels in respect of adverse impacts;
- the placement, design, and schedule of monitoring at all piezometers should have the concurrence of DWE;
- a comprehensive and accurate accounting of all water inflows to, and waters pumped from underground operations, and from the adjacent borefield in order to quantify groundwater seepage;
- river flow gauging be undertaken at appropriate locations within the eastern, and western reaches of the Goulburn River (identified in PDA 2007a). These locations and monitoring facilities would need to be agreed and approved by DWE;
- a review of impacts on the groundwater system be conducted by an independent expert approved by DWE prior to the completion of each longwall panel. As a minimum the review should assess strata depressurisation, provide a water balance for underground operations, and identify any trends that might indicate future adverse impacts on the Goulburn River, The Drip, existing private bore water supplies or any identified groundwater dependent ecosystems.

Yours sincerely

Mackie Environmental Research Pty. Ltd.

C.D. Mackie

References:

Moolarben Coal Project (MCP), 2006a. Environmental Assessment Report – Appendix 5, Groundwater assessment. *Prepared by Peter Dundon & Associates P/L for Moolarben Coal Project, Report 05-0158-R01J.*

Moolarben Coal Project (MCP), 2006b. Preferred Project Report – Appendix A10. Preferred project groundwater assessment. *Prepared by Peter Dundon & Associates P/L for Moolarben Coal Project, Report 05-0158-R04B.*

Peter Dundon & Associates P/L (PDA), 2007a. Groundwater assessment – April 2007 Report. *Prepared by Peter Dundon & Associates P/L for Moolarben Coal Project, April 2007, Report 05-0158-R06H.*

Peter Dundon & Associates P/L (PDA), 2007b. *Letter and appended report submitted to DoP and detailing results of further groundwater modelling undertaken by Aquaterra. July 2007.*