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Attention: Mr Peter Martin

Dear Peter

Hume Coal Project Environmental Impact Statement - Potential Groundwater Contamination Issues Associated with Placement of Washery Fines Material into Mine Voids - Review of Appendix K: Hydrogeochemical Assessment

1. Purpose of this Report

I have been requested by Mr Peter Martin of Coal Free Southern Highlands Inc. to review the sections of the Environmental Impact Statement (EIS) for the Hume Coal Project that address the potential geochemical impacts of placement of a high-density slurry of washery fines material into mine voids.

This letter report provides that review.

My review focusses on Appendix K to Volume 4 (itself Appendix E) of the Hume Coal Project EIS. Appendix K provides the most detailed geochemical assessment in the EIS, which is then summarised within the overlying layers of the EIS – Sections 8.7.2 and 11.2.2 of Appendix E and Sections 2.3.2 and 6.4 of the main report.

The effect of induced leakage of saline water from the Wianamatta group to the Hawkesbury Sandstone was also considered in Appendix K and is reviewed in this report.

2. Background

Section 2.3.2 of the EIS indicates that '*all coal rejects will be returned underground to partially backfill mined-out voids*' and '*whilst mine backfill is a mature technology in metalliferous mines, this technology has so far only been adopted at one other Australian underground coal mine as a trial*'. I understand that the mine where this trial was carried out is the Metropolitan Mine at Helensburgh, north of Wollongong. The technique had previously been used at Walsum in the Ruhr Valley (Tarrant et al 2012).

Metallurgical coal is mined from the Bulli seam at Metropolitan. Although the upper Illawarra Coal Measures at Helensburgh are overlain by the Narrabeen Group and the basal units of the Hawkesbury Sandstone, these formations do not host useful aquifers in that area. Thus the Hume Project proposal is the first time that this process has been proposed to be carried out below a productive aquifer.

I understand that the coal rejects that it is proposed to emplace will be washery rejects, composed primarily of claystone fines, with some residual coal fines.

The Wongawilli seam includes interbeds of carbonaceous claystone, claystone, tuff and sandstone. These are generally of alluvial origin but there is evidence of marine incursion at the base of the seam (Sherwin and Holmes 1986, Byrnes et al 1981). Material associated with these interbeds, particularly thin interbeds, that is unavoidably mined with the coal is separated during coal washing and together with residual coal fines becomes the washery reject (the NSW Environment Protection Authority (EPA) *Coal Washery Rejects Order 2014* permits up to 30% combustible material in coal washery rejects used in earthworks for civil engineering purposes).

I note that whilst the SEARs do not identify washery reject emplacement as a specific issue to be addressed in the EIS, it is highlighted in the NSW EPA’s agency comments, and the SEARs specific requirements regarding water include the following:

- an assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, DPI's and Water NSW's requirements and recommendations (see Attachment 2);
- an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users.

3. Potential Impacts on Groundwater Quality

There are two principal concerns regarding the potential impact of washery reject backfill on groundwater quality in the overlying Triassic Sandstone aquifers.

The first concern is that oxidation of sulphide minerals in the backfill material would cause acidification of the pore water and consequently acid leaching of heavy metals form the fines. The fine-grained reject backfill material would have a high surface area to volume ratio and would have been exposed to air on the ground surface during the washing process. It may also be exposed to oxidised PWD water injected into mine voids. Water contaminated with heavy metals and sulphate could then move upwards from the mine void into the overlying aquifers.

The Wongawilli coal contains about 0.6% sulphur (EMM 2015, consistent with Huleatt 1991). Neither geochemical nor mineralogical data on solids composition are provided in the EIS, but the sulphur content of carbonaceous mudstone interbeds deposited under freshwater conditions is likely to be similar to that of the coal, while mudstones deposited during marine incursions are likely to have higher sulphur content. This sulphur would be present predominantly as sulphides. Whilst the Wongawilli may rank as a low-sulphur coal, a sulphur content of 0.6% is equivalent to 18 kg of sulphuric acid per tonne when fully oxidised.

The second concern is that the washery rejects may be contaminated with surfactants or other chemicals used in the washing process. There is no information in the EIS as to what chemicals are likely to be used in the washery. Whilst possible candidates are methyl isobutyl carbinol (MIBC) and 4-methylcyclohexane methanol (MCHM), and there have been contamination issues due to MCHM release to surface waters from coal washing in the US, it is not possible to make an assessment of potential impacts without detailed information on the chemicals to be used. This information should have been provided in the EIS.

These are significant and reasonable concerns. It would be expected that they would be fully evaluated in the EIS.

This report is a review of the assessment of these issues in the EIS. It focusses on Appendix K of Appendix E of the EIS, which is the Hydrogeochemical Assessment prepared by Geosyntec

Consultants (Geosyntec), and which provides the technical basis for treatment of this issue in the EIS as a whole. Section references are to Appendix K.

In my opinion the EIS does not provide an adequate assessment of the issue of potential groundwater contamination resulting from placement of washery reject material in mine voids, primarily because the dataset on which the assessment was based was itself inadequate, but also because insufficient hydrogeochemical modelling was carried out. Furthermore, important information including the report on the column testing that forms the basis for the leaching assessment, and the hydrogeochemical modelling inputs, formulation and detailed outputs are not included in the EIS.

These information gaps should be remedied.

4. Baseline Hydrogeochemical Characterisation

Geosyntec's baseline hydrogeochemical characterisation of each stratigraphic unit is provided in Section 5. The basic stratigraphic approach to discussion of the hydrogeochemical sampling results is a logical starting point. However, as shown below, the stratigraphic distribution of groundwater monitoring wells is very uneven.

- Robertson Basalt (2)
- Wianamatta Group shales (1)
- Hawkesbury Sandstone (23)
- Illawarra Coal Measures (3)
- Wongawilli Seam (15)
- Tongarra Seam (2)

Whilst it is important to have good hydrogeochemical sample coverage of groundwater in the Hawkesbury Sandstone and Wongawilli seam (and the dataset does provide that), the coverage of other units, particularly the Wianamatta Shales, is inadequate.

The way the data are presented is unusual, and in my opinion potentially misleading. In this presentation, all samples from a stratigraphic unit are pooled, regardless of the well from which they were obtained or the time when they were taken. This approach:

- Clouds the interpretation by blending spatial variability with temporal variability, and
- Biases the interpretation towards wells from which a larger number of samples were obtained (i.e. multiple samples were obtained from the same well at different times).

An example of this approach being potentially misleading can be found in Section 5.2.2 where the phrase '*some of the shale groundwater'* obscures the fact that the entire discussion is based on data from a single well.

A more conventional, and in my opinion better, approach would be to first examine the temporal dataset for each well and comment on any observed trends or other temporal patterns (in individual wells and between wells) then choose representative values for each analyte at each well (which could be an average, or a concentration measured at a particular time) and analyse this subset for spatial variability.

It is usual to present temporal variations as plots of concentration against time for individual analytes in individual wells, and plot spatial variations on a map. Spatially or temporarily representative values can then also be plotted on (for example) Pourbaix or Piper diagrams, avoiding confusion and bias.

I do note that representative values were plotted on the single piper diagram used in this presentation and that there are a few temporal plots, but this appears to be quite ad-hoc and is not sufficient to communicate an understanding of the variability present.

Conclusion. *The dataset is not adequate. More monitoring wells are required to give better spatial coverage of formations other than the Hawkesbury Sandstone and Wongawilli Seam. Better analysis and presentation of the existing data are required to clearly define baseline conditions and define both spatial and temporal variability in each stratigraphic unit.*

5. Water Quality Change from Induced Inter-Aquifer Transfer

Section 6.1 considers the impact of induced inter-aquifer transfer of water and solutes from the Wianamatta Group to the Hawkesbury Sandstone as a result of aquifer depressurisation caused by mining. This assessment uses a simple mixing model with three inputs:

- the inter-aquifer volumetric flow (incorrectly described as flux in the report) between the Wianamatta Shales and Hawkesbury Sandstone as calculated using the numerical model,
- the average salinity (as TDS) in the Wianamatta Shales, and
- the average salinity in the Hawkesbury Sandstone.

Unfortunately, the average salinity used for the Wianamatta Shales is the average of the data from a single monitoring well. Whilst the value used (1700 mg/L) lies within the range recorded for the Wianamatta Shales elsewhere in the Sydney Basin, groundwater salinity in the Wianamatta Shales is very variable, and 1700 mg/L certainly does not lie in the upper part of the range. Because there is only one monitoring well, there is no way of knowing whether the value used is typical of the proposed mine area. Given the low salinity of the Hawkesbury Sandstone groundwater, the calculated impact for any mixing ration will be almost directly proportional to the salinity value adopted for the Wianamatta Shales.

Conclusion. *The dataset is not adequate. More data (i.e. more monitoring wells) are required for the Wianamatta Shales to allow a locally representative salinity value to be derived, or a more conservative (higher) salinity based on regional Sydney Basin data should be used.*

6. Water Quality Effects of Reject Slurry Emplacement in Underground Mine Voids

Section 6.2 considers the water quality effects of washery reject emplacement in mine voids.

The EIS provides little information on the coal-washing process to be used as part of the coal-preparation process, and no information concerning the use of surfactants, flocculants or other chemicals in this process.

Leaching of such chemicals or their potential effect on the chemical leaching process was not discussed in Section 6.2 of Appendix E.

Section 6.2 assumes that, once emplaced, the washery-reject slurry will re-saturate with native groundwater from the Wongawilli seam. The effect of mixture with injected PWD water is not considered, but it has the potential to significantly affect the geochemistry of the groundwater, and should have been included in the assessment.

The primary input to the assessment of the anticipated change to groundwater quality arising from this process of emplacement of washery-reject slurry was the geochemical testing (Kinetic Leaching Column - KLC testing) results reported by RGS (2016). The RGS report was not provided with the EIS.

There is no way of assessing, from the data presented in the EIS:

- How representative the single drill core used for KLC testing has of the necessarily spatially heterogeneous geology and ROM coal,
- How representative the column packing materials (synthetic reject materials) generated from drill-core were of the actual reject material that will be produced by the coal preparation process,
- The effect of partial oxidation of sulphides in the slurry prior to emplacement on acid generation post-emplacement,
- Whether the most appropriate test column results were selected for the analysis presented in Section 6.2,
- Whether the kinetic column tests were representative of likely contact times between groundwater and emplaced reject material in the ground, and
- Whether the intimacy of mixing with limestone fines achieved in the KLC 24 column test can be reproduced on a large scale, and what the significance of poor mixing is likely to be.

It is also not clear:

- why a larger range of the column test results was not considered, if only to contribute to a sensitivity analysis,
- why geochemical and mineralogical (XRD) analysis of the rock core or synthetic slurry was not carried out and provided in the EIS, and
- why the reaction process was not then modelled using PHREEQC, utilising the laboratory column work as control and allowing a longer reaction period to be simulated.

In Section 6.2.4, dealing with mitigation options, there is no indication as to how effective the proposed mixing is likely to be or what degree of mixing is practicably achievable.

Finally, the EIS considers only one of several possible mechanisms for resaturation of the slurry by groundwater – lateral flow through the Wongawilli seam, and only one fate for groundwater that has been in contact with the slurry – downgradient flow within the seam. There are other possibilities for resaturation, including:

- Partially-saturated vertical flow, either intergranular or through defects, from the overlying Hawkesbury Sandstone
- A rising water table from below, as underlying rocks resaturate.
- Inflow controlled by fracturing associated with regional structures including faults.

Initial resaturation may therefore be spatially variable, and as the stratigraphic column resaturates, groundwater may move vertically upwards through defects, local or regional, not just laterally through the coal seam. If this occurs – and it is likely to occur – then groundwater contaminated by materials leached from oxidised reject material would move directly into the overlying aquifers.

Conclusion. *The EIS does not provide a reliable assessment of the impact of washery-reject slurry placement on groundwater quality, or of the combined impact of slurry emplacement and PWD water injection.*

7. Water Quality Management for Surface Storage of CPP Reject Material

The methodology and assumptions adopted to assess the impacts on water quality of surface storage of CPP material are considered to be generally appropriate. There are, however, many unquantified variables associated with preparation and storage of the columns, and obviously, in reality, the length of wetting and drying cycles, and stockpile temperatures, will vary randomly. The extent to which the heated drying process used in the tests adequately simulates the elevated temperatures that may develop due to oxidation reactions in coal reject stockpiles (if that was the intention of applying heat) is not clear.

The results thus provide a general indication of likely drainage water quality, not an accurate or adequate prediction.

The effectiveness of the proposed mitigation methodology (amendment with limestone fines) will depend upon the intimacy of mixing achieved. This approach, while appropriate, is not a substitute for an adequate impermeable base liner, appropriate cover and collection and management of all drainage from the stockpiles.

Conclusion. *The results presented in the EIS provide a reasonable general indication of the quality of water that may drain from the stockpiles. In my opinion, however, physical as well as chemical measures will be required to manage stockpile drainage.*

8. PWD Water Quality Assessment for Subsurface Disposal

The methodology and assumptions adopted to assess the quality of CPP water are considered to be generally appropriate, except that it cannot be assumed that the first flush from the column tests is necessarily representative of the worst case, given the time-dependence and relatively slow kinetics of sulphide oxidation reactions. There are many unquantified variables associated with preparation and storage of the columns. As with the slurry assessment, PHREEQC could also have been used to model this reaction process, thus allowing a longer time-frame to have been simulated.

The PHREEQC geochemical modelling method adopted is considered appropriate as far as it goes; the results presented are consistent with the changes that would, broadly, be expected. It would, however, have been straightforward to model a number of groundwater samples instead of just one, and thus provide some sensitivity analysis. Having set up this model, it would also have been possible, and appropriate, to use the capabilities of PHREEQC to model the mixing of the three water types and then the reaction of the mixed water with the reinjection host rocks (Wongawilli and Hawkesbury Sandstone).

Conclusion. *Whilst the results presented in the EIS are broadly consistent with expectations, more modelling could and should have been carried out to provide greater confidence concerning the range of possible outcomes and long-term effects.*

9. Overall Conclusion

The EIS does not provide an adequate assessment of the issue of potential groundwater contamination resulting from placement of washery reject material in mine voids, primarily because the dataset on which the assessment was based was itself inadequate, but also because insufficient hydrogeochemical modelling was carried out. Furthermore, important information including the report on the column testing that forms the basis for the leaching assessment, and

the hydrogeochemical modelling inputs, formulation and detailed outputs are not included in the EIS.

Summary of Information (known to be available) that is missing from the EIS and should be requested from the Department Planning and Environment now.

- The RGS (2016) report.
- Tables A1 to A6 of Appendix A of Appendix K of Appendix E in readable electronic spreadsheet form.
- The existing PHREEQC modelling.
- Specification of chemicals to be used in coal washery.

Summary of Information that is missing from the EIS and should be obtained and provided by the Proponent.

- Additional geochemical data for groundwater from the following units:
  - Robertson Basalt
  - Wianamatta Group shales
  - Illawarra Coal Measures
  - Tongarra Seam
- Chemical and mineralogical analysis of rock cores / synthetic slurry.
- Better analysis and presentation of the existing data to clearly define baseline conditions and define both spatial and temporal variability in each stratigraphic unit.
- Additional PHREEQC modelling as described in this review.

For and on behalf of
C. M. JEWELL & ASSOCIATES PTY LTD

CHRIS JEWELL
Principal

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