KALBAR
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Fingerboards Mineral Sands Project

Environment Effects Statement

August 2020

Attachment I

Water
Independent Peer Review Report and Proponent Response

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Fingerboards Mineral Sands Project

Independent Review of Water Related Studies

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Independent Review of Water Related Studies

Client: Department of Environment, Land, Water and Planning

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Review Summary

AECOM was engaged by DELWP to review the water related aspects of the Fingerboards Mineral Sands Project, based on information, briefings and reports provided up until 10 May 2019.

The review was led by Bryan Chadwick, a hydrogeologist with 25 years' experience in the resource sector. Bryan was supported by a number of AECOM specialists in the fields of dam engineering, surface water and ecology.

The initial phase of the review involved AECOM providing a set of comments on a number of early draft reports, and ranked their importance from high to low based on the materiality of potential change in the impact assessment outcome. Subsequent to those early draft comments, this review report is based on the updated reports and responses, and focused on the Groundwater and Surface Water Impact Assessment Report (Coffey, 2019a), given its stated intent to collate all relevant information on water related aspects.

Eight subordinate reports were reviewed at a high level to check information and conclusions in the Coffey (2019a) report.

In general, the overall quality of the work undertaken is of a suitable standard, with the utilisation of appropriate methods and numerical models. However, the review has raised questions regarding the conceptualisation of the groundwater systems with a potential that the nature and extent of impacts have been underestimated. It is also noted that the level of design for key element of water management also limits the assessment of impacts and does not meet all the obligations of the Project's *Scoping Requirements.*

The following list the material issues from the review which result in a conclusion the groundwater and surface water study is not sufficient to support the impact assessment and Project's *Scoping Requirements*:

- The high likelihood that the conceptual hydrogeological model presented does not represent the observed conditions with regards the local mine site aquifers in a number of aspects, the consequence of which is that the predictive numerical model outputs may not show the full nature and extent of groundwater mounding and its subsequent risks;
- The absence of design for the proposed water management structures, including the temporary TSF, means it is not possible to assess constructability, operational constraints and the associated risks; and
- The surface water and groundwater supply scenarios did not consider all matters listed in Section 40 of the *Water Act 1989*, as required in a *Take & Use Licence* application.

There are other material issues highlighted in this review, and it is recommended they should be taken into account in any revision to impact assessment report(s).

1.0 Background

AECOM Australia Pty Ltd (AECOM) was engaged by Department of Environment, Land, Water and Planning (DELWP) to provide an independent review of the Fingerboards Mineral Sands EES on water related aspects.

The review focuses on surface water and groundwater impact assessment associated with the proposed Fingerboards Mineral Sands Project. The surface water and groundwater issues are intimately linked to issues associated with mining and processing, rehabilitation and closure within and beyond the Project boundary. Recognising that water management must be considered in the context of integrated mine management, this review refers to other aspects of the proposed project, as necessary.

The review involved the following:

- initial briefing (teleconference) on 20 December 2018;
- review of multiple versions of reports and documents;
- meeting (teleconference) on 27 February 2019; and
- Technical Reference Group (TRG)[1] meetings on 20 March 2019 and 23 May 2019.

The broad objectives of the independent review were:

- review and verify the quantity and quality of groundwater and surface water information considered as part of the assessment and whether it is sufficient to support the impact assessment under the *Environment Effects Act 1978* and Project's *Scoping Requirements*[2].
- review and verify the current conceptual hydrogeological model including an assessment of technical robustness, rigour and level of confidence in the interpretations and analyses; and
- review the assessment of risks, and the proposed mitigation and management measured.

The review has been primarily undertaken by Bryan Chadwick, a professional hydrogeologist with over 25 years of local and international experience specializing resource sector groundwater impact assessments. He has familiarity of the mineral sand industry and the Gippsland Region through previous project and site visits in the region.

The primary reference document provided for this review was:

- Fingerboards Mineral Sands Project. Groundwater and surface water impact assessment. Coffey. 9 May 2019.

Additional, subordinate documents to the above were provided and subjected to partial review commensurate with review focus and objectives included:

1. Fingerboards Groundwater Modelling Report. EMM. May 2019. V8.
2. Fingerboards Mineral Sands Project – Conceptual Surface Water management Strategy and Water Balance. EMM. January 2019
3. Fingerboards Mineral Sands. Surface Water Assessment – Site study. Water Technology Pty Ltd. February 2019
4. Fingerboards Mineral Sands. Surface Water Assessment – Regional study. February 2019
5. Fingerboards Mineral Sands. Revised Landscape Stability and Sediment Transport Regime Assessment. Water Technology Pty Ltd. April 2019
6. Detailed Ecological Investigations. EHP, February 2019.
7. Fingerboards Mineral Sands Project – Landform, Geology, and Soil Investigation. 31 October 2018

[1] As defined in Ministerial guidelines for assessment of environmental effects under the EE Act 1978. (DSE, 2006)
[2] https://www.planning.vic.gov.au/environment-assessment/browse-projects/projects/fingerboards-mineral-sands

8. Fingerboards Mineral Sands Project – Mine Rehabilitation & Closure Plan. February 2019.

The following should also be noted in the context of this review:

- AECOM did not undertaken a site visit to inspect the site and surrounds;
- AECOM did not engage with any relevant agencies, other than through joint attendance of TRG meetings.

Bryan was supported in his review by the following experts:

- Dam Engineer - Dr Gavan Hunter;
- Geomorphologist - Mark Mabin; and
- Ecologist - Chris White.

2.0 Project Description

In any impact assessment there is always the question as to the level of detail needed to sufficiently describe the Project to allow an assessment of potential environmental impacts, and in this the *Scoping Requirements* aim to direct the proponent as to the minimum aspects that needed to be included:

> Details of all the project components, to the extent practicable, including:
>
> - location, footprint, layout and access arrangements during site establishment, construction and operation;
> - design, methods, staging and scheduling of the proposed mining, including direction and timing of mining across the site and its operational life, volumes to be mined (overburden and ore), total production and production rate and timing of expected decommissioning, closure and rehabilitation;
> - function and design principles and capacity of main components of works, including overburden handling, ore extraction (including reagents to be used), mineral separation, tailings management and electricity supply and use;
> - water resources for operational use, including details on storage provisions, daily and annual use (including an operation and post-closure water balance);
> - necessary works directly associated with the project, such as an infrastructure and services upgrade and relocation, or augmentation of existing plant and facilities, including potential construction of roads and other linear services required for transporting ore and heavy mineral concentrate on and off-site;
> - proposed construction techniques and extent of areas to be disturbed during site establishment and construction, including total area expected to be cleared, particular requirements for traffic and floodwater management, dust and noise management, as well as for sensitive environmental locations;
> - approach to be taken regarding mine site rehabilitation, including progressive rehabilitation and mine-closure.

Two aspects of the Project Description emerge from the review and whether they meet the *Scoping Requirements* and more broadly are sufficient to allow an assessment of environmental impacts:

- Design level for key water structures; and
- Project progression.

2.1 Design Level

It is considered that to meet the "*..layout*.."; "*function and design principles and capacity of main components…*" and "*details on storage provisions*.." aspects of the *Scoping Requirements*, the documentation provided is lacking in terms of a number of key aspects:

- **Tailings Storage Facilities (TSF)**: The above ground TSFs are acknowledged to be temporary features (operational ~3 years). However, other than an outline of the footprint there does not appear to be a level of design sufficient to allow an assessment of their Consequence Category[3], which in turn supports the key design aspects (and risk), such as: spillway requirements; freeboard depth; foundation preparation; liner requirements (if any); and/or embankment volumes/properties.
- **Diversion-Drains**: Diversion of surface water run-off is a major component of the Project, with management at any one time of multiple sub-catchments, both of impacted areas and diversion

[3] The ANCOLD Guidelines on the Consequence Categories for Dams (ANCOLD, 2012) provides a method to assess dams on the basis of the potential severity of damage and loss, in conjunction with the risk to human life which may result from a dam failure.

'clean' water of undisturbed areas. There is not a clear illustration of the key design features, such as: achievable grade based on proposed alignment; storm event capacity; and erodibility issues/risks.

- **Outlet/discharge structures**: Each diversion-drain and water storage feature needs an outlet of some type to allow safe and controlled discharge into the local catchment. None of the documentation provides an understanding of these structures in terms of their location and key design features (such as storm event capacity, energy dissipation, and erosion control).
- **Water storage dams**: There appears to be numerous water storage and water management dams required for the Project, ranging in size from the large fresh water storage dam (2.2GL) to numerous small (and temporary) sediment ponds and water management dams (sizes undefined). As with the TSFs a conceptual type level design is missing from all these features to allow assessment of their Consequence Category, which in turn supports the key design aspects (and risk).

It is not suggested that the same conceptual level of design is needed for all of these features, especially given the size and 'life' of a number. However, to meet the *Scoping Requirements* it is considered that additional design detail for some structures is required to provide confidence that the following is understood and any resultant risks can be defined:

- material volumes for construction and the location of their source, such as clay core;
- foundation preparation (if any), and disposal of unusable materials;
- constructability and operational constraints; and
- decommissioning and closure.

2.2 Project Progression

The Project's description outlined in the groundwater and surface impact assessment (Coffey, 2019) provides a description of key aspects and a series of figures that show the maximum outline of all structures over life of mine. A key aspect to the Project is its progression and changing footprint, which is not clear in the documents reviewed.

It is considered that there would be benefit in providing more detail of the key features and activities at major milestones throughout the Project's proposed life. Specifically, highlighting the Project's relative complexity with regards the dynamic nature of pre-stripping, water collection/movement, mining, processing, backfilling and rehabilitation. The benefit is not only in making it clearer as to how the Project progresses, and minimises the perception that all areas are working/disturbed all the time, but provides confidence that the proponent understands how all the moving features interact at any time throughout the project life and those aspect are captured within the risk assessment.

This additional level of detail for the water related aspects would also meet the *Scoping Requirements*, in terms of the "…*staging and scheduling of the proposed mining, including direction and timing of mining across the site and its operational life*..".

It is recommended that a set of figures, tables and/or descriptions which is able to highlight at a number of key milestones through the Project's life the following:

- list of key water realted activities;
- disturbance footprint (and non-work areas) and/or active sub-catchments;
- the active water collection, water storage, water pipelines and water discharge features; and
- rehabilitation area(s).

3.0 Existing Conditions

The *Scoping Requirements* list six elements that need to be addressed in terms of characterising the Project catchment's existing surface water and groundwater environment:

- Identify and characterise the relevant groundwater and surface water environments, including the protected beneficial uses and values, existing drainage functions and behaviours and catchments, including that of the Gippsland Lakes Ramsar site.
- Characterise existing sedimentation within the Mitchell and Perry River systems including the physical and chemical properties of river bed sediments.
- Identify existing groundwater and surface water users and allocations in the broader area, including downstream of the site.
- Characterise the interaction between surface water and groundwater within the project site and the broader area.
- Provide a sufficient hydrogeological characterisation (e.g. a model) of the current allocations, extractions and uses of groundwater or surface water (e.g. town drinking water supply, irrigation use, stock and domestic use and environmental flows) in the broader area, including downstream of the site.
- Characterise the physical and chemical properties of the project area soils including the potential environmental risks (e.g. potential for erosion, salinity, nutrients and acidification).
- Describe the existing infrastructure for water supply, irrigation, wastewater collection and power supply in the project area and in its vicinity.

It is clear that one of the main purposes of the ***Groundwater and surface water impact assessment*** (Coffey, 2019) is to address all the points listed above in terms of defining the existing conditions as it relates to water.

In achieving this purposed there are broadly three environments that this report addresses: groundwater, surface water and biodiversity, and the review comments on these three aspects are provided as follows:

3.1 Groundwater

The regional and local scale groundwater environments are described in Section 3.5 of the impact assessment report (Coffey, 2019), which is largely support by the hydrogeological modelling report (EMM, 2019).

Both reports are detailed and include a thorough analysis of all the relevant information to describe the local and regional groundwater setting. In particular the EMM report (2019) is considered a detailed and well-structured report of the background conditions, which is able to justify the numerical model set-up.

The following outlines the review comments that focused on: a) the regional scale understanding associated with the potential for groundwater extraction; and b) local scale understanding and whether it is sufficient to assess the interaction of mining activities.

3.1.1 Groundwater Extraction

The broad regional scale hydro-stratigraphy is well presented and described, with what appears to be a collation of the available information and documentation of the area.

There remains uncertainty in the following areas:

- Potential water quality of the formation overlying the bore field's target aquifer to allow assessment of potential long term changes to extracted water quality; and
- Potential compressibility formation overlying the bore field's target aquifer to allow assessment of potential long term subsidence.

The site investigation work associated with the bore field meets industry standards and provides sufficient understanding to assess the likely impacts, with the exception of the following comment:

- Understanding of the test bore's well efficiency, which appears to be relatively poor, which may impact on the assumed maximum yield from future wells in the bore field.

The identification of the existing groundwater users and allocations in the broader area, including downstream of the site is reasonable, with the exception as to the likelihood for non-registered groundwater users (e.g. spring fed dams and non-registered bores).

3.1.2 Local Scale Mine Activities

At a local scale the hydrogeology described is a reasonable representation of the various aquifers systems, with the exception of two key aspects where the listed data is considered to represent a materially different conceptual model to that presented:

Layering within Coongulmerang Formation

The Coongulmerang Formation is the geological unit within which the orebody lies and upper aquifer is located. It is the formation which all mining activities directly interact, albeit that the orebody is well above water table.

There is considered to be reasonable likelihood that the conceptualisation of the 90 meter thick Coongulmerang Formation is not as simple as represented, with the potential for low permeability layers and creation of perched systems beneath the mine footprint. The occurrence of these features within the Coongulmerang Formation is recognised, although their extent, significance and importance within the conceptual model appears to be down played, which is difficult to understand given the occurrence of a perched water table in one of the seven monitoring bores installed across the site.

It is understood that there is information from the resource drilling done by Kalbar and others over the years to provide evidence that the likelihood for an extensive perched system(s) is low, however, it is questionable in my view that the logging would observe such layers unless it was a specific objective of the investigation.

In summary, the risk and consequences of an increased layered complexity and resultant for perched (layered) system in the Coongulmerang Formation is not described in the conceptual hydrogeological model and not translated into the numerical model, and is lacking as a result.

The key issues that emerge with this lack of complexity in the model are as follows:

- Potential for seepage to mound from a much higher elevation, with resultant impacts such as:
  - groundwater daylighting as seeps higher up the escarpment and sub catchments;
  - saturate the orebody and flood active mine pit areas, with implications on site water management; and
- Potential for mounding to interact with various engineered structures (for example TSF and water storage embankments) with implications on their stability.

Balook Formation Permeability

The aquifer unit beneath the Coongulmerang Formation is listed as the Balook Formation, which forms part of the Middle Tertiary aged Latrobe Valley Group.

The nature and extent of this formation is important as it is essentially the receiving system for the majority of seepage water loss from mining operations. It is through this aquifer unit that there is a potential for groundwater from mine seepages to reach the Woolglen Aquifer Storage Recharge (ASR) ASR scheme.

Conceptually, it has been assumed that the Balook Formation has a relatively high permeability (3.0 and 0.03 m/day, Kh and Kv respectively – silty sand). The basis for this assumption is apparently from investigations undertaken east of the site where the formation underlies the Mitchell River alluvial system as is part of the ASR scheme.

What appears to have been missed is the implication of the lithology recorded in MW09, the only bore drilled at the site to depth which intersects the formation (214m), and at least 100m below the base of the Coongulmerang Formation.

The lithological drilling results from MW09 show that the top of 80-90m of the Balook Formation is dominated by high plasticity clay. The consequence is that the hydraulic conductivity would be at least 2 to 3 orders of magnitude lower than that assumed.

It is recognised that aquifer testing and sampling has been conducted in MW09. However, the screen interval selected for this bore was across a sand/gravel horizon that is approximately 100m below the top of the unit and unlikely to be representative of the formation directly underlying the Coongulmerang Formation. Therefore, none of the reported testing and sampling results are particular relevant as a definition of the underlying formation characteristics.

The implication of this different conceptualisation has not been considered in either the Coffey or EMM reports. Furthermore, the sensitivity analysis done in the EMM modelling report does not capture the potential effects of the upper portion of the Balook Formation being a clay unit.

The key issue that emerges assuming a clay unit underlying the Coongulmerang Formation in the model is that water seepage from the mining activities will be unable to vertically dissipate to any significant degree into the Balook Formation. The potential implications of this scenario occurring are:

- Nature and extent of the local mounding in the Coongulmerang Formation will be significantly greater, and take significantly longer to dissipate; and
- Less flow (if any) into the groundwater system that is connected to the Mitchell River ASR scheme.

Secondary Issues

A number of secondary issues have been raised in the review associated with local mine site understanding, and still warrant consideration to meet the *Scoping Requirements*:

- Coongulmerang Formation geochemistry in particular the potential for Acid Sulphate Soils, to allow an assessment on the changes in groundwater chemistry with increased saturation within the aquifer;
- Potential for, and the existence of, springs emerging from the Coongulmerang Formation aquifer, in particular at the based on the Mitchel River escarpment.

3.2 Surface Water

There are five subordinate reports which link to the surface water elements of the impact assessment and which aim to describe the existing conditions of the regional and local surface water environment. These are:

1. Surface Water Assessment – Regional study, Water Technology (2019). This report provides a thorough overview of the regional scale surface water environment (Mitchell and Perry River catchments), and addresses all key regional water quantity and quality conditions extending downstream to the Gippsland Lakes.
2. Surface Water Assessment – Site study, Water Technology (2019), describes the local surface water environment, including all the sub-catchments, and potential influences.
3. Revised Landscape Stability and Sediment Transport Regime Assessment, Water Technology (2019). This report describes the existing landscape stability and stream/river sediment transport within the site and downstream, which has generally been covered in sufficient detail.
4. Conceptual Surface Water management Strategy and Water Balance, EMM (2019), which utilises the Water Technology work at a local and regional scale and modelled the local catchment, from it has estimated the locations where surface water run-off converges and leaves the project area.
5. Aquatica (2016), which amongst other aspects, includes a survey on the status of various creeks, dams and water bodies within the project area.

All of this work is summarized in Section 3 and 4 of the impact assessment report, and is a reasonable summary of all the input investigations and summaries.

Overall the regional scale description of existing conditions meets the *Scoping Requirements* and is considered sufficient to allow for an assessment of impacts.

At a local scale there are a number of potential limitations of the work undertaken:

- Minimal geotechnical and geochemical properties of the project area soils including the potential environmental risks (e.g. potential for erosion, salinity, nutrients and acidification). Whether these aspects are material issues and are a risk to the management of the site is difficult to determine at this time.
- Lack of surface water quality and flow monitoring within the project area. This is understood to have been unavoidable due to the lack of surface water flow over the period of site investigation works, but adds some uncertainty of the existing conditions, and most likely the degree to which the modification of the catchment over the last century (land clearing, plantation, and general agricultural practices) has altered water quality from its former pristine catchment setting.

In summary, the local scale catchment setting is lacking based on unavoidable monitoring data gaps. However, the report would have benefited from an assessment on the significance of these data gaps and assumptions (and their level of conservatism) taken into the impact assessment. Whether the monitoring data gaps are important in terms of defining the water quality range is unknown.

3.3 Biodiversity

In regards to biodiversity the *Scoping Requirements* list the following with specific relevance to water related aspects:

- Characterise the distribution and quality of native vegetation, terrestrial and aquatic habitat and any wildlife movement in the area, taking into account the potential changes in composition due to recent bushfires, that could be impacted by the project.
- Identify and characterise any groundwater dependant ecosystems that may be affected, in particular by mine dewatering. This characterisation is to be informed by relevant data, literature and appropriate seasonal or targeted surveys.

The broad ecological assessment of the project area appears to reasonably cover the distribution and quality of native vegetation, terrestrial and aquatic habitat and wildlife movement in the project area.

One aspect not addressed is an assessment of biodiversity that would potentially be impacted by extraction of water from the Mitchell River. The aspects of the Mitchel River that could be impacted by mine site activities (including groundwater extraction) were covered, and the project description provides two options was to the approximately location for a surface water off-take. However, no assessment of specific ecology in Mitchell River at those extraction locations was undertaken. This is considered a significant element missing from the existing conditions assessment.

The initial broad desktop assessment on potential for Groundwater Dependent Ecosystems (GDEs) was based on the National Atlas of Groundwater Dependent Ecosystems (BOM, 2015), which is key reference to start any assessment on GDEs in Victoria. The comment that the GDE Atlas is likely to overestimate the dependence of aquatic and terrestrial ecosystems on groundwater within the project area are not based any factual information, and is potentially misleading. The counter is that groundwater perched systems, unmapped springs and general complexity to groundwater flow within the project area given the highly variable topography may means the regional mapping of GDEs is underestimated.

Site specific GDE desktop mapping was conducted by EHP (2019) and their specialist Austral Research Consulting (2019), with the following noted:

- Desktop methodology is sound and the data set used appropriate.
- Although the desktop area assessed is reasonably large, there is risk it does not cover all areas that may be impacted and therefore does not meet the *Scoping Requirements* in terms of “identifying and characterising any groundwater dependant ecosystems that may be affected”.

This based on the point made herein that the groundwater mounding may be significantly greater than presented to date (Section 4.1.2).

- No apparent on-ground mapping/surveying or ground truthing was conducted of the GDEs, therefore there is a question as to whether it has met the *Scoping Requirements* in terms of 'appropriate seasonal or targeted surveys'. Furthermore, the potential for unmapped springs and small scale features exists with limiting the assessment to a desktop methodology. Their likelihood and significance is not able to be determined.
- The focus of the conclusions appears to be largely on the potential for changing non-GDEs to GDEs as a result of mounding. What the GDE assessment did not address, which may be material is:
  - Groundwater Quality. The existing groundwater quality that each GDE is connected is not included. This means the impact assessment is unable to comment on the consequences of mounding water quality. The water quality impacts in the GDE assessment were a clear exclusion from the study;
  - GDE value. There is no apparent assessment of each GDE's value and whether there are existing impacts through historic or current land uses. It is considered a reasonable precautionary assumption that all GDEs are of a comparable value.

4.0 Impact Assessment

The *Scoping Requirements* list five areas to be addressed in assessing the impacts from the Project:

- The potential for adverse effects on the functions, values and beneficial uses of groundwater due to the project's activities, including water extraction, interception or diversion of flows, discharges from mining and other operational areas or saline water intrusion.
- The potential for adverse effects on the functions, values, beneficial and licensed uses of surface water due to the project's activities, including water extraction, interception or diversion of flows, discharges from operational areas or saline water intrusion.
- The potential for adverse effects on nearby and downstream water environments (including the Mitchell and Perry Rivers, King and Wellington Lakes, and Gippsland Lakes Ramsar wetland of international importance overall) due to changed water quality, flow regimes or waterway conditions during construction, operations, rehabilitation, decommissioning and post-closure.
- Ore, product, overburden, tailings and mining by-products management, in the context of potential water quality impacts including those arising from sedimentation, release of radionuclides, other contaminants and pollutants, tunnel erosion, acid sulphate soils, acid/metalliferous drainage formation, and salinity.
- Potential erosion, sedimentation and landform stability effects during construction, operations, rehabilitation, decommissioning and post-closure.

4.1 Groundwater

As with the review of the existing conditions, the impact assessment is divided into a review of: a) regional impacts from groundwater extraction; and b) local mine site impacts.

4.1.1 Groundwater Extraction

It is understood that up to 3GL/year (~95L/sec) groundwater may be extracted for 15 years from the Latrobe Group aquifer at a site 4km south of the mine site.

Even though there appears to be some uncertainty as to the final water source and what volumes will be used for the project, the groundwater impact assessment assumed the full 3GL requirement would be taken and appropriately conducted the impact assessment based on this assumption.

On the basis of the review comments by HydroGeoLogic (2019) and the conceptualisation presented in the Coffey report (2019) the numerical model outputs provide a reasonable assessment to understand the potential impacts on the beneficial uses and that 3GL/year groundwater extraction is achievable from the proposed bore field.

That said there are a number of key aspects to the proposed bore field extraction that warrant further explanation to allow a more complete assessment of the potential impacts and risks:

- Section 40 of the *Water Act 1989*. Assessment of all matters listed in Section 40 has not been completed in the impact assessment report (Coffey, 2019) and is both possible from the information provided and needed to meet the *Scoping Requirements*.
- Bore field Area. The bore field set-up that was modelled (EMM, 2019) falls outside the bore field area designated in the impact assessment (Coffey, 2019). If the bore field can only lie within the area designed, it will likely constrain the groundwater volume that can be extracted due bore interference effects.
- Production bore efficiency. The pumping test analysis should include an assessment of bore efficiency and the risks that significantly less can be yielded from each bore and thus there may be a need for more bores than currently assumed.

- Subsidence risks. The Seaspray Gp which overlies the target aquifer is described as 'moderately' consolidated[4] thus some level of assessment is needed to quantify the level of subsidence risk from long term extraction.
- Chemistry Changes. The Seaspray Gp which overlies the target aquifer is likely to have a different groundwater chemistry to that of the target Latrobe Group aquifer and there is the potential over time for some level of leakage to occur from Seaspray Gp into the Latrobe Group aquifer. The question is whether leakage from the Seaspray Gp will materially change the bore field water chemistry entering the mine site, and change various associated assumptions.

4.1.2 Mine Site Activities

As outlined in Section 3.1of this review the EMM groundwater model and report (2019) is considered suitable to support assessment of regional scale impacts. However, the uncertainties highlighted with regards the local scale hydrogeological conceptualisation and the likelihood of a more complex system beneath the mine site area suggest the EMM groundwater model is not suitable to fully assess the environmental impacts from the mine site activities on the local catchment.

Section 3.1.2 of this review highlighted those aspects of the local groundwater system which suggest the model and impact assessment presented is not sufficient. Critically, there is considered to be sufficient evidence to suggest the nature and extent of the groundwater mounding, given the assumed seepage loss rates, may be materially underestimated. A mounding larger than presenting could have the following risks:

- extended inundation stresses to terrestrial ecology and GDEs;
- surface water flow and quality changes from mounding daylighting across escarpment and within various local sub-catchments;
- greater level of mine water management due to mounding entering active pit areas;
- increased pore pressures on engineered structures and potential impacts to their stability; and
- reduced ability to meet closure criteria within assumed timelines given the mounding will take longer to dissipate.

It is recommended that the EMM model consider the local scale complexities through either an expanded sensitivity analysis and/or inclusion of a scenario with differing layer properties. The outcomes of this assessment should inform as to the need for an additional, local scale, numerical model to allow an assessment of impacts, management and mitigation strategies and support engineering designs for those risks listed above.

4.2 Surface Water

4.2.1 Water Extraction

It is understood that up to 3GL/year (~95L/sec) surface water may be extracted for 15 years from the Mitchell River. Two potential off-take locations are provided in the Project description, however, unlike the groundwater extraction scenario no assessment and/or modelling of impacts has been undertaken.

The impact assessment (Coffey, 2019) does not include any assessment of the local impacts from extraction within the Mitchell River, and therefore has not met a number of the *Scoping Requirements*. This level of assessment is considered relevant for the EES irrespective of whether an allocation can be obtained.

As a minimum, the impact assessment on the Mitchell River off-take should give consideration of the matters listed in Section 40 of the *Water Act 1989*.

4.2.2 Mine Site Impacts

The regional scale definition of the surface water systems is considered a good representation of the existing conditions. The Water Technology report (2019) provides an overview of the regional scale surface water environment (Mitchell and Perry River catchments) and allows a reasonable

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[4] Australia Stratigraphic Units Database: https://asud.ga.gov.au/search-stratigraphic-units/results/16717

assessment of potential effects of the project on regional water quantity and quality extending downstream to the Gippsland Lakes.

A key issue with all the surface water assessments, both local and regional, is that the impacts depend on the EMM report that addresses water leaving the mine site and entering the regional water environment. EMM has appropriately assessed regional surface water flows using industry standard modelling software (EWater Source). The water quality and water quantity effects appear to be small at this regional scale, but they depend very largely on the accuracy of the site water balance modelling by EMM. Any relatively moderate change in site surface water management could materially change the impact assessment, both locally and regionally.

The local site water impact assessment, during operations and in the rehabilitated site landscape is again dependent upon the outputs of the EMM water balance study, and also the Landloch rehabilitation study. Taking those as inputs, it has appropriately developed an assessment of site scale surface water movement and water quality effects in flood conditions. Industry standard Tuflow modelling has been used.

The conceptual Surface Water Management Strategy and Water Balance (EMM, 2019) is a critical report as many other studies rely on the outputs of the water balance, such as:

- How much water is needed?
- Where will it come from?
- What happens to it onsite?
- How will it be discharged back to the environment?
- What effects will it have on downstream environments and users?

It is with this aspect where a project flaw could emerge. Although there work done to date is of a standard and quality that is reasonable and highly defendable, the volume of water that is being transferred around the site at any one time means there is little redundancy in the system. Any project modification (even relatively modest), or any change in assumption, will result in a significant change in the site water balance.

As with the other surface water studies, the actual assessment using Goldsim in this case, has been appropriately carried out and modelled. Key issues are inputs – where the water comes from; and transfers within the model – which are nearly 3 times the annual inputs required. As discussed above, if anything changes, there would be a large project risk. In particular the transfers between the WCP and sand tailings, WCP and MUPs, and WCP and fine tailings are all very large. The risk of this water movement changing does not appear to have been addressed, or any clear acknowledgement or strategy in terms of managing ‘change’. This in turn raises an issue: can the project be shut down safely if the economics or water resources are reduced or not able to be met in any one year. This aspect has not been included in the impact assessment.

The landscape stability and sediment transport regime assessment (Water Technology, 2019), which addresses landscape stability and stream/river sediment transport within the site and downstream, has generally been covered in sufficient detail. It is noted that there will be a relatively long boundary (many kilometres in length) between mined and non-mined areas. What is not clear is how this direct interface between the mine and the environment to be managed, as it is considered an area where there is the potential for significant environmental impacts.

4.2.3 Biodiversity

The following warrants further assessment of the potential impacts on the biodiversity:

- impacts to listed GDEs due to potential changes in groundwater chemistry from the predicted mine seepage;
- impacts to listed GDEs and terrestrial ecology from an extended duration of inundation (water logging) from rising (mounding) groundwater levels;
- potential for salinization of soils and resultant impacts to terrestrial ecology from rising (mounding) groundwater levels; and

- impacts on aquatic ecology of Mitchell River from 3GL/year surface water extraction at the two nominated off-take locations.

5.0 Conclusions

The overall summary of the AECOM review and assessment on the quantity and quality of groundwater and surface water information considered as part of the assessment is that in a number of areas it is not sufficient to support the impact assessment under the *Environment Effects Act 1978* and Project's Scoping Requirements.

Furthermore the review of the conceptual hydrogeological model suggests that although there is a good level of technical robustness, rigour and a high level of confidence in most interpretations a number of aspects are not fully defendable and bring into question the predicted impacts.

The questions regarding the technical impact assessment means this review did not progress to a complete review of the proposed mitigation and management measures.

A summary of the key points from the AECOM review which explain the above conclusions are as follows:

Project Description:

- Absence of design for key water engineering structures, which results in an incomplete understanding of construction, operation and closure risks;
- Benefit in providing more detail on the progression of the Project overtime with respect to key activities.

Groundwater:

- Two key assumptions to the local mine site hydrogeology are considered to be over simplified or misrepresented in the numerical model and as a consequence the estimate of mounding may be significantly larger in the Coongulmerang Formation than presented;
- Groundwater model is not considered suitable to assess mine site scale impacts given the highlighted hydrogeological complexities and it regional scale focus. This could be addressed through increased sensitivity analysis and/or additional predictive scenarios, with an assessment as to whether a different, local scale, model is required to fully assessment the mine site activities on the local catchment.
- Groundwater extraction scenario should consider all Section 40 (*Water Act 1989*) matters in the impact assessment.

Surface Water

- The various surface water assessments are detailed and thorough and use appropriate models and assumptions.
- Some minor limitations appear to exist with definition of current conditions due to lack of surface water monitoring possible within proposed mine footprint;
- Impact assessment does not include the localised Mitchel River extraction activities, where there is neither the definition of the local off-take conditions or impacts from in-river extraction. As with the groundwater extraction, all Section 40 (*Water Act 1989*) matters should be considered in the impact assessment;
- The mine site impact assessment is considered appropriate and commensurate with the site activities, however, given the volumes of water being managed around the site at any one time are nearly 3 times the annual inputs required, there is considered to be significant risk in any change in mine plan and no detail on how risk will be managed.

Biodiversity

- The assessment of the existing biodiversity across the Project area is broadly appropriate, with the exception of the following aspects:
  - local conditions within the Mitchell River at the proposed off-take locations;
  - extent of desktop GDE assessment, given the potential for an increased mounding extent;

  - ground surveys or ground truthing of the desktop GDE assessment, and the potential risk that small scale and local GDEs have been missed;
- It has been concluded (Austral, 2019) that any significant increase to period of inundation (from mounding) is likely to impact on ecosystem health and potentially water quality, however no apparent assessment on the implications of this aspect is included in the risk assessment and proposed management and mitigation measures.

6.0 Limitations

AECOM Australia Pty Limited (AECOM) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of DELWP and only those third parties who have been authorised in writing by AECOM to rely on the report.

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The methodology adopted and sources of information used by AECOM are outlined in this the Report.

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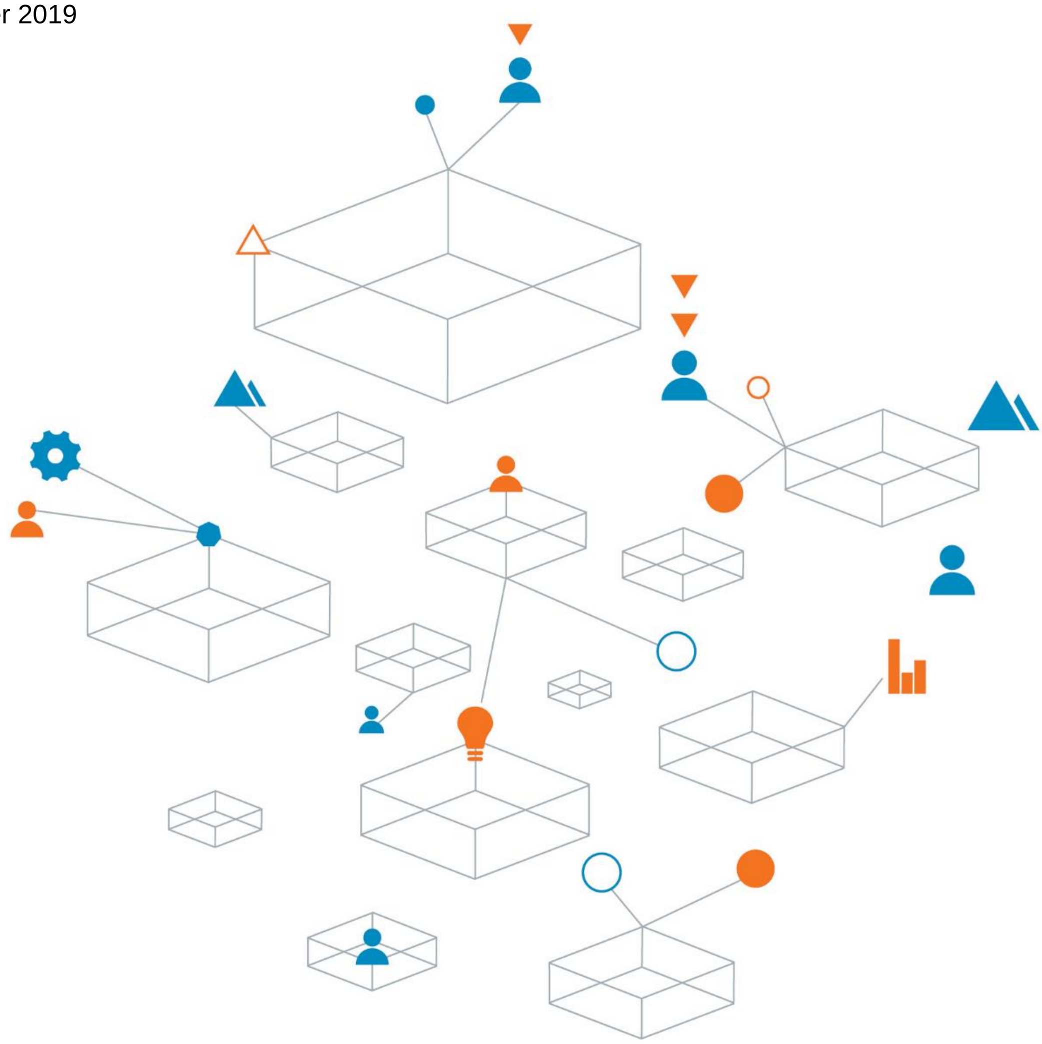
Kalbar Pty Ltd
Fingerboards Mineral Sands Project
Response to Independent Review of Water Related Studies
754-ENAUABTF11607AI

03 October 2019



Trust is the cornerstone of all our projects

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Fingerboards Mineral Sands Project Response to Independent Review of Water Related Studies

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1. Introduction

This document provides a response to the ‘Independent Review of Water Related Studies’ prepared by AECOM (2019), hereafter referred to as ‘the Review’.

AECOM was engaged by the Department of Environment, Land, Water and Planning (DELWP) to review the water related aspects of the Fingerboards Mineral Sands Project, based on information, briefings and reports provided up until 10 May 2019. The Review noted that it focused on the Groundwater and Surface Water Impact Assessment Report (Coffey, 2019), with the eight subordinate reports reviewed at a high level to check information and conclusions in the Coffey (2019) report.

The Review reported that the overall quality of the work undertaken is of a suitable standard, with the utilisation of appropriate methods and numerical models. The review also raised a number of issues that were considered ‘material’ by the reviewer, who concluded that based on these issues, the Groundwater and Surface Water Impact Assessment Report (Coffey, 2019) was not sufficient to support the impact assessment and the Project Scoping Requirements.

Section 2 of this document provides responses to the items raised in the Review, and addresses the key issues raised.

2. Response

The responses provided below are referenced against the headings and structure of the Review.

2.1. **Design Level** (Review S.2.1)

The Review noted that the water study documentation was lacking in key aspects related to: TSFs, diversion drains, outlet/discharge structures, and water storage dams.

The Review considered that to meet the Scoping Requirements, additional design detail for some structures is required to provide confidence that key aspects can be understood, and any resultant risks defined.

Response:

Attention is drawn by the proponent to the Scoping Requirements that, as stated, aim to direct the proponent to the minimum aspects that are needed to be included. In particular, the Scoping Requirements require: “Details of all the project components, to the extent practicable, including: design, methods, staging and scheduling etc, and function and design principles and capacity of main components of works, etc”.

We note that the Scoping Requirements also establish that detailed design, particularly of minor infrastructure components is not expected. The proponent considers that the level of detail in general complies with the Scoping Requirements. It is noted that some comments in the Review, such as material volumes for construction and the location of their source, such as clay core, and foundation preparation (if any), and disposal of unusable materials, and constructability and operational constraints are unrelated to the water impact assessment. In addition, such would constitute detailed design that goes beyond ‘*to the extent practicable*’ as required in the Scoping Requirements.

Notwithstanding the above, in response to the Review comments it is advised that key details for water storage are provided in Section 1.4.6 including dams for freshwater storage, process water, contingency water, and water management. Figure 1-3 shows the indicative locations of these features, and a summary of the various water storages, their general design and construction considerations is provided in Table 1.3. This table details the purpose of each storage and the staging (i.e. period of use) together with construction type, seepage management, adopted design specifications, and the relevant design guidance to be adopted.

Additional detail has now been provided in Section 1.4.7 in relation to water management priority and scheduling that contains additional operational detail for the dams. In addition to this, Figure 1-5 is a schematic of mining activity, and Figure 1-6 illustrates the water management dams. Figure 1-7 illustrates staging for the water management dams.

It is considered that the information presented is sufficiently detailed and consistent with the Scoping Requirements.

2.2. **Project Progression** (Review S.2.2)

The Review raised that there would be benefit in providing more detail of the key features and activities at major milestones throughout the Project's proposed life, including highlighting the Project's relative complexity with regards the dynamic nature of pre-stripping, water collection/movement, mining, processing, backfilling and rehabilitation. It was raised that the benefit is not only in making it clearer as to how the Project progresses, and minimises the perception that all areas are working/disturbed all the time, but provides confidence that the proponent understands how all the moving features interact at any time throughout the project life and those aspect are captured within the risk assessment.

It was also raised that this additional level of detail for the water related aspects would also meet the Scoping Requirements, in terms of the '...staging and scheduling of the proposed mining, including direction and timing of mining across the site and its operational life…'

Response:

Additional description of the mining process is provided in Section 1.4.1 and 1.4.4 and supported by new Figure 1-5 to describe the progressive mining method.

Additional detail has been provided to describe the water related aspects of the project, in Sections 1.4.5 (water), 1.4.6 (water storage) and 1.4.7 (water management). These are supported by Figures 1-6 (water management dams) and Figure 1-7 (indicative water management staging).

Supporting information is also provided in Figure 1-3 (proposed project water infrastructure), Figure 1-4 (proposed infrastructure located outside of the project area) and Table 1.3 (water storage construction summary).

2.3. **Existing conditions – groundwater** (Review S.3.1.1)

The Review identified that the Coffey and EMM reports are detailed and include a thorough analysis of all the relevant information to describe the local and regional groundwater setting.

Section 3.1.1 of the Review identified uncertainty in:

- Potential water quality of the formation overlying the bore field target aquifer to allow assessment of potential long term changes to extracted water quality; and
- Potential compressibility of the formation overlying the target aquifer to allow assessment of potential long term subsidence.

The site investigation work associated with the bore field was found to meet industry standards and provide sufficient understanding to assess the likely impacts, with the exception of the following comment:

- Understanding of the test bore's well efficiency, which appears to be relatively poor, which may impact on the assumed maximum yield from future wells in the bore field.

Response:

<u>Potential water quality of the overlying formation</u> - Low permeability formations of the Seaspray Group provide hydraulic confinement of the Latrobe Group aquifer (the borefield target aquifer). Groundwater modelling has shown that drawdown in the overlying formations is likely to be very low. The Seaspray

Group, which acts as an aquitard, has very low predicted drawdown levels at around 0.5 m, and the risk of water quality impacts are also considered low. A groundwater monitoring well was installed in the Seaspray Group for groundwater level monitoring associated with the aquifer pumping test in the underlying Latrobe Group. This well will be included as part of the ongoing baseline groundwater quality monitoring program.

Potential compressibility and subsidence of the overlying formation – We note this is not a specified requirement in the Scoping Requirements but has now been considered in Section 8.3.6 of the Groundwater and Surface Water Impact Assessment Report (Coffey, 2019).

Subsidence risks for the Latrobe Group aquifer and the overlying formations are low because the level of pressure reduction will be not excessive. In addition, the Seaspray Group lithology is low-risk of compaction because it comprises calcareous sand, sandy and silty limestone, and is ferruginised with patchy carbonate sediment. Formations having a high subsidence risk typically comprise silt and clay lithologies, which are susceptible to compaction.

Groundwater modelling has been used to consider the effects of drawdown on the area surrounding the mine site. It is important to realise that significant historical drawdown within the Seaspray Group and the deeper Latrobe Group has already occurred. Historical drawdown within these deeper units is attributed to factors including oil and gas depressurisation (from below), large pumping from the overlying Boisdale aquifer and minor pumping directly from these units.

To illustrate this comparison, Latrobe Group bore 47063 currently shows a groundwater level measuring approximately -9 mAHD. Based on a 2010 CSIRO study and simple linear trend assessment of a hydrograph for this bore, the pre-stressed groundwater pressure here is estimated to be around 30 mAHD, equating to a historical drawdown impact of around 40 m. In the immediate vicinity of the borefield, the model estimates further Latrobe Group pressure reductions of 12 m and 14 m for the 3-year and 15-year pumping periods respectively. The cumulative drawdown impact, and thus expected subsidence, is predicted to be minimal compared to the historical stresses. In the unlikely event that subsidence did occur, maximum effects would be limited to the immediate vicinity of the borefield.

In addition, as already discussed, the majority of drawdown will occur at depth within the Latrobe aquifer and is unlikely to exceed 0.5 to 1 m drawdown over the wider area surrounding the project. Groundwater levels will recover quickly post-mining due to the confined nature of the Latrobe Group. Consequently, drawdown in the overlying formations (and resultant subsidence risk) is very low. The Seaspray Group aquitard has predicted drawdown levels at around 0.5 m and the overlying Boisdale Aquifer has drawdown values at only 0.2 m.

Test bore well efficiency – The well construction was considered satisfactory for purpose, and it is noted that the well-efficiency does not influence the derived aquifer parameters. Actual pumping wells would be constructed with high-efficiency well-screens, filter packs and adequately developed to ensure satisfactory performance. It is noted that low efficiency wells do not represent an environmental risk.

2.4. **Existing conditions – local scale mine activities** (Review S.3.1.2)

Section 3.1.2 of the Review identified uncertainty in the risk and consequences of an increased layered complexity, and the resultant perched (layered) system in the Coongulmerang Formation is not described in the conceptual hydrogeological model and not translated into the numerical model and is lacking as a result.

The key issues raised are:

- Potential for seepage to mound from a much higher elevation, with resultant impacts.
- Potential for mounding to interact with various engineered structures (for example TSF and water storage embankments) with implications on their stability.

In addition to the above, Section 3.1.2 of the Review raised uncertainty in the Balook Formation conceptualisation. The key issue raised, assuming a clay unit underlying the Coongulmerang

Formation in the model, is water seepage from mining activities will be unable to vertically dissipate to any significant degree into the Balook Formation. The Review raised that potential implications of this scenario are:

- Nature and extent of the local mounding in the Coongulmerang Formation will be greater, and take longer to dissipate; and
- Less flow (if any) into the groundwater system that is connected to the Mitchell River ASR scheme.

Secondary issues raised in the review were associated with local mine site understanding, and warrant consideration to meet the Scoping Requirements:

- Coongulmerang geochemistry in particular the potential for ASS, to allow an assessment on the changes in groundwater chemistry with increased saturation within the aquifer;
- Potential for, and the existence of, springs emerging from the Coongulmerang aquifer, in particular at the based on the Mitchell River escarpment.

Response:

Perched groundwater - We note that the significance and importance of perching has not been downplayed, but rather was assessed and considered to be low based on the extensive drilling records available. Water strike was a specific objective of the exploration drilling as it is a critical consideration for the mine design, noting that all exploration logging was undertaken by the same qualified and experienced geologist who identified the perched layer at MW07, and installed the monitoring well.

The numerical model is based on the best available data, but cannot reasonably reflect aquifer heterogeneity at a local scale to account for perched groundwater, and in any case the benefits of such for simulating a hypothetical scenario that is not based on real world data would be low.

The model simulates the proposed project based on best available data as well as considering a range of sensitivities and uncertainties. Should any of these uncertainties eventuate and differ materially to the modelled outcome they will be identified early by the groundwater monitoring program, enabling adaptive management actions to be taken.

Mounding and conceptualisation

Additional drilling investigations, undertaken by Kalbar, indicated a potential for the boundary of the Seaspray Group to extend further north and because of the indicated low-permeability of the Seaspray Group, this could have implications for mounding due to tailings seepage to the watertable.

A revised conceptualisation was developed to simulate the potential impacts, and additional modelling was undertaken by EMM to investigate the potential impacts of this. This is reported in Section 6.7.3 and Appendix B of the revised Groundwater and Surface Water Impact Assessment Report (Coffey, 2019). The modelling indicates a greater simulated mound extent across the tailings cells, particularly in the south-western area of the site, compared with the base case, but the modelling does not indicate increased risk of impact to environmental receptors from groundwater mounding alone (EMM, 2019).

Regional mounding is not indicated to be greater than for the base case conceptualisation, as the Seaspray Group minimises the ability of the mound front to move outwards in the south-western section of the project site, and there is no additional mound extent indicated to the north and east (EMM, 2019).

Particle tracking assessment

Mine related seepage impacts were assessed through particle tracking originating from the mine site, to determine if flow paths exist between the mine and the Woodglen ASR site (reported in Section 6.7.4 and Appendix B of the water study). Particle tracking was performed on a no mining scenario (with baseline flows only) a mining scenario with predicted seepage, and groundwater extraction from Woodglen ASR site at the maximum net usage (171 ML/year). Particles were simulated in the

Coongulmerang Formation and Latrobe Valley Group/Balook Formation across the boundaries of the mine footprint and tracked through the duration of mining (EMM, 2019).

Particles originating in the Coongulmerang Formation predominantly travel downwards after release, with some discharging to the Mitchell River floodplain locally. Deeper particles released for the mining scenario show a greater southward flow distance from the western sections of the mine, becoming eastward as they approach the lower transmissivity Seaspray Group (EMM, 2019). The particles move downward into the more transmissive Latrobe Group, and travel south at an increased rate under the prevailing hydraulic gradient.

The seepage and mounding of the watertable due to mining do not result in any significant deviation in particle flow paths towards Woodglen to the north, even with the presence of groundwater extraction from the ASR site (EMM, 2019).

Particle tracking was undertaken on the revised conceptualisation to provide a comparison against the base case. The results are presented in Appendix B and show that the advective particles flowing south from the site are impeded by the modelled extent of the Seaspray Group (EMM, 2019). Additional observations include:

- Regional flow to the south is stopped at the northern edge of the Seaspray Group, and there is limited downward flow into the Latrobe Group; and
- Greater evapotranspiration occurs in the vicinity of the tailings cells due to the increased mounding from seepage.

<u>Acid sulfate soil (ASS)</u>

The potential of ASS is considered in Section 6.3.4 of the Groundwater and Surface Water Impact Assessment Report (Coffey, 2019), which found that the overburden material removed during mining will comprise sands and gravels that have been subject to unsaturated/oxidised conditions on a geologic time scale. Such conditions are generally not conducive to formation of potentially acid sulfate soils (EGI, 2019). The sulfur data for overburden is limited, however the available data allows a first-pass indication in relation to whether the mine site should be considered prospective in terms of coastal ASS. The data available indicate low sulfur contents, and that the ASS risk will also be low, which is consistent with the site being remote from Agriculture Victoria (DEPI, 2002) mapped areas for coastal ASS.

The available data indicates sulfur contents within soil and overburden above the ore zone are low, with most of the profile containing as little as 0.01%S. The sulfur contents of the surface topsoil/subsoil are slightly higher, but within this highly weathered zone it can be assumed that all the sulfur would be oxidised and occur exclusively as sulfate, which does not contribute acid forming potential.

The available data indicates sulfur content within the ore zone is low and the risk in relation to occurrence of ASS will also be low.

<u>Engineering and stability of structures</u>

The potential for impacts due to interaction with groundwater are design issues, and it is noted that structures, foundations and dams will be constructed and engineered in accordance with the appropriate regulations (as detailed in the Groundwater and Surface Water Impact Assessment Report - Coffey, 2019) and to relevant standards.

2.5. Existing conditions – surface water (Review S.3.2)

Section 3.2 of the Review referred to five subordinate reports which link to the surface water elements of the impact assessment and which aim to describe the existing conditions of the regional and local surface water environment. It was noted that this work is summarised in Sections 3 and 4 of the impact assessment report, and is a reasonable summary of the input investigations and summaries.

The Review noted that overall the regional scale description of existing conditions met the Scoping Requirements and was considered sufficient to allow for an assessment of impacts.

At a local scale, potential limitations of the work undertaken were raised:

- Minimal geotechnical and geochemical properties of the project area soils including the potential environmental risks (e.g. potential for erosion, salinity, nutrients and acidification). Whether these aspects are material issues and are a risk to the management of the site is difficult to determine at this time.

- Lack of surface water quality and flow monitoring within the project area. This is understood to have been unavoidable due to the lack of surface water flow over the period of site investigation works, but adds some uncertainty of the existing conditions, and most likely the degree to which the modification of the catchment over the last century (land clearing, plantation, and general agricultural practices) has altered water quality from its former pristine catchment setting.

These were noted as unavoidable data gaps. However, the report would have benefited from an assessment on the significance of these data gaps and assumptions (and their level of conservatism) taken into the impact assessment. Whether the monitoring data gaps are important in terms of defining the water quality range was noted as unknown.

Response:

It is noted that the geotechnical and geochemical aspects of the comments were not within the scope of the groundwater and surface water impact assessment. However erosion has been considered and is detailed in the Surface Water Assessment – Site study report (Water Technology, 2019b) addressing potential erosion, sedimentation and landform change during construction, operation and rehabilitation, decommissioning and post-closure.

In addition the Landscape Stability and Sediment Transport Regime Assessment report (Water Technology, 2019a) addressed key Scoping Requirement questions:

- Potential erosion, sedimentation and landform stability effects during construction, operations, rehabilitation, decommissioning and post-closure.
    - What is the expected behaviour of the landforms, gullies and tributaries, within the context of the various mine phases (construction, operation, rehabilitation, decommissioning and post-closure)?
- Potential erosion, sedimentation and landform stability effects of the project including the direct impact of mining on waterways and their subsequent rehabilitation.
    - What are the likely impacts of the mining project on the adjacent waterways (including sediment transport) and how can they be rehabilitated?

<u>Flow monitoring and sampling</u>

An event based surface water flow monitoring network was established within the ephemeral drainage gullies and creeks within the project area (refer EMM, 2018b). Three sites were nominated for monitoring stream flow and water quality; Lucas Creek, Simpson Gully and the tributary of Honeysuckle Creek (Figure 4 2). Each monitoring location was located directly upstream of a culvert that had been surveyed.

Flow monitoring is ongoing and event-based. Environmental monitoring specialists from Ventia are retained on standby to mobilise during a flow event to collect representative surface water samples from each of the event-based monitoring locations.

A flow event occurred on 3 June 2019 after approximately 25 to 30 mL of rain fell across the project area. Surface water quality results from the flow event are included in Section 4.1. Water quality modelling conducted by Water Technology (2019b) has been updated to take into account results of the flow event and an updated assessment of baseline water quality in ephemeral drainage gullies has been provided in Section 6.6.

2.6. Existing conditions – biodiversity (Review S.3.3)

Section 3.3 of the Review found that the broad ecological assessment of the project area appears to reasonably cover the distribution and quality of native vegetation, terrestrial and aquatic habitat and wildlife movement in the project area.

The Review raised that:

- An assessment not made of biodiversity that would potentially be impacted by extraction of water from the Mitchell River surface water off-take locations.
- Comment regarding the GDE Atlas being likely to overestimate the dependence of aquatic and terrestrial ecosystems on groundwater is not based any factual information, and potentially misleading.
- Site specific GDE desktop mapping (e.g. EHP 2019 and Austral Research Consulting 2019) assessed a large area, but there is risk it does not cover all areas that may be impacted, and that the groundwater mounding may be significantly greater than presented.
- On-ground mapping/surveying or ground truthing of the GDEs was not conducted, therefore questions whether the Scoping Requirements are met in terms of 'appropriate seasonal or targeted surveys'. Furthermore, the potential for unmapped springs and small scale features exists with limiting the assessment to a desktop methodology. Their likelihood and significance are not able to be determined.
- That the GDE assessment did not address:
  - Groundwater quality. The existing groundwater quality that each GDE is connected is not included. This means the impact assessment is unable to comment on the consequences of mounding water quality.
  - GDE value. There is no apparent assessment of each GDE's value and whether there are existing impacts through historic or current land uses. It is considered a reasonable precautionary assumption that all GDEs are of a comparable value.

Response:

Section 8.4.1 of the Groundwater and Surface Water Impact Assessment Report (Coffey, 2019) now deals with surface water extraction from Mitchell River. This section provides our assessment of the potential impacts based on the information available. We expect that SRW will conduct their own risk assessment as part of their assessment of Kalbar's application and will only issue a new licence for the project when satisfied that the risks are acceptably low. Further discussion in relation to the potential impact of extraction of water from the Mitchell River surface water off-take locations is provided in Section 2.9 of this document.

The comment regarding the GDE Atlas being likely to overestimate the dependence of aquatic and terrestrial ecosystems on groundwater has now been removed.

In relation to the extent of the GDE assessment and groundwater mounding extent, we refer to our responses elsewhere in this document – refer Sections 2.4, 2.8 and 2.11.

Field assessment of key GDEs in the riparian area of the lower reach of Moulin Creek was undertaken by Ecology and Heritage Partners (EHP) (Austral, 2019). GDEs in the lower reach of Moulin Creek, north of the project area, have been ground-truthed and an updated assessment of risk posed by groundwater mounding is provided in Sections 3.5.4 and 8.3.2

Discussion in relation to the GDE assessment is provided in Section 2.11 of this document, and in addition the reviewer is referred to Austral (2019) and EHP (2019) for further explanation of the methods. We note that the GDE impact assessment takes into consideration the potential impacts of both groundwater quality and quantity.

2.7. Impact assessment – groundwater (Review S.4.1.1)

Section 4.1.1 of the Review raised aspects of the proposed bore field extraction for further explanation:

- Section 40 of the *Water Act 1989*. Assessment of all matters listed in Section 40 has not been completed in the impact assessment report (Coffey, 2019) and is both possible from the information provided and needed to meet the Scoping Requirements.

- Bore field area. The bore field set-up that was modelled (EMM, 2019) falls outside the bore field area designated in the impact assessment (Coffey, 2019). If the bore field can only lie within the area designed, it will likely constrain the groundwater volume that can be extracted due bore interference effects.

- Production bore efficiency. The pumping test analysis should include an assessment of bore efficiency and the risks that significantly less can be yielded from each bore and thus there may be a need for more bores than currently assumed.

- Subsidence risks. The Seaspray Group which overlies the target aquifer is described as 'moderately' consolidated thus some level of assessment is needed to quantify the level of subsidence risk from long term extraction.

- Chemistry changes. The Seaspray Group which overlies the target aquifer is likely to have a different groundwater chemistry to that of the target Latrobe Group aquifer and there is the potential over time for some level of leakage to occur from Seaspray Group into the Latrobe Group aquifer. The question is whether leakage from the Seaspray Group will materially change the bore field water chemistry entering the mine site, and change various associated assumptions.

Response:

Section 40 of the Water Act - Section 40 specifies matters to be taken into account in relation to applications for bulk entitlement (under Section 36). Kalbar are not applying for bulk entitlement, but for a take and use licence.

Although Section 40 requirements only apply to bulk entitlements, Kalbar accepts that the Minister may take such matters (or similar matters) into consideration, with respect to the abovementioned requirement of Section 51(2)(b). Accordingly, a separate document addressing key Section 40 matters that may be relevant to Ministerial decision making has been provided to support the licence application to be made to SRW. In this document Kalbar demonstrate that their licence application addresses and complies with Section 40 requirements, should the relevant authority adopt such requirements as guidance when assessing the licence application (which they may not, as the application is not for a bulk entitlement).

Bore field area – comments noted.

Production bore efficiency – Production bores would be constructed to best practice design with specified high-flow screen intervals and filter packs. The need to install more bores is a commercial risk, but not an environmental risk.

Subsidence risks – Not a specified requirement in the Scoping Requirements, but now considered in Section 8.3.6 of the Groundwater and Surface Water Impact Assessment Report (Coffey, 2019).

Subsidence risks are very low – refer to response in 2.3 above.

Chemistry changes – Low permeability formations of the Seaspray Group provide hydraulic confinement of the Latrobe Group aquifer. Groundwater modelling has shown that drawdown in the overlying formations, is likely to be very low. The Seaspray Group, which acts as an aquitard, has very low predicted drawdown levels at around 0.5 m, and the risk of water quality impacts are also considered low.

2.8. Impact assessment – mine site activities (Review S.4.1.2)

The Review highlighted uncertainties regarding the local scale hydrogeological conceptualisation and the potential for a more complex system beneath the mine site, and hence that the EMM groundwater model may not be suitable to fully assess the environmental impacts.

The Review raised that the nature and extent of the groundwater mounding, given the assumed seepage loss rates, may be underestimated, and a larger mounding could have the following risks:

- Extended inundation stresses to terrestrial ecology and GDEs;
- Surface water flow and quality changes from mounding daylighting across escarpment and within various local sub-catchments;
- Greater level of mine water management due to mounding entering active pit areas;
- Increased pore pressures on engineered structures and potential impacts to their stability; and
- Reduced ability to meet closure criteria within assumed timelines given the mounding will take longer to dissipate.

Additional modelling was recommended, the outcomes of which to inform the need for an additional, local scale, numerical model to allow an assessment of impacts, management and mitigation strategies and support engineering designs for those risks listed above.

Response:

Based on this, a revised conceptualisation was developed to simulate the potential impacts that could arise due to a more extensive Seaspray Group, and additional modelling was undertaken by EMM to investigate the potential impacts of this (refer Section 6.7 of the updated Groundwater and Surface Water Impact Assessment Report - Coffey, 2019). This is summarised below.

The updated Seaspray Group conceptualisation as represented in the numerical model was incorporated by revising the zone and extent of the Seaspray Group and Latrobe Valley Group, as compared to the previous (base case) conceptualisation (EMM, 2019). This is illustrated in Figure 7.40 in EMM (2019).

The revised conceptualisation considered the potential for the Seaspray Group to extend further north and west than indicated for the Victorian Aquifer Framework, and potentially occurring in the vicinity of the south-western boundary of the site.

Modelling for this scenario indicates a greater simulated mound extent across the tailings cells, particularly in the south-western area of the site, compared with the base case (EMM, 2019). Regionally, the 0.5 m contour is largely unchanged to the north and east but is buffered by the Seaspray Group south of the site, and the modelling does not indicate increased risk of impact to environmental receptors from groundwater mounding alone (EMM, 2019).

The modelling indicated that residual mounding along the south-western portion of the site takes longer to dissipate, as the transmissivity below this area is reduced with the extended Seaspray Group (EMM, 2019). Regional mounding is not indicated to be greater than for the base case conceptualisation, as the Seaspray Group minimises the ability of the mound front to move outwards in the south-western section of the project site, and there is no additional mound extent indicated to the north and east (EMM, 2019).

The extension of the Seaspray Group further to the north and west does not result in significant changes to model calibration or environmental impacts on a regional scale, and from an environmental perspective less water will report to the environment, thereby reducing water level or water quality risks to sensitive receivers.

2.9. Surface Water – water extraction (Review S.4.2.1)

The Review raised issues regarding the two potential Mitchell River off-take locations, and that no assessment and/or modelling of impacts has been undertaken, and that the impact assessment does not include any assessment of the local impacts from extraction within the Mitchell River, and therefore has not met Scoping Requirements. It was raised that this level of assessment is considered relevant for the EES irrespective of whether an allocation can be obtained, and that the impact assessment on the Mitchell River off-take should give consideration of the matters listed in Section 40 of the *Water Act 1989*.

Response:

We refer to the response provided in Section 2.7, above and re-iterate that Section 40 specifies matters to be taken into account in relation to applications for bulk entitlement (under Section 36). Kalbar are not applying for bulk entitlement, but for a take and use licence.

In this, Kalbar demonstrate that their licence application addresses and complies with Section 40 requirements, should the relevant authority adopt such requirements as guidance when assessing the licence application.

In addition, Section 8.4.1 and Section 8.5.1 now deal with surface water extraction from Mitchell River. This section provides our assessment of the potential impacts based on the information available. We expect that SRW will conduct their own risk assessment as part of their assessment of Kalbar's application and will only issue a new licence for the project when satisfied that the risks are acceptably low.

Section 8.4.1 and Section 8.5.1 also considers the potential impact of a winter-fill licence from the Mitchell River leading to:

- Reduced flow rates in the Mitchell River impacting beneficial uses including:
    - Water dependent ecosystems
    - Human consumption (via the EGW's extraction location for potable water supply)
    - Recreational and aesthetic uses of the river
    - Cultural and spiritual values.
- Reduced flow rates in Mitchell River altering water quality (specifically the salinity profile) within Jones Bay and Lake King of the Gippsland Lakes, and potentially affecting aspects of ecosystem health dependent on environmental flows.

As noted in Section 8.4.1 and Section 8.5.1 the potential for impacts is low.

2.10. Surface Water – mine site impacts (Review S.4.2.2)

Section 4.2.2 of the Review provides a commentary on a range of aspects including water modelling and the outputs of such, and notes that although the work done to date is of a standard and quality that is reasonable and highly defendable, the volume of water that is being transferred around the site at any one time means there is little system redundancy, and any project modification or any change in assumption, will result in a significant change in the site water balance.

Section 4.2.2 of the Review also provides a general commentary on the inter-relationship between the EMM modelling, and other specialist studies that rely on its output.

The Review hypothesises that if anything changes, there would be a large project risk, in particular the transfers between the WCP and coarse sand tailings, WCP and MUPs, and WCP and fines tailings. The risk of this water movement changing does not appear to have been addressed, or any clear acknowledgement or strategy in terms of managing 'change'. And can the project be shut down safely if the economics or water resources are reduced or not able to be met in any one year.

Response:

The design of water management infrastructure will be to high standards as detailed elsewhere in the report. It is not accepted that the system redundancy presents risks, or that any project modification or any change in assumption, will result in a significant change.

Such modifications, if undertaken, would necessarily be considered in terms of project risk, and cannot be known in advance. It is accepted that changes in water movement may potentially arise if the project operations were to be changed. It is noted that any such changes would require that the potential effect on water management would need to be considered prior to undertaking any such changes.

2.11. Surface Water – biodiversity (Review S.4.2.3)

The Review raised that the following points may warrant further assessment of the potential impacts to biodiversity:

- Impacts to listed GDEs due to potential changes in groundwater chemistry from the predicted mine seepage;
- Impacts to listed GDEs and terrestrial ecology from an extended duration of inundation (water logging) from rising (mounding) groundwater levels;
- Potential for salinisation of soils and resultant impacts to terrestrial ecology from rising (mounding) groundwater levels; and
- Impacts on aquatic ecology of the Mitchell River from 3 GL/year surface water extraction at either of the two nominated off-take locations.

Response:

The assessment of GDEs was conducted by Austral (2019), and appended to EHP (2019). The following summarises the method.

The assessment of potential impact GDEs focussed on the expected mounding impacts of mine operation and tailings seepage into the shallow aquifer, proximal to the mine site. Although drawdown impacts are expected in other aquifers, the impact to GDEs from the deeper confined aquifers was not assessed for reasons provided in EMM (2019) and the peer review – viz. it is assumed that intervening aquitards provide sufficient barriers to protect the shallow aquifer.

Potential impact to GDEs was based on the EMM (2019) framework, that was in turn adapted from CDM Smith (2015) and Froend and Loomes (2004). The potential impact classification is based on both expected change in depth to water due to groundwater mounding, and the GDE sensitivity to changes in groundwater quality and quantity.

The premise for classification is that dryland ecosystems (Class 5) have the least tolerance for watertable rise, and permanent wetlands (Class 1) have the greatest tolerance. Tolerance for other intermediate ecosystem types fall between these end members.

A gridded surface of predicted watertable mounding under the worst-case scenario at mine end (15 years) was provided by EMM. The target area was defined by the base-case scenario area of impact at the predicted 0.1 m contour.

Hence the method is appropriate for assessing impacts to listed GDEs due to potential changes in groundwater chemistry from mine seepage, as well as impacts resulting from an extended duration of inundation from mounding.

The potential for salinisation of soils and resultant impacts to terrestrial ecology from groundwater mounding is considered low, because the predicted mounding impacts are not considered excessive, and the expected salinity of groundwater is not high. In addition, any impacts that did occur would be transient, because mounding will over time recede, allowing any salts in the upper soil profile to leach to groundwater, as occurs in general saline shallow groundwater settings.

Potential impacts on aquatic ecology of the Mitchell River from 3 GL/year surface water extraction at either of the two nominated off-take locations is discussed in Section 2.6 above.

2.12. Review conclusions

The Review provides a summary of the key points raised in its conclusion section, and responses to these points are addressed in the sections of this document above. For convenience, they are referenced below.

Project Description:

- Absence of design for key water engineering structures, which results in an incomplete understanding of construction, operation and closure risks.
  - **Response** – refer to Section 2.1 above.
- Benefit in providing more detail on the progression of the Project overtime with respect to key activities.
  - **Response** – refer to Section 2.2 above.

Groundwater:

- Two key assumptions to the local mine site hydrogeology are considered to be over simplified or misrepresented in the numerical model and as a consequence the estimate of mounding may be significantly larger in the Coongulmerang Formation than presented.
  - **Response** – refer to Section 2.4 above.
- Groundwater model is not considered suitable to assess mine site scale impacts given the highlighted hydrogeological complexities and it regional scale focus. This could be addressed through increased sensitivity analysis and/or additional predictive scenarios, with an assessment as to whether a different, local scale, model is required to fully assess the mine site activities on the local catchment.
  - **Response** – refer to Section 2.4 above.
- Groundwater extraction scenario should consider all Section 40 (*Water Act 1989*) matters in the impact assessment.
  - **Response** – refer to Section 2.7 above.

Surface Water

- Some minor limitations appear to exist with definition of current conditions due to lack of surface water monitoring possible within proposed mine footprint.
  - **Response** – refer to Section 2.6 above.
- Impact assessment does not include the localised Mitchell River extraction activities, where there is neither the definition of the local off-take conditions or impacts from in-river extraction. As with the groundwater extraction, all Section 40 (*Water Act 1989*) matters should be considered in the impact assessment.
  - **Response** – refer to Section 2.9 above.
- The mine site impact assessment is considered appropriate and commensurate with the site activities, however, given the volumes of water being managed around the site at any one

time are nearly three times the annual inputs required, there is considered to be significant risk in any change in mine plan and no detail on how risk will be managed.

    - **Response** – refer to Section 2.8 and 2.10 above.

Biodiversity

- The assessment of the existing biodiversity across the Project area is broadly appropriate, with the exception of the following aspects: local conditions within the Mitchell River at either of the proposed off-take locations; extent of desktop GDE assessment, given the potential for an increased mounding extent; ground surveys or ground truthing of the desktop GDE assessment, and the potential risk that small scale and local GDEs have been missed.
    - **Response** – refer to Section 2.11 above.
- It has been concluded (Austral, 2019) that any significant increase to period of inundation (from mounding) is likely to impact on ecosystem health and potentially water quality, however no apparent assessment on the implications of this aspect is included in the risk assessment and proposed management and mitigation measures.
    - **Response** – refer to Section 2.11 and 2.8 above.

3. References

AECOM, 2019. Fingerboards Mineral Sands Project - Independent Review of Water Related Studies. Report prepared for DELWP, 2nd July 2019.

Austral, 2019. Groundwater dependent ecosystem report. Report prepared for Ecology and Heritage Partners Pty Ltd.

Coffey, 2019. Fingerboards Mineral Sands Project – Groundwater and surface water impact assessment. September 2019.

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FINGERBOARDS GROUNDWATER MODELLING INDEPENDENT REVIEW

Prepared for:	Kalbar Resources Limited	25 February 2019

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Version 1	11 January 2019	Initial draft re version 4 of EMM report
Version 2	23 January 2019	Updated re version 5 of EMM report
Version 3	4 February 2019	Updated after discussion with EMM on technical issues raised in v2.
Version 4	25 February 2019	Fixed minor typos

THIS REPORT SHOULD BE CITED/ATTRIBUTED AS:

Middlemis H (2019). Fingerboards Groundwater Modelling Independent Review. Prepared by HydroGeoLogic for Kalbar Resources Limited. 25 February 2019.

1. Introduction

This report summarises the outcomes of an independent review of the Fingerboards Mineral Sands Project groundwater modelling studies conducted by EMM Consulting as part of Environmental Effects Statement (EES). The review scope is presented in Appendix C.

This review was conducted by Hugh Middlemis (HydroGeoLogic) in accordance with the best practice principles and procedures of the Australian Groundwater Modelling Guideline ('AGMG'; Barnett et al. 2012), augmented by the recent guidance on uncertainty analysis (Middlemis and Peeters, 2018). The review is summarised by the guideline compliance checklist (Table 1), while the detailed criteria assessment tables are presented in Appendix A and B.

The review process involved an initial review of draft report versions, notably v4 and v5 dated 19 December 2018 and 14 January 2019, and preparation of a draft review report that was discussed with the hydrogeology and modelling staff of EMM Consulting on 4 February 2019. The issues raised related to the report documentation rather than technical/methodology flaws, and these have been addressed during finalisation of the reports, leading to preparation of this brief report.

2. Review Outcome Summary

It is my professional opinion that the Fingerboards groundwater modelling investigation has been conducted with a high degree of professionalism and consistent with best practice, notably the MODFLOW-SURFACT modelling, and the related deterministic predictive scenario sensitivity/uncertainty assessments.

The Fingerboards groundwater modelling studies are suitable for supporting environmental impact assessments and management and mitigation strategies, and for supporting engineering designs and costings and risk management.

The 3D MODFLOW-SURFACT model domain, layer setup, grid design, boundary conditions and parameters applied are consistent with the available information and conceptualisation, with a bias towards conservative assumptions where warranted, appropriate for an environmental assessment. The conceptualisation is mature, based on a range of investigations over many years, and has been implemented competently in the model. The model calibration performance is sound (see further discussion later), and the simulated groundwater flow patterns reflect the hydrogeological conceptualisation.

Table 1 - Groundwater Model Compliance Checklist: 10-point essential summary

Question	Y/N	Comments re Fingerboards groundwater model
1. Are the model objectives and model confidence level classification clearly stated?	Yes	Objectives are well-defined in Section 1. Section 4.1 indicates Class 2 model confidence level, appropriate for impact assessment.
2. Are the objectives satisfied?	Yes	Competent model design and calibration to groundwater levels at 27 bores over 61-year period, and Mitchell River baseflow, demonstrating fitness for purpose. Sensitivity analysis conducted, and targeted uncertainty assessments.
3. Is the conceptual model consistent with objectives and confidence level?	Yes	Conceptualisation is mature, consistent with data, objectives and Class 2 confidence level for mining project impact assessment and management purposes.
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	Report illustrates how previous studies and literature has been carefully considered and combined with the available data to develop a sound conceptual model. Competent hydrogeologists and modellers have evaluated the data, conceptualisation, model design and outcomes.
5. Does the model design conform to best practice?	Yes	The model software, design, extent, layers, grid, boundaries and parameters are a good example of best practice design and execution. Data limitations identified, and a conservative approach has been applied such that potential impacts would be over-estimated. ET extinction depth of 1.2m seems shallow, but 6m setting tested via sensitivity.
6. Is the model calibration satisfactory?	Yes	Transient model calibration performance is acceptable (6% SRMS error using all data). Residual values are mostly less than about 3m in mine area, a few bores up to 6m. Sensitivity and predictive uncertainty analysis conducted.
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Model parameter values consistent with available info and previous studies. Water table contours and time series are matched, and fluxes consistent with river baseflow estimates. Shallow discharge features to coastal boundaries based on sound levels, but less reliable data on significant deep discharge due to offshore extraction.
8. Do the model predictions conform to best practice?	Yes	Impact assessments are interpreted with consideration of risk implications for existing groundwater users, GDEs and sensitive receptors. Overall methodology is consistent with best practice and suitable for guiding management plans and decision making.
9. Is the uncertainty associated with the simulations/predictions reported?	Yes	The hydrogeological conceptualisation and model design and execution process considered structural and data uncertainties, including geology, faulting, rainfall recharge, tailings seepage rates, aquifer parameters, water balances, river baseflow, groundwater level data and effects of offshore extraction. A deterministic predictive scenario sensitivity/uncertainty assessment targeted key parameters
10. Is the model fit for purpose?	Yes	My professional opinion is that the Fingerboards groundwater modelling is a sound example of best practice in design and execution. The model is suitable for supporting environmental impact assessments and management and mitigation strategies, and for supporting engineering designs and costings and risk management.

3. Discussion

The report (EMM Consulting 2019) is well-structured and provides clear explanations of the conceptual model, and the numerical model design and execution.

3.1 Model Confidence Level Classification

Although the "model confidence level classification" is identified as a key issue in the latest groundwater modelling guidelines, there are identified limitations with the concept, as outlined in the draft IESC report on groundwater modelling uncertainty, along with methods to address its limitations (Middlemis and Peeters, 2018, in review).

This review conducted an independent assessment of the model confidence level classification, consistent with the guidelines but based on the method outlined in Middlemis and Peeters (2018), finding that Class 2 confidence level is indeed justified (Table 2). Table 2 indicates that the model exhibits about equal numbers of Class 2 and 3 attributes, indicating that an overall Class 2 model confidence level would be a reasonable classification, confirming the model as suitable for impact assessment scenario modelling purposes.

Table 2 – Fingerboards groundwater model confidence level

Class		Data		Calibration		Prediction		Quantitative Indicators
1 (simple)		Not much / Sparse coverage		Not possible.		Timeframe >> Calibration		Timeframe >10x
		No metered usage.		Large error statistic.		Large stresses/periods.		Stresses >5x
	~	Low resolution topo DEM.		Inadequate data spread.	~	Poor/no validation.	~	Mass balance > 1% (or one-off 5%)
		Poor aquifer geometry.		Targets incompatible with model purpose.		Transient prediction but steady-state calibration.		Properties <> field values.
		Basic/Initial conceptualisation.						No review by Hydro/Modeller.
2 (impact assessment)	√	Some data / OK coverage.		Weak seasonal match.		Timeframe > Calibration		Timeframe = 3-10x
	~	Some usage data/low volumes.		Some long term trends wrong.		Long stress periods.		Stresses = 2-5x
	√	Baseflow estimates. Some K & S measurements.	~	Partial performance (e.g. some stats / part record / model-measure offsets).		OK validation.	√	Mass balance < 1%
	√	Some high res. topo DEM &/or some aquifer geometry.	√	Head & Flux targets used to constrain calibration.		Calib. & prediction consistent (transient or steady-state).		Some properties <> field values. Review by Hydrogeologist.
	~	Sound conceptualisation, reviewed & stress-tested.	√	Non-uniqueness and qualitative uncertainty partially addressed.		Significant new stresses not in calibration.		Some coarse discretisation in key areas of grid or at key times.
3 (complex simulator)	~	Plenty data, good coverage.	~	Good performance stats.	√	Timeframe ~ Calibration	√	Timeframe < 3x
	~	Good metered usage info.	√	Most long term trends matched.	√	Similar stresses & periods.	√	Stresses < 2x
	√	Local climate data.	~	Most seasonal matches OK.		Good validation.		Mass balance < 0.5%
	√	Kh, Kv & Sy measurements from range of tests.		Present day head/flux targets, with good model validation.	√	Transient calibration and prediction.	√~	Properties ~ field measurements.
		High res. topo DEM all areas & good aquifer geometry.	~	Non-uniqueness minimised, qualitative uncertainty justified.			√	No coarse discretisation in key areas (grid or time).
	~	Mature conceptualisation.					√	Review by experienced Modeller.

(after Table 2-1 of Barnett et al (2012) Australian Groundwater Modelling Guideline)

3.2 Model Design, Calibration and Prediction

The semi-regional scale Fingerboards model design and execution has applied the principle of parsimony, with well-reasoned justification, consistent with the modelling guidelines Guiding Principle 3.1 and other statements (Barnett et al. 2012):

- 'The level of detail within the conceptual model should be chosen, based on the modelling objectives, the availability of quality data, knowledge of the groundwater system of interest, and its complexity.'

- 'In regional problems where the focus is on predicting flow, predictions depend on large scale spatial averages of hydraulic conductivity rather than on local variability. Moreover, in large regions there may be insufficient data to resolve or support a more variable representation of hydraulic conductivity. A parsimonious approach may be reasonable, using constant properties over large zones, or throughout a hydrostratigraphic unit.'
- 'Model predictions that integrate larger areas are often less uncertain because characterisation methods are well-suited to discern bulk properties, and field observations directly reflect bulk system properties.'

The uniform spatial distributions of parameter values applied to the Fingerboards model is consistent with the above best practice guidance.

After an initial steady-state ("long term average") warm-up period, the transient history-match calibration extends over 61 years: 1958-2019. The scatter plot of measured versus model groundwater levels (Figure 5.1) includes all calibration period data (not simply for a snapshot in time), and yet the scaled RMS statistical performance criterion of 6% is at the low end of the 5-10% criterion usually considered adequate (Barnett et al. 2012).

The sound calibration performance is achieved not simply on the basis of the SRMS, but simultaneously on other key criteria, consistent with the guidelines, and in the context of the careful model design and spatially uniform parameter distributions:

- using a calibration history match period 1958-2019 that includes substantial hydrological variability (climatic and groundwater stresses including existing users and offshore oil & gas; see sections 2.7 & 2.9);
- aquifer parameters and recharge estimates consistent with available information (Table 2.3; sections 2.7.5, 2.9 & 2.11; Table 5.1 and Figures 4.3 to 4.16);
- flux constraints in terms of existing groundwater extractions (up to 35 ML/d, see Table 5.2; also section 2.9.2 and Figures 2.21-2.23) and consistency with Mitchell River baseflow estimates (sections 2.10 and 5.4.2).

Improvements to the model calibration performance could possibly be achieved with spatial variations in the parameter distributions, and/or with automated PEST methods. However, the effort is not warranted, given the sound calibration performance achieved and parsimonious model design and parameterisation approach applied, including careful design for conservative impact assessments of potential impact pathways to sensitive ecological receptors. The ongoing monitoring program is designed to provide the data in due to course to improve confidence in the model performance.

The 15-year mining period predictive simulations 2020-2034 have a justified focus on assessing the groundwater flow system effects of the proposed mining-related activities, particularly the mounding due to seepage from the tailings placed into the mine path, and the drawdown due to proposed borefield extraction, and effects on Mitchell River alluvials and baseflow. Subsequent 100-year post-mining simulation shows predicted aquifer recovery and low residual impacts.

During mining, the additional 3 GL/yr (or 8.2 ML/d) proposed extraction from the mine water supply borefield in the first 3 years of mining is about 23% of the existing 12.7 GL/yr (or 34.9 ML/d) groundwater user extraction rate (excluding offshore extraction). The additional seepage from tailings and slimes (about 3 GL/yr) is about one tenth of the volume of modelled leakage from the rivers (32.8 GL/yr). This means that the model calibration process involved an effective stress-test in terms of pumping and recharge processes, consistent with the guidelines. The predicted offshore extraction post-2020 was assumed to not have incremental drawdown effects into the future. While this is conservative for impact assessment purposes (i.e. does not over-estimate existing drawdown effects), it may be helpful to test the sensitivity of the predictions to an assumption of the continued effect. The seepage rates from the tailings emplaced in the mine path were based on water balance analysis conducted by others and have not been reviewed.

A coastal drain boundary condition feature was invoked at 1990 to represent the effects of offshore extraction (consistent with GHD 2010). It is arguably apparent (e.g. Figure 5.2 for bore 47063) that the drawdown effect of offshore extraction may have been manifest earlier than 1990. However, the assumption to not extend it prior to 1990 is conservative and justified in terms of a lack of data to otherwise constrain the model settings, and its low sensitivity in terms of its low component of overall water budget. For the prediction scenarios, this drain feature for offshore extraction effects is held at a steady level. This is justified in that the impact assessment results are presented in terms of drawdown due to the Fingerboards project, which is valid whether or not the boundary condition is held constant or some other level condition is assumed into the future. It is noted that the drawdown effects due offshore extraction are significantly greater than the drawdown effects predicted for the Fingerboards project, and that fundamental hydrogeological principles mean that such effects would continue long into the future even if the offshore extraction ceased immediately.

3.3 Sensitivity and Uncertainty Analysis

A calibration sensitivity analysis has been conducted with the Fingerboards model, and the results used to guide a deterministic predictive sensitivity/uncertainty assessment, consistent with best practice guidance (Barnett et al. 2012; Middlemis and Peeters, 2018).

The deterministic predictive scenario sensitivity/uncertainty assessment targeted key parameters. The method applied is the basic level of uncertainty analysis (Middlemis and Peeters, 2018), suitable for projects with a relatively low risk context. It is arguably appropriate in this case, given the scale of the impacts predicted. It is well-supported by the risk-based impact assessment that has been conducted into the water-related impacts on existing users and sensitive receptors and with consideration of GDEs and potential exposure pathways.

Guidance on methods to model climate change scenarios is provided in DELWP (2016), which states at Recommendation 7 that “recent climate is considered to be a better approximation of likely future conditions than GCM projections.” It recommends at Section 4.1 the use of a “current climate baseline from July 1975” to evaluate the effects of climate variability.

The Fingerboards groundwater model history match calibration comprised a 61-year run over the period 1958-2019. This effectively forms a climate baseline that demonstrates that there is a very subdued signal of climatic variability over this extended period when there was substantial hydrological variability, including the Millennium Drought and subsequent record wet 2010-12 wet period. The prediction runs assumed the same recharge, evapotranspiration and river level settings as for the baseline calibration, thus effectively providing a simulation of the potential effects of climate variability. This was augmented by additional simulations that assumed relative changes to recharge and evapotranspiration consistent with other climate change modelling guidance.

The impact assessments, sensitivity and uncertainty analyses and interpretations are supported by the data available and the evidence presented, and the ongoing hydrogeological investigations will provide additional data for future model refinements and improvements in performance (e.g. comprehensive transient calibration) and for further uncertainty analysis that should be used to guide monitoring, management and mitigation programs.

4. Conclusion

This independent review finds that the Fingerboards groundwater modelling is fit for the purpose of environmental impact assessment and informing management and mitigation strategies, and for supporting engineering designs and costings and risk management.

The ongoing hydrogeological investigations will provide additional data for future model refinements and improvements in performance and for further uncertainty analysis that should be used to guide monitoring and management programs.

5. Declarations

No potential conflict of interest is identified by the reviewer, but for the record and in the interest of full disclosure, we note the following:

- Hugh Middlemis is an engineer, hydrogeologist and independent modelling specialist with more than 37 years' experience across Australia and internationally. He established HydroGeoLogic in Adelaide in 2014 as an independent consultancy after 15 years with Aquaterra based in Perth and Adelaide. Hugh was principal author of the first Australian groundwater modelling guidelines (Middlemis et al. 2001) that formed the basis for the latest guidelines (Barnett et al. 2012) and he was awarded a Churchill Fellowship in 2004 to benchmark groundwater modelling best practice. Hugh has also co-authored a guideline on groundwater modelling uncertainty analysis (Middlemis and Peeters, 2018).
- Hugh has previously worked with the current EMM Consulting hydrogeologists while they worked at Aquaterra (Adelaide): Joel Georgiou (2002-2011) and Doug Weatherill (2004-2009).
- Hugh has not previously worked for Kalbar Resources or on the Fingerboards project.
- Hugh is currently engaged by EMM Consulting to peer review the MODFLOW groundwater model being developed by them for the Snowy 2.0 pumped hydro EIS, and the FEFLOW model being developed by CloudGMS to inform Snowy Hydro Ltd geotechnical engineering investigations.
- Hugh provided independent review services to EMM Consulting in 2016 on the Chandler Salt Project (NT).
- Hugh was appointed by Southern Rural Water to the Independent Technical Review Panel on the Barwon Downs borefield investigations being conducted by Barwon Water and their consultants.

6. References

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Middlemis H and Peeters LJM (2018). Uncertainty Analysis — Guidance for groundwater modelling within a risk management framework. Prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia.
www.iesc.environment.gov.au/publications/information-guidelines-explanatory-note-uncertainty-analysis

Fingerboards Project Groundwater Model Independent Review

Project Reviewed:	**Fingerboards Mineral Sands**
Independent Reviewer:	Hugh Middlemis, 4 February 2019
Evidentiary Basis:	EMM Consulting (2019). Fingerboards Groundwater Modelling Report. Prepared for Kalbar Resources. Version 5. 14 January 2019.

Australian Groundwater Modelling Guidelines ('AGMG'; Barnett et al, 2012) formed the principal criteria for the review, notably the guideline checklists (Tables 9-1 & 9-2), augmented by the uncertainty analysis guidance ('UAG'; Middlemis and Peeters, 2018).

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A. and Boronkay A. (2012). ***Australian Groundwater Modelling Guidelines***. Waterlines report 82, National Water Commission, Canberra. http://webarchive.nla.gov.au/gov/20160615064846/http://archive.nwc.gov.au/library/waterlines/82

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Table A-1: Compliance Checklist: 10-point essential model study attributes list, summarising overall compliance

Essential Compliance Question	*Yes/No*
1. Are the model objectives and model confidence level classification clearly stated?	Yes
2. Are the objectives satisfied?	Yes
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes
5. Does the model design conform to best practice?	Yes
6. Is the model calibration satisfactory?	Yes
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes
8. Do the model predictions conform to best practice?	Yes
9. Is the uncertainty associated with the predictions reported?	Yes
10. Is the model fit for purpose?	Yes

Table A-2: Review criteria on detailed compliance issues

	Review questions	*NA or not known*	*'Deficient' or 'No'*	*'Missing' or 'Maybe'*	*'Adequate' or 'OK'*	*'Very Good' or 'Yes'*	***Comment / Objective Evidence re Fingerboards Project***
1.	**Planning**						
1.1	Are the project objectives stated?					Very good	s.1 – mineral sands mining project EES and BFS
1.2	Are the model objectives stated?					Very good	s.1 – for groundwater impact assessment to meet EES Scoping and Technical Reference Group (TRG) requirements; https://www.planning.vic.gov.au/environment-assessment/browse-projects/projects/fingerboards-mineral-sands#overview
1.3	Is it clear how the model will contribute to meeting the project objectives?					Very good	s.1 - focus on predicted groundwater drawdown/mounding and water balance changes during mining and post-mining, and related effects on existing users and ecological receptors, and assessment of uncertainties. s.3.6 – model also used to inform the GDE management strategy.
1.4	Is a groundwater model the best option to address the project and model objectives?					Yes	Best practice methods have been applied
1.5	Is the target model confidence-level classification stated and justified?					Yes	s.4.1 – Class 2 model, suitable for impact assessment
1.6	Are the planned limitations and exclusions of the model stated?					Very good	s.4.10, s.9.
2.	**Conceptualisation**						Section 2.
2.1	Has a literature review been completed, including examination of prior investigations?					Very good	Section 2, Table 2.1
2.2	Is the aquifer system adequately described?					Very good	s.2, esp. s.2.7
2.2.1	Hydrostratigraphy including aquifer type (porous, fractured rock)					Yes	s.2.7, figure 2.5
2.2.2	Lateral extent, boundaries and significant internal features such as faults and regional folds					Yes	s.2.6, s2.7, Figure 2.24 to 2.26
2.2.3	Aquifer geometry including layer elevations and thicknesses					Yes	s.2.7, figures 2.7 & 2.8
2.2.4	Confined or unconfined flow and the variation of these conditions in space and time?					Yes	s.2.7
2.3	Have data on groundwater stresses been collected and analysed?					Yes	s.2.9
2.3.1	Recharge from rainfall, irrigation, floods, lakes					Yes	s.2.9, order of 25 to 70 mm/yr
2.3.2	River or lake stage heights					Yes	s.2.10, Figures 2.29 to 2.31

	Review questions	*NA or not known*	*'Deficient' or 'No'*	*'Missing' or 'Maybe'*	*'Adequate' or 'OK'*	*'Very Good' or 'Yes'*	***Comment / Objective Evidence re Fingerboards Project***
2.3.3	Groundwater usage (pumping, returns etc)					Yes	s.2.9.2, Table 2.6, Figures 2.21 to 2.23 and 2.24 to 2.26
2.3.4	Evapotranspiration					Yes	s.2.9.2, max of 500 mm/yr, ok for ET from water table
2.3.5	Other?					Yes	Bass Strait oil & gas extraction effects (Figures 2.24 to 2.26).
2.4	Have groundwater level observations been collected and analysed?					Yes	s.2.7.4, Figures 2.11 to 2.19
2.4.1	Selection of representative bore hydrographs					Yes	Figure 2.18
2.4.2	Comparison of hydrographs					Yes	Figure 2.18
2.4.3	Effect of stresses on hydrographs					Yes	Figure 2.18, Figures 2.24 to 2.26
2.4.4	Water table maps/piezometric surfaces?					Very good	s.2.7.4, Figures 2.11 to 2.17
2.4.5	If relevant, are density and barometric effects taken into account for interpretation of groundwater head & flow data?					NR	
2.5	Have flow observations been collected and analysed?					Yes	s.2.9.2; s.2.10;
2.5.1	Baseflow in rivers					Very good	s.2.10
2.5.2	Discharge in springs	Not known					Springs not identified as key features
2.5.3	Location of diffuse discharge areas?					Yes	Groundwater discharge to lakes and coast. Mining is above water table, but tailings placement in mine path likely to cause water table mounding.
2.6	Is the measurement error or data uncertainty reported?				Adequate		Discussed where measurement is important, such as flow gauging on the Mitchell River and reported erroneous data at Rose Hill (s.2.10).
2.6.1	Measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)				Adequate		See 2.6
2.6.2	Spatial variability/heterogeneity of parameters				OK		Spatially uniform distributions in model, consistent with best practice parsimonious approach (AGMG guiding principle 3.1).
2.6.3	Interpolation algorithm(s) and uncertainty of gridded data?	Not known					Not an issue with modern software and 50-200m grid discretisation.
2.7	**Have consistent data units and geometric datum been used?**					Yes	
2.8	**Is there a clear description of the conceptual model?**					Very good	s.2.12
2.8.1	Is there a graphical representation of the conceptual model?					Very good	Figures 2.43 to 2.44

	Review questions	NA or not known	'Deficient' or 'No'	'Missing' or 'Maybe'	'Adequate' or 'OK'	'Very Good' or 'Yes'	Comment / Objective Evidence re Fingerboards Project
2.8.2	Is the conceptual model based on all available, relevant data?					Yes	Key features well shown, but draft could be improved with annotations re water balance and aquifer properties.
2.9	**Is the conceptual model consistent with the model objectives and target model confidence level classification?**					Very good	Geology, hydrology and hydrogeology all considered, along with risk-based assessment of water effects on existing users and sensitive receptors (s.3) and with consideration of GDEs and potential exposure pathways.
2.9.1	Are the relevant processes identified?					Yes	s.2.12, Figs 2.43-2.44
2.9.2	Is justification provided for omission or simplification of processes?				Adequate		Some processes simplified to a reasonable degree (e.g. baseflow, given issues with data quality).
2.10	Have alternative conceptual models been investigated?				OK		Not strictly reported as such, but report includes discussion of previous investigations over many years in the area, so low risk of need for alternative conceptual models.
3.	**Design and construction**						Sections 2, 3 and 4.
3.1	**Is the design consistent with the conceptual model?**					Yes	s.2, s.3.
3.2	**Is the choice of numerical method and software appropriate?**					Very good	s.4.2. Modflow-Surfact with Vistas 7.
3.2.1	Are the numerical and discretisation methods appropriate?					Yes	s.4.2. Includes adaptive time stepping applied to ensure numerical stability and unsaturated zone capability of MODFLOW-SURFACT.
3.2.2	Is the software reputable?					Yes	One of top five in industry.
3.2.3	Is the software included in the archive or are references to the software provided?					Yes	References provided.
3.3	**Are the spatial domain and discretisation appropriate?**					Yes	s.4: 50x50km domain. 11 layers. Finite difference grid of 50-200m cells.
3.3.1	1D/2D/3D?					Yes	3D
3.3.2	Lateral extent?					Yes	s.4: 50x50km, boundaries distant from mining area and extend to coast. Appropriate physical boundaries to north and south.
3.3.3	Layer geometry?					Yes	s.4.3, Figures 4.3 to 4.16. 11 layers. Designed for impact assessment purposes.
3.3.4	Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?					Yes	s.4.4 & Fig 4.1; minimum cell size 50m in mine area and proposed borefield, and 200m max. regionally.
3.3.5	Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of					Yes	s.4.5 - Layering based on VAF state-wide 3D aquifer surfaces, and consistent with previous studies, but refined where improved data is available.

	Review questions	*NA or not known*	*'Deficient' or 'No'*	*'Missing' or 'Maybe'*	*'Adequate' or 'OK'*	*'Very Good' or 'Yes'*	**Comment / Objective Evidence re Fingerboards Project**
	propagation of responses in the vertical direction?						
3.4	**Are the temporal domain and discretisation appropriate?**					Yes	
3.4.1	Steady state or transient?					Yes	s.4.9. Pseudo-steady state warm up, then transient calibration 1958-2019. Transient mine predictions 2020-2034. Post-mining 100 year recovery.
3.4.2	Stress periods?					Yes	s.4.9. Annual
3.4.3	Time steps?					Yes	s.4.2. Adaptive time stepping
3.5	**Are the boundary conditions plausible and sufficiently unrestrictive?**					Yes	s.4.7 and Figure 4.17. Mostly OK; ET question below.
3.5.1	Is the implementation of boundary conditions consistent with the conceptual model?				Adequate		s.4.7. Includes drain cells to allow for historical and ongoing extraction off-shore, and extraction from existing/licensed on-shore groundwater users. ET extinction depth 1.2m may be too shallow given topo data set resolution (VAF DEM; s.4.10). Sensitivity run 6m ET extinction depth OK.
3.5.2	Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?				Adequate		Boundaries have been established distant from the mine area, and figures in s.7 show that predicted drawdown generally does not extend to boundaries, except for the northern boundary in some aquifers/layers, which is the physical extent of the productive coastal plain aquifers and thus reasonable. Coastal boundary conditions also attempt to represent continued extraction of-shore and related drawdown effects at boundary (similar to GHD 2010, which was independently reviewed). s.4.7. Long term average river levels applied, to conservatively simulate long term effects of mining (not dynamic seasonal effects). River stage level based on long term levels (interpolated between data points from agency data) and river bed assumed at 2m depth; all OK.
3.5.3	Is the calculation of diffuse recharge consistent with model objectives and confidence level?					Very good	Diffuse recharge rates at annual average rates (25 mm/yr, s.4.7), enhanced at mine site tailings storage. Time series plots suggest little actual potential for significant episodic recharge. No flood recharge applied, but Mitchell River alluvium receives 50mm/yr recharge (s.4.10). Calibration sensitivity to recharge has been tested (s.6).
3.5.4	Are lateral boundaries time-invariant?				OK		Time invariant, except southern/coastal boundary in layers 10 & 11, to represent the continued drawdown effect due to off-shore extraction.
3.6	**Are the initial conditions appropriate?**					Yes	s.4.9. Pseudo-steady state warm up.
3.6.1	Are the initial heads based on interpolation or on groundwater modelling?					Very good	s.4.9. Modelling, pseudo-steady state initial stress period.
3.6.2	Is the effect of initial conditions on key model outcomes assessed?	Not known					s.4.8. Iterative model runs applied, with feedback of final conditions to inform initial conditions during refinement (good practice).
3.6.3	How is the initial concentration of solutes obtained (when relevant)?	NA					No solute transport.

	Review questions	NA or not known	'Deficient' or 'No'	'Missing' or 'Maybe'	'Adequate' or 'OK'	'Very Good' or 'Yes'	Comment / Objective Evidence re Fingerboards Project
3.7	**Is the numerical solution of the model adequate?**					Yes	
3.7.2	Solution method/solver					Very good	PCG4 (s.4.2)
3.7.2	Convergence criteria	Not known					Presumably ok, because 0.6% model water balance error term (Table 5.2).
3.7.3	Numerical precision	Not known					Presumably ok, because 0.6% model water balance error term (Table 5.2).
4.	**Calibration and sensitivity**						s.5, s.6.
4.1	**Are all available types of observations used for calibration?**					Yes	s.5.4. Groundwater levels, Mitchell River baseflow estimates.
4.1.1	Groundwater head data					Yes	Fig. 5.1. SRMS 6%. All available groundwater level data has been used. Some apparent bias to over-predict levels at high elevations (>20mAHD). Time series plots very good (Figure 5.2). Little apparent transient response, which means that the average annual recharge and river level approach is OK over calibration period 1958-2019, which contains substantial hydrological variability, including pumping stress (i.e. non-uniqueness not a big issue in this case). Thus there appears to be very little climatic variability signal in the groundwater system. .
4.1.2	Flux observations				Adequate		s.5.4.2. Baseflow in Mitchell River; noting also that the calibration is constrained by flux in terms of data on existing abstractions. Fluxes appear consistent with data; possible exception of offshore extraction not extending back before 1990, but there is no data before that time that could be used to constrain the calibration, so assumptions OK.
4.1.3	Other: environmental tracers, gradients, age, temperature, concentrations etc.				Adequate		Consideration of previous studies, notably GHD 2010, which applied the Vic DPI estimate of recharge from the EnSym model.
4.2	**Does the calibration methodology conform to best practice?**				Adequate		
4.2.1	Parameterisation					Yes	s.4.6. Parsimonious parameterisation applied, consistent with best practice
4.2.2	Objective functions					Yes	s.5. Best practice KPIs applied.
4.2.3	Identifiability of parameters			Missing			Draft report does not consider identifiability (ignoring is common practice).
4.2.4	Which methodology is used for model calibration?				OK		s.5. Traditional best practice method of successive approximation. Calibration history match period 1958-2019 includes substantial hydrological variability (climatic and groundwater stresses including existing users and offshore oil & gas; see sections 2.7 & 2.9).
4.3	**Is a sensitivity of key model outcomes assessed against?**				Adequate		s.6
4.3.1	Parameters				Adequate		Table 6.1 – Sensitivity testing of Kh & Kv for key units showing low sensitivity. ET extinction depth sensitivity test to 6m.

	Review questions	*NA or not known*	*'Deficient' or 'No'*	*'Missing' or 'Maybe'*	*'Adequate' or 'OK'*	*'Very Good' or 'Yes'*	*Comment / Objective Evidence re Fingerboards Project*
4.3.2	Boundary conditions				OK		Not tested for sensitivity, but most boundary conditions appear to be ok in design terms, and demonstrated low climate variability signal.
4.3.3	Initial conditions				OK		s.4.9. Pseudo-steady state warm up means low risk of sensitivity.
4.3.4	Stresses					Yes	Recharge rate tests show high sensitivity (Fig.6.11), but adopted calibration is justified by match to Mitchell River baseflow.
4.4	**Have the calibration results been adequately reported?**				OK		
4.4.1	Are there graphs showing modelled and observed hydrographs at an appropriate scale?				OK		Figure 5.2 shows 27 time series plots, with good spatial distribution.
4.4.2	Is it clear whether observed or assumed vertical head gradients have been replicated by the model?			Maybe			Little discussion in report of vertical gradients, except at s.7.8, although there is some suitable data for assessment. Results show effect of regional thick aquitard in limiting upward transmission of drawdown effects, so low risk of material effects being manifest in this way.
4.4.3	Are calibration statistics reported and illustrated in a reasonable manner?					Very good	Figure 5.1 SRMS=6% (all data used). Figure 5.3 error bubble plot.
4.5	**Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?**					Yes	See 4.4.3 above and comments below.
4.5.1	Spatially					Yes	Fig. 5.3 calibration error bubble plot shows spatial variations. Could be improved with modelled contour levels
4.5.2	Temporally				OK		See also 4.4.1.
4.6	**Are the calibrated parameters plausible?**					Yes	Aquifer parameters and recharge estimates consistent with available information (Table 2.3; sections 2.7.5, 2.9 & 2.11; Table 5.1 & Fig 4.3-4.16).
4.7	**Are the water volumes and fluxes in the water balance realistic?**				OK		s.5.4. Fluxes OK in terms of existing groundwater extractions (up to 35 ML/d, see Table 5.2; also, section 2.9.2 and Figures 2.21-2.23) and consistency with Mitchell River baseflow estimates (s.2.10 & s.5.4.2). The coastal drain feature to represent the effects of offshore extraction is invoked at 1990 (consistent with GHD 2010). But it is apparent from Figure 5.2 for bore 47063 that the drawdown effect of offshore extraction may have been manifest earlier than 1990. This assumption is conservative and justified in terms of a lack of data to otherwise constrain assumptions about extending it backwards in time, and the low sensitivity expected given its low component of overall water budget.
4.8	**Has the model been verified?**				OK		Not strictly verified, but OK in the sense that it benchmarks against the GHD 2010 model, which was independently reviewed by Dr Noel Merrick.
5.	**Prediction**						Section 7
5.1	**Are the model predictions designed in a manner that meets the model objectives?**					Yes	s.7.1. Focus on groundwater flow system effects in terms of levels and fluxes and identified GDEs and sensitive receptors.

	Review questions	*NA or not known*	*'Deficient' or 'No'*	*'Missing' or 'Maybe'*	*'Adequate' or 'OK'*	*'Very Good' or 'Yes'*	***Comment / Objective Evidence re Fingerboards Project***
5.2	**Is predictive uncertainty acknowledged and addressed?**				Adequate		See item 6 below.
5.3	**Are the assumed climatic stresses appropriate?**					Yes	s.7.5. Continuation of calibration period stresses on annual basis, although drain feature for offshore extraction effect holds steady level (OK in that impact assessment results are presented in terms of drawdown due to Fingerboards project, which is valid whether or not the boundary condition is held constant or some other level condition is assumed into the future).
5.4	**Is a null scenario defined?**					Yes	s.7.6. Non-mining null scenario and difference assessments applied.
5.5	**Are the scenarios defined in accordance with the model objectives and confidence level classification?**					Yes	Appropriate for model complexity and impact assessment purpose.
5.5.1	Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?					Yes	s.7.5. Additional 3 GL/yr (or 8.2 ML/d) pumping from proposed borefield for mine water supply in first 3 years of mining is about 23% of the existing groundwater user extraction rate (excluding offshore extraction) that was part of the calibration. Note that model drain features shows that offshore extraction is almost double existing onshore groundwater use, although both elements are not large components of the water balance.
5.5.2	Are well losses accounted for when estimating maximum pumping rates per well?	Not known					Not an issue for impact assessment purposes, and FWL package applied (s.4.7) to manage pumping rates and permissible drawdown constraints.
5.5.3	Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?					Yes	s.5. 61-year calibration period 1958-2019. 15-year prediction 2020-2034. All OK. 100-year post-mining prediction also acceptable.
5.5.4	Are the assumed stresses and timescale appropriate for the stated objectives?					Yes	See also 4.7 & 5.5.1 above. Offshore extraction assumed to not have incremental drawdown effects into future. Seepage rates from tailings in mine path were based on water balance analysis conducted by others.
5.6	**Do the prediction results meet the stated objectives?**					Yes	s.7.6-7.8 and related figures. Groundwater system effects illustrated well in terms of drawdown due to borefield pumping, mounding due to tailings seepage, and effects on Mitchell River alluvials and baseflow. The effects of the predictive sensitivity scenarios are very well-presented and explained in s.8. Calibration history match confirms little climate signal in groundwater system, and assumption about continuation of long term average recharge, ET and river level conditions for prediction runs is consistent with DELWP 2015 guidance that repeated "*current climate baseline from July 1975*" is adequate to evaluate climate variability effects.
5.7	**Are the components of the predicted mass balance realistic?**				OK		

	Review questions	NA or not known	'Deficient' or 'No'	'Missing' or 'Maybe'	'Adequate' or 'OK'	'Very Good' or 'Yes'	Comment / Objective Evidence re Fingerboards Project
5.7.1	Are the pumping rates assigned in the input files equal to the modelled pumping rates?				OK		Presumably (model data files not examined). Application of the FWL package (s.4.7) is designed to manage extractions when groundwater levels draw down significantly, and s.5.4 describes some model checks implemented in that regard.
5.7.2	Does predicted seepage to or from a river exceed measured or expected river flow?				OK		Not apparent from benchmarking of model results against estimated baseflow volumes, which are less than river flow data.
5.7.3	Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?				OK		None are obvious/apparent.
5.7.4	Is diffuse recharge from rainfall smaller than rainfall?				OK		Not apparent.
5.7.5	Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?				OK		Not apparent.
5.8	**Has particle tracking been considered as an alternative to solute transport modelling?**	NA					Solute transport and particle tracking not conducted.
6.	**Uncertainty**				Adequate		s.8
6.1	**Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?**					Yes	s.8 "Uncertainty Analysis" presents the results of a deterministic predictive scenario sensitivity analysis (i.e. probabilities are not assessed). The measures considered are appropriate, including SRMS, drawdown and mounding impacts for base case and best and worst cases, percentage changes to water balance components and baseflows. As the calibration sensitivity analysis show generally low parameter sensitivity, it is not surprising that the predictive scenario sensitivity analysis also showed low sensitivity to Kh & Kv, and high sensitivity to recharge. An additional scenario was run assess the effects of extending the proposed borefield extraction from 3 to 15 years. See comments at item 4.1.1 about low climatic variability signal in the groundwater system.
6.2	**Is the model with minimum prediction-error variance chosen for each prediction?**				OK		Effectively, yes, as the calibration sensitivity analysis identified that the adopted calibration provides the best match to river baseflow estimates as well as the statistical SRMS measure used as a simple KPI for the sensitivity analysis.
6.3	**Are the sources of uncertainty discussed?**				Adequate		e.g. s.2 when discussing data sources, and s.3 when discussing the risk-based approach to the sensitive receptors assessment, and s.4.10 and s.9 when discussing the modelling assumptions and limitations.
6.3.1	Measurement of uncertainty of observations and parameters				Adequate		See item 6.3.

	Review questions	*NA or not known*	*'Deficient' or 'No'*	*'Missing' or 'Maybe'*	*'Adequate' or 'OK'*	*'Very Good' or 'Yes'*	***Comment / Objective Evidence re Fingerboards Project***
6.3.2	Structural or model uncertainty				OK		Not strictly discussed, but the report includes discussion of previous investigations over many years in the area, so there is a low risk of the need for uncertainty analysis with alternative conceptual models.
6.4	**Is the approach to estimation of uncertainty described and appropriate?**				OK		The deterministic predictive scenario sensitivity analysis applied is the basic level of uncertainty analysis, suitable for projects with a relatively low risk context, and arguably appropriate in this case.
6.5	**Are there useful depictions of uncertainty?**					Yes	Overall, the results provide a reasonable indication of the base case and the best and worst case predictions, thus bracketing the range of predicted effects for the parameters/scenarios tested. Results are presented in Tables (8.1 to 8.5) and Figures (8.1 to 8.16), plus commentary in s.8.
7.	**Solute transport**	NA					Solute transport not conducted.
8.	**Surface water–groundwater interaction**						Sections 2.9, 2.10, 2.12, 3.4.1, 4.7, 5.4.2 & 7 and related figures & tables.
8.1	**Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?**					Yes	Surface and groundwater interactions were analysed using topography, stream flow data and baseflow estimation methods, stream and lake level data, groundwater levels and salinity. Also informed by previous studies (e.g. GHD 2010).
8.2	**Is the implementation of surface water–groundwater interaction appropriate?**					Yes	Appropriate features were used for streams based on data available, and allowing for riparian ET, with benchmarking to measured data, and sensitivity testing of parameters including ET extinction depth to 6m to help compensate for topo data uncertainty).
8.3	**Is the groundwater model coupled with a surface water model?**				OK		Not dynamically coupled. Average annual river and lake levels applied.
8.3.1	Is the adopted approach appropriate?					Yes	See items above
8.3.2	Have appropriate time steps and stress periods been adopted?					Yes	See items above
8.3.3	Are the interface fluxes consistent between the groundwater and surface water models?					Yes	e.g. benchmarking to river baseflow estimates.

Is there evidence of engagement ('without prejudice') between the project proponent and regulatory agencies, from the project outset and at subsequent key stages (Figure 3): • to discuss and agree on the project objectives and the modelling objectives? • to discuss and agree on the uncertainty analysis methodologies, including the nature and scope of the (minimum requirement) qualitative uncertainty analysis, and the quantitative uncertainty analysis for high-risk projects? • to review the reporting on the modelling and uncertainty analyses? • to agree on justifications of assumptions/criteria applied to implement the methodology? • to understand the implications of the results in terms of environmental decision-making? • to identify whether an independent technical review of the modelling and/or the uncertainty analysis is warranted?	Yes. Section 1 of report identifies consultation with DEWLP and TRG. EES scoping and Consultation Plans on DELWP website: https://www.planning.vic.gov.au/environment-assessment/browse-projects/projects/fingerboards-mineral-sands#overview It is not known for certain whether these methods, assumptions and criteria have been specifically discussed and agreed with the TRG.
Is the modelling and uncertainty analysis methodology designed to provide information for decision makers on the effects of uncertainty on the project objectives (echoing the definition of risk in AS/NZS ISO31000:2009) and on the effects of potential bias?	Yes. Section 8 describes the deterministic predictive scenario sensitivity analysis that has been applied. This basic level of uncertainty analysis is suitable for projects with a relatively low risk context (arguably appropriate in this case).
Are the adopted conceptual model, complexity–simplicity balance and applied modelling package capabilities commensurate with the overall risk context and the model purpose of investigating the uncertainty/risk issues (i.e. based on the evidence available of engagement identified in item 1)?	Yes. A conservative approach has been applied to the model design and execution for the purpose of impact assessment with a focus on potential impact pathways to GDEs and sensitive receptors. Parsimonious approach to spatially uniform aquifer parameters, and sound model calibration performance.
Has the uncertainty assessment and modelling methodology been designed and implemented using all the available data? Detailed consideration of the hydrological stressors arising from the development and of natural stressors, including climate variability, and unbiased consideration of water-related asset values and causal pathways for potential impacts (direct, indirect and cumulative) should be provided.	Yes, adequately described in section 8 (Uncertainty Analysis) for the predictive scenario sensitivity analysis that has been conducted.
Where history-match conditional calibration is undertaken, has it minimised non-uniqueness and error variance (using approaches recommended in the AGMG)? If not, is a reasoned justification provided? Is an acceptable level of model-to-measurement mismatch defined for the conditional calibration?	Yes. Non-uniqueness addressed with calibration constrained by flux estimates (baseflows and existing extractions, plus accepted wisdom on recharge and ET estimates). Error variance not considered because PEST methods not used. But calibration sensitivity analysis identified that the adopted calibration provides the best match to river baseflow estimates as well as the statistical SRMS measure and other KPIs.
Are all simulations consistent with all relevant information/data (using approaches recommended in the AGMG)? If not, is a reasoned justification provided?	Yes. Section 2 and Table 2.1 summarise the data sources. Robust model calibration performance has been achieved.
Has the model been submitted to stress testing in which a number of extreme parameter combinations (representing a computationally intensive automated conditional calibration or stochastic model evaluation) are tested for model convergence?	No. Automated calibration not applied (see also comments re calibration at item 4 in Appendix A above). However, model calibration over 61 years 1958-2018, covers a wide range of climatic and other stresses, which is a reasonable stress test.
Has a parameter sensitivity analysis and/or a parameter identifiability analysis been completed to identify which parameters can be constrained by the available observations and which parameters affect the simulations the most? Are the implications discussed?	Calibration Sensitivity Analysis is well-documented at Section 6, and Uncertainty Analysis at Section 8. Report does not consider identifiability (ignoring it is common practice, and best conducted only when PEST methods are used). Implications of the predictive scenario sensitivity analyses that have been conducted are well presented.
Have all reports been prepared in an open, honest and transparent way that is: • open to independent scrutiny and not prone to misinterpretation based on agreed and transparent model objectives • tailored to decision-makers' needs (focusing on messages relevant to their decisions) • presented in plain and clear language (precise, jargon-free, calibrated), with useful graphics.	Yes.

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Request for Proposal

Groundwater Modelling Peer Review

Introduction

Kalbar Resources Ltd (Kalbar) is developing the Fingerboards Minerals Sands Project (the project). The Fingerboards Project lies within the greater Glenaladale Mineral Sands Deposit located about 20 km west of the town of Bairnsdale in East Gippsland, Victoria. The Fingerboards Project, which is defined as a 20 year mining project life targeting the higher-grade Upper mineralised units, is now the focus of an Environmental Effects Statement (EES) and a Bankable Feasibility Study (BFS).

As part of the EES, Kalbar Resources Ltd (Kalbar) engaged EMM Consulting Pty Ltd (EMM) to undertake the groundwater modelling component of the groundwater impact assessment, which aims to determine the effects the proposed mine operations may have on the existing groundwater system and its receptors.

The draft Fingerboards Project EES has been reviewed by the Technical Reference Group (TRG), which has submitted comments to be addressed prior to submission of the EES.

Kalbar now requires independent peer review of the groundwater modelling conducted in support of the EES, to identify its fitness for purpose.

Scope

Kalbar requires an independent desktop-based peer review of the groundwater modelling, and associated documentation, carried out in support of the EES, to identify its fitness for purpose. The review should be conducted with reference to the Australian Groundwater Modelling Guidelines (Barnett et al, 2012) and address the modelling and documentation submitted to the TRG as well as any modifications and/or response to the TRG leading to the final EES submission.

Specific tasks to be covered by the review are:

- Review of the conceptual model and supporting data and its implementation (via design of model layers, grid, boundary conditions and temporal discretisation) in the numerical model with reference to the modelling objectives and the project's Scoping Requirements;
- Evaluation of the model's calibration performance and suitability of the model as a predictive tool;
- Review of predictive modelling and uncertainty analysis;
- Review of model documentation with commentary on whether it meets industry requirements; and
- Provision of any further advice in relation to the modelling, or future modelling of the project, that may be of benefit.

In addition the standard model review requirements listed above, Kalbar would like the independent reviewer to provide review comments against the recent TRG review. In summary, the TRG noted the following:

- more thorough description on all identified receptors including ASR bores, springs, 3rd party users etc;
- more detail on exclusions and limitations on the current understanding of the conceptual model;
- update report text related to field and laboratory based aquifer/aquitard permeabilities, including results on new core data and how this has been included within the model study;
- update reporting text to explain how recharge and evapotranspiration are calculated including assumptions applied;
- calculate river baseflow rates and compare to model estimates;
- update report text and conceptualisation related to the deep Latrobe Group aquifer (based on pending drill program, schedule in October 2018);
- summarise Latrobe Group drilling study findings;
- update model and run new groundwater supply prediction and associated impact assessment;
- Complete more detailed predictive uncertainty analysis which may include, the list is not exhaustive:
    - Aquifer properties (Kh, Kv and storage)
    - River bed conductance
    - Climatic deep recharge to evapotranspiration
    - Aquitard hydraulic resistance

Deliverables

The reviewer should provide a brief report that summarises the review and evaluates the fitness for purpose of the modelling and associated documentation.

Material to be provided

Kalbar (or EMM on Kalbar's behalf), will provide the reviewer with copies of the modelling report/s, relevant model files and TRG comments. Further relevant material may be provided upon request.

Project Schedule

The updated modelling report is due by the 18 November 2018 and the model review report is due 2 weeks after. To facilitate the process, the independent review should also consider meeting the EMM staff in their Adelaide office. This will allow the fundamentals of the model to be discussed and physically viewed on EMM's modelling PCs.

Proposal Requirements

Proposals should include a fee to conduct the scope or work and any periods when the reviewer will not be available. Please respond to the undersigned at your earliest convenience.

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