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In the matter of the Fingerboards Mineral Sand Project EES

Inquiry and Advisory Committee

Proponent: Kalbar Operations Pty Ltd

Supplementary Expert Witness Statement of John Sweeney

Expert of Kalbar Operations Pty Ltd

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Figure 1: Conceptual layout of centrifuge plant locations during mine life (extract from Annexure A)

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1. Name and address

Mr John Sweeney

Senior Associate Hydrogeologist

Level 1, 436 Johnston Street, Abbotsford, VIC 3067 Australia

2. Qualifications and experience

I am a hydrogeologist and environmental scientist with over 15 years' experience in the field of environmental management and impact assessment with specialisations in:

- Soil and groundwater contamination assessment
- Mining hydrogeology
- Water resource assessment
- Groundwater remediation
- Groundwater and surface water impact assessments

My curriculum vitae is attached as Annexure A which provides further details of my qualifications and expertise.

Qualifications

I hold a Bachelor of Science (Hons) degree from the University of Melbourne.

Affiliations

I hold the following positions and professional affiliations:

- Registered Professional Geoscientist (No. 10212): Hydrogeology, Environmental Geoscience
- Victorian Branch Committee Member, Australian Institute of Geoscientists
- Member, International Association of Hydrogeologists

3. Scope

3.1. Role in preparation of the EES

I am a co-author of the *Groundwater and Surface Water Impact Assessment* (Coffey, 2020), herein referred to as the GSWIA report. The GSWIA report was submitted as Appendix A006 of the Fingerboards mineral sands project (Project) environmental effects statement (EES).

3.2. Previous expert witness statement provided to the IAC

I submitted my expert witness statement dated 2 February 2021 to the IAC, which provides my findings in relation to the Project and responses to submissions received by the IAC where they related to the GSWIA.

3.3. Further instructions

I have been provided further instructions by White and Case Pty Ltd (White and Case), acting as legal advisors to Kalbar Operations Pty Ltd (Kalbar), to prepare this supplementary expert witness statement to assist the Inquiry and Advisory Committee (IAC) being held by Planning Panels Victoria.

White and Case has requested that I:

1. Read the information submitted to the IAC on 18 January 2021 (provided as Annexure B), which outlines, amongst other things, proposed changes to the project to include the use of centrifuges to dewater the fine tailings and corrections to the water balance.

2. Prepare a supplementary expert witness statement in which I set out the implications of the proposed project changes on my statement dated 2 February 2021.

I have read Planning Panels Victoria's Guide for Expert Witnesses and I am aware that I have an overriding duty to the Panel on matters relevant to my expertise.

3.4. Other persons who assisted

I have made enquiries with the following people to obtain the information and seek clarifications I believed necessary to form my opinions on the potential impacts to groundwater and surface water;

- Stefan Wolmarans and Martin Van Wyk from Wave International Pty Ltd: I sought further information on the proposed centrifuge technology, the type of flocculants that would be used, and discussed the likely behaviour of flocculants in the environment.

- Jarrah Muller from EMM Consulting Pty Ltd: I sought initial advice and clarification of the expected changes that the centrifuges would have on the project water balance, seepage and tailings water recovery.

4. Methodology

I applied the following methodology when developing this supplementary expert witness statement:

1. Read the information submitted to the IAC on 18 January 2021 (Appendix B).

2. Reviewed my statement dated 2 February 2021 and considered implications of the proposed changes on the assessment that I provided.

3. Prepared this supplementary expert witness statement that documents amendments to my statement dated 2 February 2021 to address the proposed changes to the project (as described in Appendix B).

5. Findings

5.1. Changes to the project description

Since submission of the GSWIA and the EES, White & Case, acting on behalf of the proponent, issued a letter to the IAC on 18 January 2021 enclosing Technical Note 01, which documented corrections and proposed changes to the project description.

The following points summarise aspects of the Technical Note (Annexure B) which have relevance to my assessment presented in the GSWIA and my expert witness statement:

- The project will use centrifuges to dewater the fine tailings to a 70% solids concentrations, which results in an 83% water recovery, compared with the 80% recovery assumed in the GSWIA.
- The use of centrifuges removes the need for a temporary tailings storage facility (TSF), which was assessed in the GSWIA and in my previous statement.
- A flocculant would be added to the fine tailing slurry to increase coagulation of clay particles and improve the rate of recovery by the centrifuge.
- The use of centrifuges would provide certainty around the water supply requirement, estimated to be reduced to 2.9 GL/year.

5.2. Summary of opinions

I adopt my expert witness statement dated 2 February 2021 as the basis of my supplementary statement, subject to the views expressed below regarding the implications of using a centrifuge.

The following sections provide my opinions where they differ from those presented in my expert witness statement, as a result of the changes to the project description outlined in Section 5.1 and provided in Annexure B.

5.2.1. Fine tailings disposal to the TSF

The proponent advised that the use of centrifuges would remove the need for fine tailings to be temporarily stored in an engineered tailing storage facility (TSF). Rather, it is understood that dewatered tailings material can be returned directly to the excavated mine void.

As the hazard (the fine tailings TSF) has been removed, the potential impacts from that hazard have also been removed. The following assessment of potential impacts would no longer apply:

1. Potential for seepage to contribute to raised groundwater levels (assessed as Low residual risk in Section 8.3.1 of the GSWIA, and Section 5.2.2 of my statement)
2. Potential for seepage to negatively affect groundwater quality and the beneficial uses of groundwater (assessed as Low residual risk in Section 8.3.1 of the GSWIA, and Section 5.2.2 of my statement)
3. Potential for catastrophic failure of the TSF and impact to the downstream surface water catchments and Gippsland lakes (assessed as Moderate residual risk in Section 8.4.7 of the GSWIA, and Section 5.2.2 of my statement)

5.2.2. Spring fed dams

My statement presented my conceptual understanding of the spring fed dams in Section 6.7.As explained in my statement, I believe that the dams are supported by near-surface drainage processes and are not connected to the regional water table aquifer.

I also recognised that there may be reasonable potential for an impact to a spring fed dam if the temporary TSF is located within the local surface water catchment that supplies the dam. This potential impact, and the suggestion that further investigation of spring fed dams in the vicinity of the temporary TSF be undertaken, is no longer relevant if the TSF is not required.

5.2.3. Process water

Effects of recycling process water on water quality

I acknowledged in my statement dated 2 February 2021 that the potential effect of recovering water from the TSF and from the mine void on the long term quality of process water was not specifically addressed by the GSWIA.

In my statement I concluded that the corrections made to the expected rate of water recovery from the fine tailings TSF, and corresponding increased water supply requirement from 3 GL/year to 5 GL/year, would reduce the risk of increased concentrations of metals in process water over time. I also stated that further work may be required to assess the potential change in process water quality over time.

I note the following points that I considered when assessing the effects of using centrifuges on process water quality:

- Table 7-7 of the GSWIA presented estimates of both the total and dissolved concentrations of metals in process water from a single leach of representative ore using water from the Mitchell River. Elevated concentrations of metals were shown to be consistently associated with the fine particulate matter in the unfiltered process water. The dissolved concentrations (including aluminium and copper) were below the laboratory limit of reporting (LOR).

- The combined use of centrifuges and flocculants will substantially improve the rate of removal of fine particulate matter from the process water compared to the use of amphirols and natural settlement in the TSF or fine tailings cells.

As the particulate matter will be removed with greater efficiency through use of the centrifuges, it is my opinion that the use of centrifuges in combination with a non-toxic flocculant, would reduce the concentration of metals in the returned process water following a single pass through the processing circuit.

The effects of the improved water efficiency and closed-loop circuit are likely to cause increased concentration of solutes over time. The net effect of improved removal of fine particulate matter and reduced dilution with fresh water is unknown, and the potential impacts to groundwater cannot be fully assessed at this stage.

I maintain that further investigation should be undertaken to predict long term average process water quality for total and dissolved metals, as well as other water quality parameters such as total dissolved solids, nutrients and other solutes that may concentrate over time.

Increased use of flocculants

Changes to the project description include the additional use of flocculants to improve the removal of fine particulate matter in the centrifuges.

Martin van Wyk of Wave International provided further information in relation to the general chemical composition of the proposed flocculant type, their toxicity and their movement through the process water circuit. I summarise following points based on my understanding of our conversation:

- The flocculant used will be a non-toxic, anionic polyacrylamide (commonly referred to as PAM).

- The majority of the flocculant will adhere to the solids particles and will be removed from the process water circuit with the fine tailings cake. Very little flocculant is expected to remain in the process water. This has not yet been quantified.

- High concentrations of flocculant in process water would be counterproductive as it interferes with the process and reduces efficiency. Therefore, flocculant dosing would be monitored closely and used sparingly.

- PAM flocculant degrades under ultra violet light forming nitrogen, ammonia, carbon dioxide and water.
- The flocculant dosing plant will be bunded to contain spills and minimise the potential for release to the environment.

Based on this information, I understand that the volume of flocculant added to the process water circuit will be ‘low’ (although the dosing rate has not been provided to me) and that at low dosing rates, the PAM will remain bound to the clay particles in the processing circuit as well as in the subsurface once it is returned to the mine void. Therefore, I believe that the PAM flocculant would largely remain with the fine tailings fraction and would not be easily mobilised via seepage to groundwater. Furthermore, based on my review of publicly available safety data sheet (SDS) for PAM, I understand PAM is not considered harmful to aquatic organisms and does not cause long-term adverse effects in the environment.

During detailed design I recommend that further work be undertaken to determine the concentrations and flux of total nitrogen and ammonia that might be generated if residual PAM is allowed to degrade in the mine void and seep to groundwater. In the absence of estimated concentrations of nitrogen and ammonia, my initial assessment is that the potential impact of these compounds on groundwater would likely be very low. This is based on my understanding that very low concentrations of PAM would be added to process water and the existing of concentrations of nitrogen and ammonia that are already present in groundwater and surface water.

5.2.4. Centrifuge plants and stockpiled fine tailings cake

Kalbar has nominated a conceptual layout of two centrifuge plant locations based on the preference that they be located in close proximity to the active mining area (Figure 1). It was estimated that the two centrifuge plants would be relocated to a new position every four to five years as mining progresses. The centrifuge plants would operate continuously, producing dewatered fine tailings cake that would accumulate in a temporary stockpile of up to 3,600 m^3 before being hauled to the mine void for disposal.

Stockpiled fine tailings represent a water quality hazard to the undisturbed downstream catchment. Runoff from the fine tailings stockpiled areas would be comparable to the quality of mine contact water quality that has been assessed in Section 5.2.7 of my statement, and Section 8.4.4 of the GSWIA.

It is my expectation that as the location of the centrifuge plants are proposed to be in close proximity to the active mining area, runoff from the stockpiles and the surrounding centrifuge plant would report to the water management dams. However, I recommend that this be required as part of the detailed design of the project.

Based on my assessment that the quality of runoff from the fine tailings stockpiles will be comparable to the quality assumed for mine contact water, I consider the conclusions presented in Section 5.2.7 of my statement and Section 8.4.4 of the GSWIA are also apply to the potential impacts associated with runoff from the stockpiles.

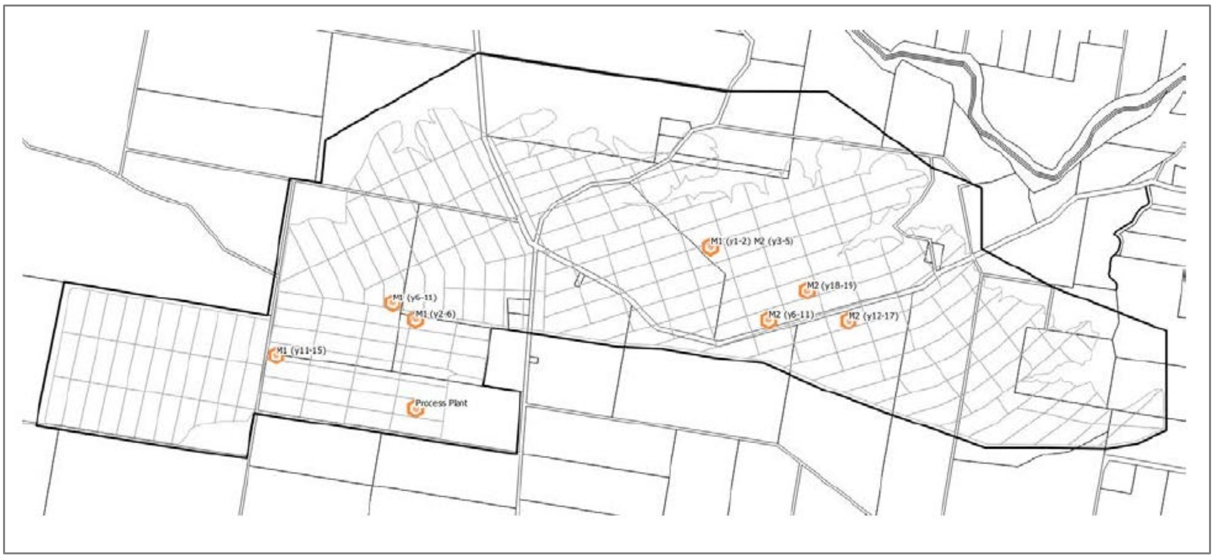

Figure 1: Conceptual layout of centrifuge plant locations during mine life (extract from Annexure A)

5.2.5. Impacts associated with reduced water supply

The proposed use of centrifuges will reduce the project's annual water supply requirement and improve water supply security for the project.

I discuss in Section 6.1.4 of my earlier statement the proponent's commitment that mine production will be tapered or halted during periods of low or no water supply to the project. My statement also recognised the perception that sustained periods of reduced water supply might threaten the commercial viability of the mine and potentially leave the mine unrehabilitated.

The use of centrifuges will significantly improve water efficiency and reduce the annual water supply requirement. This will also allow Kalbar to operate with a higher tolerance to drought and reduced water supply. However, the risk remains that water may not be available in a given year and the assessed risk and proposed management measures presented in Section 6.1.4 of my statement, and the GSWI remain valid.

6. Declaration

I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Inquiry and Advisory Committee.

Signed ………………………………………………

Dated ……8 February 2021……………….…

Annexure A – Curriculum Vitae

Our people

John Sweeney BSc (hons) MIAG RPGeo

Senior Associate Hydrogeologist

Professional profile

I am a hydrogeologist and environmental consultant with over 15 years of experience supporting clients across the mining, oil and gas, defence, civil infrastructure, property development, and water sectors.

Throughout my career I have gained broad experience working on Australian and international projects where I have applied my technical expertise in groundwater conceptualisation, hydraulic testing, water resource assessment, geochemistry, and environmental impact assessment. I also have extensive experience in contaminated land assessment including the assessment of former industrial properties, contaminant hydrogeology, and the assessment of natural attenuation processes.

Qualifications

- University of Melbourne, 2004, Bachelor of Science (honours)

Other training

- Applied Groundwater Modelling Using Visual MODFLOW (Schlumberger).
- Soil and Groundwater Pollution (National Groundwater Association).
- Introduction to Hydrogeochemistry (Minerals Council of Australia)
- Introduction to Hydrogeology (Minerals Council of Australia)

Professional associations & positions

- International Association of Hydrogeologists (Member)
- Australian Institute of Geoscientists:
  - Registered Professional Geoscientist
  - Victorian Branch Committee Member
  - Registration Review Panel Member

Career summary

- 2016-present, Senior Associate Hydrogeologist, Coffey Services Australia Pty Ltd
- 2013 – 2016, Senior Hydrogeologist, Hydrus Consulting Pty Ltd
- 2008 – 2013, Senior Hydrogeologist, WorleyParsons Pty Ltd
- 2005 – 2007, Environmental Scientist, Golder Associates Pty Ltd

Areas of expertise

- Physical hydrogeology
- Groundwater resource management
- Environmental impact assessment
- Groundwater resource exploration
- Mining hydrogeology
- Aquifer testing
- Groundwater modelling
- Dewatering assessments
- Contaminant hydrogeology

Environmental impact assessment

Bawdwin Mine, Myanmar Metals Ltd, Myanmar.

Designed and established the baseline groundwater and surface water monitoring program to assess existing conditions at the 600-year old Bawdwin mine in northern Shan State, Myanmar. Scope included in country assessment to develop a conceptual model of the water environment, characterise groundwater and surface water occurrence and quality, and assess potential impacts of the proposed mine redevelopment and ancillary infrastructure on sensitive water receptors. The in-country assessment included training local environmental specialists to continue periodic baseline groundwater and surface water monitoring.

Gold Ridge Mine, Gold Ridge Mining Ltd, Solomon Islands

Lead the scoping and implementation of a baseline groundwater assessment to support the environmental approvals to redevelop the Gold Ridge mine. Scope included in-country assessment to develop a conceptual hydrogeological model, identification of historical contamination issues, and establishing a network of groundwater monitoring wells. Authored the groundwater sub-plan for the site Environmental Management Plan.

Wafi-Golpu Project, Wafi-Golpu Joint Venture, Papua New Guinea.

Authored the groundwater impact assessment chapter for the proposed block cave copper-gold mine located approximately 300 kilometres (km) north-northwest of Port Moresby. Located in a high rainfall zone and combined with potentially acid-forming characteristics of the rock, the project required consideration of groundwater impacts, and a robust water management strategy through operation and closure. Presented impact assessment conclusions to key stakeholders, including PNG government, and independent review panel.

Sepik Development Project, Frieda River Limited, Papua New Guinea.

Authored the groundwater impact assessment chapter for the Sepik Development Project environmental impact statement (EIS). The project included two commercial projects: the Frieda River Copper-Gold Project and the Frieda River Hydroelectric Project. The assessment considered potential groundwater impacts associated with a new integrated tailings storage facility and hydroelectric dam reservoir located within the Frieda River valley, and a conventional open-pit mine operation.

Waisoi Project, Namosi Joint Venture, Fiji.

Completed the baseline characterisation and groundwater and surface water impact assessment for the Waisoi Copper Gold project located on Viti Levu, approximately 30 km northwest of the Fijian capital Suva. Adopted a significance assessment approach to assess the level of impact of the project on identified environmental values.

Tonkolili ESHIA, African Minerals Ltd, Sierra Leone.

Conducted a groundwater and surface water baseline assessment across the greenfield mine site, infrastructure corridor and new port development. Developed a conceptual understanding of the hydrological cycle and completed a groundwater and surface water impact assessment for the project. Provided input into the ESHIA report for submission to regulators and international investors.

Poltava Mine DFS, Ferrexpo Poltava Mining, Ukraine.

Liaised with local senior mine management to develop an Integrated Water Management Plan for expansion of this existing iron ore mine. Assessed mine water security and potential environmental impact from the mine expansion. Developed input for the definitive feasibility study (DFS) report on issues of hydrogeological resource assessment, dewatering production rates, likely environmental impacts, and water management issues.

Water Resource Assessment, Eurasia Gold, Kyrgyzstan.

Preliminary water resource assessment for proposed mining development in Kyrgyzstan. Identified and worked within international best practice standards and legislation for transboundary aquifer management. Produced a preliminary water resource assessment report to guide the development of further scoping studies.

Mining

Iron Duke TSF dewatering, OneSteel, South Australia. Developed a numerical groundwater model (MODFLOW) to assess different methods of combating rising water levels around two tailings storage facilities. The model was used to identify the optimal arrangement of dewatering wells, drains and caissons to achieving the required drawdown. Supervised a program of aquifer testing at wells adjacent to a tailings storage facility. Interpreted results to refine the aquifer parameters and provide recommendations for sustainable pumping rates and pump sizing. Developed an ongoing groundwater level and quality monitoring program.

Groundwater Exploration, OneSteel, South Australia. Desktop assessment followed by a groundwater exploration program aiming to identify a sustainable process water supply for the Southern Middleback Range mine sites. Supervised a programme of groundwater exploration drilling and aquifer tests at Iron Baron to identify a sustainable mine water supply.

Groundwater assessment, Incitec Pivot, Phosphate Hill, Australia. Developed a transient site water balance and reviewed projected dewatering requirements to incorporate into a long term groundwater resource assessment. Provided an estimate of groundwater storage and the ability of the major aquifers to meet future demand. Assessed alternative resources in neighbouring groundwater basins and developed an exploration schedule to ensure future water supply security. Provided a preliminary groundwater impact assessment for submission to regulators.

Tengrela Groundwater Assessment, Perseus Mining Ltd, Cote d'Ivorie. Reviewed existing exploration and environmental baseline data to direct a groundwater exploration program at a greenfield mine development. Used GIS tools to interpret numerous data sets and identify exploration target zones. Provided remote assistance during drilling activities ahead of onsite aquifer test work.

Tonkolili DFS, African Minerals Ltd, Sierra Leone. Carried out a groundwater resource assessment for a greenfield mine development. Identified groundwater resource options for construction and operational phases of the mine site, 200 km railway and a deep water port. Provided groundwater resource estimates including quantity, quality and likely extraction potential for inclusion in the client's DFS report.

Tonkolili Tailings Assessment, Perseus Mining Ltd, Cote d'Ivorie. Developed a 3D numerical model (MODFLOW) to predict TSF infiltration rates in an environmntally sensitive area. Used the numerical model to test the effectiveness of different TSF water management options on infiltration rates. Preparations made to advance the model to assess contaminant transport and the potential for impact to environmental receptors.

Poltava Mine DFS, Ferrexpo Poltava Mining, Ukraine. Liaised with local senior mine management to develop an Integrated Water Management Plan. Assessed risks to the reliable supply of mine water and potential issues of environmental impacts. Developed input for the definitive feasibility study (DFS) report on issues of hydrogeological resource assessment, dewatering production rates, likely environmental impacts, and water management issues. Provided advice and drafted input for inclusion in DFS report.

Water Resource Assessment, Eurasia Gold, Kyrgyzstan. Preliminary water resource assessment for a proposed mining development in Kyrgyzstan. Identified and worked within international best practice standards and legislation for transboundary aquifer management. Produced a preliminary water resource assessment report to guide the development of further scoping studies.

Infrastructure & Construction

North East Link Project (Tender Submission), Victoria, Australia. Formed part of the specialist hydrogeological team supporting ViaNova's (consortium of John Holland Group, Acciona Construction, Lendlease Services, Plenary Group, Acciona Concesiones) tender submission for the design, construction and operation of this $16 billion tunnelling and road infrastructure project located in Melbourne's inner east. Responsibilities included providing technical advice to the design and construction teams, identification of high value groundwater dependent ecosystems, assessing the potential project impacts of the proposed design to sensitive groundwater and surface water receptors, and developing suitable mitigation measures to minimise potential impacts.

M6S1 tunnel (Tender Submission), New South Wales, Australia. Formed part of the specialist hydrogeological team supporting CPB-Ghella Joint Venture's tender submission for design and construction of this $2.5 billion road tunnel project in Sydney's inner south. Responsibilities included providing technical hydrogeological advice, assessing existing groundwater contamination risk, assessing the potential project impacts to the surrounding environment and groundwater users, and developing appropriate mitigation measures.

Level Crossing Removal Project – North West Program Alliance, Melbourne. Groundwater and land contamination assessment and management advice during delivery of a programme of grade separation projects for the North West Program Alliance.

420 Spencer St, Maxcon Pty Ltd, Melbourne Australia. Carried out groundwater sampling, aquifer testing and groundwater modelling for a proposed residential development at 420 Spencer St Melbourne to establish the likely range of groundwater drain flows associated with permanent dewatering of an excavated and constructed basement.

Casey Cultural Precinct, City of Casey, Australia*.* Engaged to conduct a field hydrogeological assessment and groundwater modelling for dewatering of the proposed Casey Cultural Precinct redevelopment. Responsibilities included project management of the installation of six groundwater monitoring wells, aquifer hydraulic testing & interpretation, and development of a numerical groundwater model to simulate dewatering of the basement excavation.

Water supply

Bylong Coal Mine water supply, KEPCO Bylong, Australia. Conducted several variable rate and 24 hour constant rate pumping tests to assess the water resources within the project area of the Bylong Coal Project, approximately 55 km north-east of Mudgee in New South Wales. The collected data was analysed to provide a preliminary feasibility assessment of a groundwater-sourced mine water supply.

Irrigation Water Supply, Hooke Property, Australia. Provided field supervision of a 7 day groundwater pumping test to investigate the suitability of using a deep lead aquifer in Serpentine, Victoria to supply irrigation water. The purpose of the was to determine if the design demand yield of 10-20 ML/day could be sustained over a long-period of time without affecting the raw water quality, overlying aquifers and Serpentine Creek.

Contaminated land

OneSteel Martin Bright, Somerton, Victoria. Project manager for $1.4M groundwater investigation and remediation project to manage hexavalent chromium and PFAS contamination associated with historical chrome plating facility. Project included installation of over 200 groundwater wells, groundwater remediation and risk assessment for two contaminant plumes migrating offsite towards groundwater dependent ecosystems. Work included developing and implementing complex scopes of work to assess groundwater, surface water, soil, stormwater and air impacts with short deadlines. Ultimately delivered close-out of contamination issues and transition to a phase of ongoing monitoring.

Environmental Manager Secondment, AkzoNobel Pty Ltd, Melbourne, Victoria. Managed the response of a global paint and coatings manufacturer to an EPA enforcement notice relating to perceived contamination of soil and groundwater. Provided guidance on the technical approach needed to respond to the notice as well as coordinate a tender for subsequent site assessment work. Represented the client at meetings with the auditor and interfaced with the client's legal team. Conducted a comprehensive Phase I Site Assessment including a review of the complex fractured aquifer setting, regional contamination issues and industrial development history of the local area.

Paisley Park Childcare Centre, Mollard Property Investments, Flemington, Victoria*.* Completed a preliminary environmental assessment of a former commercial property in Flemington, Victoria. The property was subject to a 53X EPA Environmental Audit required to rezone the site for redevelopment as an early learning centre. Developed a work plan to potential contamination risks identified during by preliminary assessment which was accepted by the appointed Auditor and is due for implementation during 2016.

Caltex Dandenong North, Caltex, Dandenong North, Victoria. Provided an assessment of groundwater contamination beneath a former Caltex Service Station being rezoned for residential development. Drafted a CUTEP (clean up to the extent practicable) submission for auditor approval based on multiple lines of evidence including; plume stability, mass flux assessment, assimilative capacity review and risk assessment to down gradient receptors.

Landfill Compliance Reporting, Wollert Landfill, Victoria. Reviewed groundwater and surface water monitoring data and drafted a groundwater monitoring plan to standardise future monitoring activities at a municipal landfill. Victoria, Australia.

Landfill Risk Assessment, Darebin City Council, Victoria, Australia. Designed the phase I and phase II site investigations of a former quarry filled with waste. Supervised a program of test pitting to delineate the extent and nature of the landfill material. Installed landfill gas bores to determine the presence and level of risk posed by landfill gas. Conducted indoor air quality monitoring in surrounding buildings. Melbourne, Australia.

Lyndhurst Landfill Compliance Monitoring, SITA, Lyndhurst, Victoria. Conducted annual groundwater and surface water monitoring data reviews for a hazardous waste landfill site. Provided guidance on the expansion of the existing groundwater monitoring network and supervised subsequent drilling activities.

Landfill Risk Assessment, London Borough of Barking and Dagenham, United Kingdom. Carried out a site investigation and risk assessment for a historical landfill to identify potential risks posed by residual contamination to human health and environmental receptors. This involved development of conceptual site model and contaminant fate and transport modelling using the Environment Agency's Remedial Targets Spreadsheet.

Tullamarine Landfill, Cleanaway, Melbourne, Victoria. Supervised geotechnical drilling (including rock core logging), groundwater monitoring well design and installation (including DNAPL wells) associated with hazardous waste landfill.

Webb Dock Redevelopment, Melbourne International Container Terminals Ltd, Melbourne, Victoria. Provided environmental support and technical advice on contaminated land issues during the tender process for the planned redevelopment of the Webb Dock East and West container terminals. Activities included strategic review of site contamination assessment information to support the Concept Design services for development of the tender response by McConnell Dowell and SMEC. This work ensured that the tender identified and accounted for all contractual and practical redevelopment issues associated with soil and groundwater contamination at the site.

Olympic Redevelopment Project, London Development Agency, United Kingdom. Undertook site investigation, soil sampling, groundwater well installation and groundwater sampling. Identified areas of soil contamination requiring offsite disposal. Undertook soil waste classification and provided estimates for tender development. Developed a soil remediation approach document.

Gasworks Groundwater Remediation, National Grid, Dunstable, UK. Undertook groundwater sampling and data analysis for development of a site conceptual model at a former gasworks. Developed, in conjunction with local stakeholders, a detailed approach to modelling the transport of dissolved phase contaminants.

Groundwater Risk Assessment, National Grid, United Kingdom. Undertook groundwater investigations at numerous former gasworks sites across the UK to develop controlled waters risk assessments. This involved the development of site conceptual models followed by contaminant fate and transport modelling and numerical groundwater modelling to assess the level of risk to controlled waters receptors. Worked closely with local stakeholders and regulators.

Groundwater Risk Assessment, Wycombe District Council, United Kingdom. Designed a groundwater monitoring programme to identify the likely source of a plume of PCE contamination detected beneath the High Wycombe town centre. Proposed a further phase of site investigation to delineate the extent of contamination and develop a numerical groundwater model to assess the risk to local controlled waters receptors.

Oil and gas

Spatial Analysis of Coal Seam Gas Water Chemistry, Queensland Department of Environment Resource Management (DERM), Australia. Spatial analysis of hydrogeochemistry and potentiometry of the Surat and Bowen Basins. Constrained local and regional flow paths. Hydrograph analysis and residual head mapping to identify zones of potential inter-aquifer flow.

Provision of Research Services on the Impacts of Coal Seam Gas and Coal Mining on Water in a Panel Arrangement, Office of Water Science, Australia. National proposal manager for successful appointment to a panel of experts to provide research services to the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Developments. Ongoing project coordination role after appointment through attendance at industry briefings in Canberra.

Bioregional Assessment, Southern Gulf Catchments, Queensland, Australia. Completed a preliminary vulnerability assessment of over 600 groundwater bores in close proximity to proposed CSG development in the Galilee Basin, Queensland. This work involved assigning a likely aquifer formation to each bore based on drilling logs, geological reference documents and petroleum & CSG exploration data in the area.

Surat Gas Project – Drilling Supervision, Arrow Energy, Queensland, Australia. Provided drilling supervision and bore construction design in the Surat Basin, Queensland. Drilling of shallow groundwater observation and pumping bores in the Condamine River Alluvium and Gubberamunda Sandstone Aquifer.

Produced Water Injection Study, Arrow Energy, Queensland, Australia. Provided hydrogeological support to various studies into the viability of injecting treated waste water from coal seam gas extraction. Developed summaries of expected groundwater chemistry across multiple aquifers leading to a study of produced water treatment requirements. Carried out an options narrowing study to identify viable injection options, technologies and methodologies.

Baseline Groundwater Assessment, Australia Pacific LNG, Darling Downs, Queensland. Involved auditing and sampling land holder groundwater bores within coal seam gas development regions of the Surat Basin. Educate landholders on CSG activities and regional hydrogeological setting. Data management and coordinate reporting for landholders.

Produced Water Injection Study, Rasheed Petroleum (Rashpetco), Egypt. Developed a numerical groundwater model using GW Vistas to assess the technical and commercial feasibility for deep injection of produced water below an onshore gas treatment facility. Modelled various scenarios to assess pressure predictions (Modflow), fluid migration (Modpath) and contaminant transport (MT3D).

Annexure B – Technical Note 01

Fingerboards Mineral Sands Project Inquiry and Advisory Committee
Technical note

TN No: TN 01
Date: 18 January 2021
Subject: Implementation of centrifuges for water recovery and tailings management

1. INTRODUCTION TO MINERAL SAND TAILINGS

The Fingerboards Mineral Sands project processing method entails the gravity separation of heavy minerals (**HM**) contained within the Congulmerang formation sands. During the processing, two separate tailing residue streams are generated, the first being the fine tailings (< 38Micron diameter) commonly referred to as "slimes" and the remaining sand, after separation of the HM, called "coarse sand" tailings.

By mass, the fine tailings represent approximately 21% of the ore and the coarse sand approximately 74%. The remaining fraction is the HMC product.

The separation of the coarse and fine material from the HM is performed with gravity separation using water. No chemical reagents are used in the separation process. After separation of the HM and coarse sand, a flocculant is added to the slimes tailings stream to improve the settlement of suspended solid particles in a thickener.[1] From the thickener underflow, the fine tailings are still a fluid slurry at approximately 30-35% solids content, as seen in Figure 1.

Figure 1 Fingerboards 30% solids fine tailings after thickening

[1] Thickener – a conical tank in which solid particles in slurry are allowed to settle to produce a clear overflow and thickened underflow.

After separation from the HM, the coarse sand tailings are pumped back to the mining pit before being dewatered to 65-75% solids content with dewatering cyclones[2]. At this density, the sand can be "stacked" and is used to backfill the mining void. A photo showing the stability of the dewatered sand is shown in Figure 2.

Figure 2 Fingerboards 73% coarse sand tailings after dewatering

2. WATER RECOVERY FROM TAILINGS

The recovery of water from the tailings streams is a key consideration in mineral sands mining.

In the Fingerboards Environmental Effects Statement (**EES**) proposal, the thickened slurry shown in Figure 1 is pumped to a tailings storage facility (**TSF**) where the slurry settles over a period of time and entrained water is released as water, with little evaporation loss. Initial dewatering up to a density of ~55% solids occurs rapidly within 24-72 hours and the tailings have a free water surface. After reaching the settled density, further dewatering to 70-72% density can take a further 4-10 months. During this second stage of dewatering, most of the entrained water is lost as a vapour to evaporation. The dewatering and increase in density from 55% to 72% can be accelerated during the first dewatering stage by using mechanical equipment such as amphirols[3], which can increase water recovery by increasing the amount of free water drainage.

In the case of the coarse sand tailings, following initial deposition into the pit, the sand continues to dewater further though seepage, reaching 80% - 90% solids density after 20-30 days. The water released during this stage of the process is recovered through underdrains installed under the sand stack and the majority of that water is recovered back to the process water dam.

While the water in the coarse sand tailings stream represents around 72% of the total water pumped in the tailing streams, it only comprises around 45% of the make-up water requirements. Most of the water losses in tailings

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[2] A dewatering cyclone (hydrocyclone) is a commonly used separation device that uses fluid pressure and centrifugal force to separate course particles (sand tailings) from a fluid (water).

[3] An amphirol is a self propelled vehicle that traverses soft tailings slurry using rotating scrolls, the action of which causes the solid particle to consolidate and dewater.

occur from water entrained in the fine tailings stream that is slowly lost to evaporation. In other words, approximately 80-90% of the water contained in the coarse sand tailings, and 50-55% in the fine tailings, is recovered for process re-use.

A method of tailings management that accelerates dewatering of the fine tailings will therefore result in greater certainty about the ability to recover water for process reuse.

3. FOOTPRINT CONSIDERATIONS

The ability to dewater the tailings has a direct correlation with the time and footprint required before the commencement of rehabilitation and final overburden backfilling activities. When using fines TSFs, as contemplated in the EES, the storage area will be filled in layers of 0.75 – 1.0m thick, and each layer will be allowed to dewater by alternating the point of discharge spigots in the TSF. This process continues until the full depth of the TSF has been reached. This method requires a large footprint for the tailings volumes, as the dewatering period can take some 10 months per lift before the material has dewatered sufficiently for the commencement of backfilling operations.

The TSF footprint area influences the mining activities, as covering topsoil cannot be placed and final rehabilitation cannot occur until the fine tailings have consolidated to the final target density. During this period, trucks must haul overburden material around the TSF area into another open void in the pit. This haul distance increases the exposed area of the pit, as well as associated dust and noise generation.

A method of tailings management that accelerates the commencement of backfilling operations and rehabilitation will have a corresponding reduction on truck haul distance.

4. EES TAILINGS METHOD – FINE TAILINGS DISPOSAL DAMS

The tailings disposal method proposed in the EES uses an initial temporary TSF near the process plant to dispose fine tailings into, until such time that sufficient space has been created inside the pit for the construction of fine tailings in-pit TSFs. The coarse sand is stacked into the pit using dewatering cyclones.

A flowsheet of the EES tailings disposal method is shown in Figure 3 below.

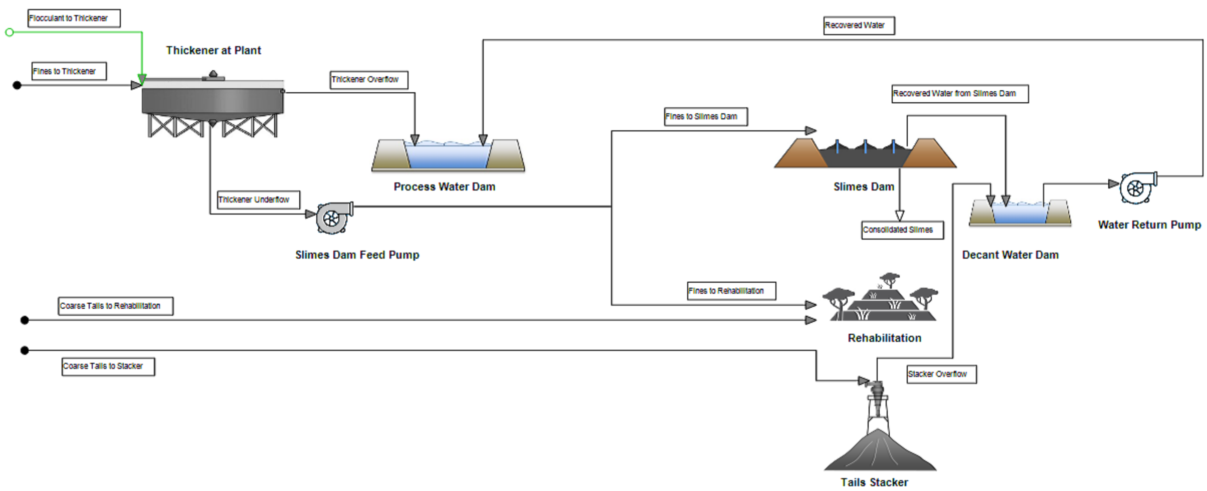

Figure 3 EES tailings flowsheet

The International Council on Mining and Metals (**ICMM**) developed a universal standard for tailings management, entitled the Global Industry Standard on Tailings Management (**GSTM**), which was launched in August 2020. The proposed TSFs can and will be constructed and operated in accordance with industry standards and norms, including the GSTM.

5. ALTERNATIVE OPTION – CENTRIFUGE TAILINGS

Although the proposed TSFs can comply with relevant standards, the GSTM requires consideration of alternatives that minimize the volume of tailings and water placed in external tailings facilities. It is expected that, in the case of this project, the need for TSFs can be avoided altogether by the use of solid bowl centrifuges, which would produce dry cake from fine tailings.

A dewatering centrifuge works by increasing the G-forces[4] that act on the slurry, increasing the separation of the heavier solids from the lighter water in fine tailings. A flocculant is added to the slurry in the centrifuge to increase coagulation of the clay particles. Typical operating bowl speeds are in the 1,000 to 1,800 rpm range, where the developed G-force range is from 600 to more than 1800 G. The centrifuge dewaters the cake to the absolute point of practical dewatering and any remnant water will remain entrained due to the capillary action between the water and solid particles. This means that any water that remains in the cake will not drain freely from the material, even when it is deposited back into the void with overburden. The risk of groundwater mounding from seepage is removed as the ability of water to seep from the fines into the underlying soil, at a rate greater than the vertical permeability of the underlying soil, is eliminated. The centrifuge flowsheet is shown in Figure 4 below.

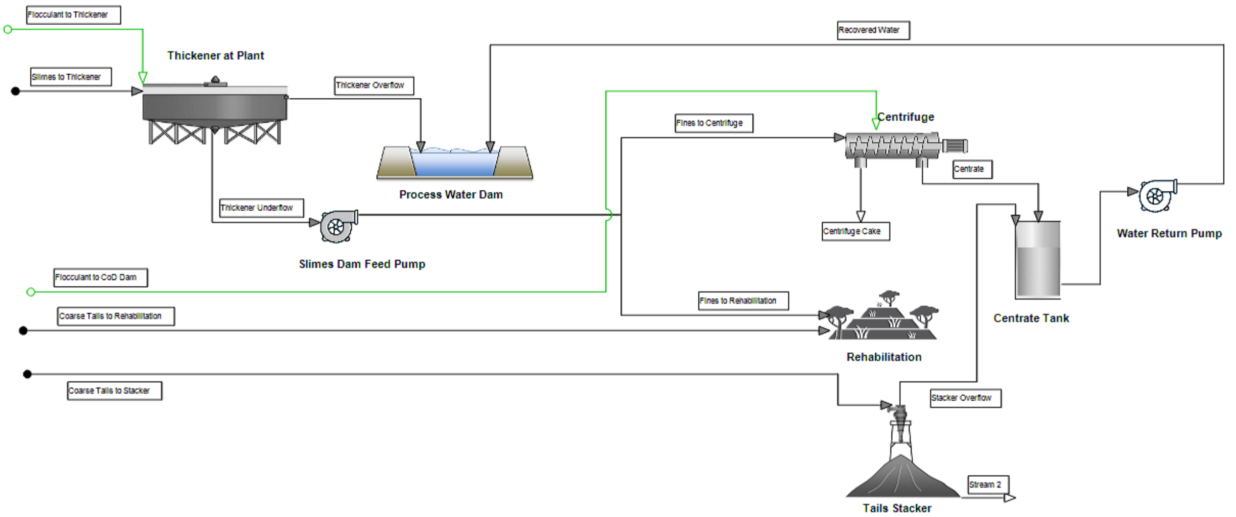

Figure 4 Centrifuge Flowsheet

After being processed through the centrifuge, two products are produced. Firstly, a clear overflow water (called the centrate) containing very little suspended solids, and secondly a readily transportable solid cake.

Examples of the centrate and solid cake producced during centrifuge trials is shown in Figure 5.

[4] G-Force - Gravitational force of the earth. In a centrifuge the tailings are subjected to a gravitational force 600 – 1,800 times greater than it would experience in a naturally draining situation

Figure 5 Centrifuged Fingerboards fines cake with centrate

Solid bowl centrifuge units are a proven technology and their application in tailings dewatering is not new, with multiple units being used globally in coal, tar sands, bauxite, iron ore, borax, gold, nickel tail dewatering applications. Centrifuges have previously been evaluated and successfully trialed, but not used, in mineral sands applications. The decision by project owners not to implement them was a cost consideration, rather than a technical reason. An example of the centrifuge units is shown in Figure 6. The centrifuges are enclosed in a building that can be cladded to reduce external noise to well within the guideline levels.

Figure 6 Centrifuge similar to the unit intended for Fingerboards

One of the main advantages of the centrifuge is that it provides certain and maximum water recovery within a controlled mechanical process, which is not affected by weather, evaporation rates or tailings deposition methods. It provides certainty about the degree of dewatering of the fine tailings that cannot be achieved in open TSFs.

Also, because the product is a truckable solid cake, the need to store and dry the fines tails slurry in TSF dams is no longer necessary and the cake can be immediately used for backfilling of the pit. The centrifuge cake will be transported during dayshift from the centrifuge facility to the active backfill area in the void, where it will be placed as backfill with the overburden. The benefit of this is that is ensures an even dispersal of the fines throughout the backfill profile, rather than concentrating the fines in in-pit TSF cells. In total, the fines cake will represent only 7% - 8% of the total overburden backfill volume and stability of the backfill is not compromised.

Avoidance of the need for TSFs would also reduce dust and noise generation by the proposed mining activities as it would reduce the active mining footprint and facilitate closer and more rapid backfilling and rehabilitation of mining voids.

Whilst the EES demonstrates that the threshold levels can be achieved for both dust and noise, any further improvement to those levels would be advantageous to the project and its stakeholders, including the local community.

6. CENTRIFUGE PLANT TECHNICAL DETAILS

The proposed centrifuges are a solid bowl decanter centrifuge using electrical power for operation. Each unit is approximately 9m long and weights around 18tons. As the project entails two mining unit plants (**MUP**) in two separate areas, two centrifuge plants would also be required. Each plant would contain three operating units and one standby unit, with a throughput rate of ~55tons solids per hour per unit and would be enclosed in a building that is approximately 23.5m long, 13.5m wide and 11.5m high at the crest of the roof. The top floor would be clad in a sound attenuation cladding, similar to the main process plant.

The proposed building layout for each plant entails the four centrifuge units on the cladded top floor, a cake discharge conveyor below them, and an external cake stacking conveyor. The centrifuge plant would operate 24 hours a day, producing a fines cake which is discharged onto a stockpile. The trucking of the cake to the mine void, where backfilling is occurring, would take place during the day shift. During evening and night periods, the cake will accumulate on the stockpile for loading and haul to pit during the following dayshift. Ancillary equipment around the plant will be a flocculant mixing tank, electrical switchroom, transformer enclosure and a bypass sump. A view of the proposed centrifuge plant is shown in Figure 7.

The stockpiles are designed to store for a maximum volume of up to 24 hours fines production, being the Sunday evening/night shift duration. This will result in a total stockpile volume of approximately 3,600m³ (6,000 tons) at each of the two centrifuge plants. The centrifuge cake will be hauled via overland haul route at a rate of approximately 680tph using dump trucks. A front-end loader (FEL) will reclaim material from the cake stockpile and load the dump trucks.

Figure 7 Centrifuge building and cake stockpile

The centrifuge plants would be located in close proximity to the mining area in order to reduce the overland haul distance of the centrifuge cake back the mining void, and thereby minimise noise and dust generation. Based on the preliminary mine planning, it is anticipated that each centrifuge plant would be relocated to a new position every four to five years. The plant has been designed to be modular so that it can be dismantled and trucked to the new location, when required. The plant positions have been selected such that the average one-way haul distance from the plant to the mine void is an average of 750m for all locations.

A conceptual layout of the centrifuge plant positions is in Figure 8, showing the spread of the two centrifuge plants east and west of the Bairnsdale-Dargo Road, each serving a separate MUP.

Figure 8 Concept layout of centrifuge plant of life of mine

The cake haul roads will be constructed haul roads with a low-silt gravel capping layer to minimise dust generation, in addition to the normal operational dust management procedures such as water trucks and road dust suppressants.

7. WATER RECOVERY COMPARISON

As described in Section 2, the ability to recover from the fine tailings is influenced by the ability to recover water in two stages. The first stage of dewatering is predominantly free water release, whilst the second stage is predominantly evaporation. The use of amphirols on the TSF surface increases the duration of the first stage in which the drying fine tailings release water freely to the surface of the tailings, rather than as an evaporating vapour. During the first stage, water is recovered by surface drainage and pumped to the process plant for re-use. Without the use of amphirols, the estimated water consumption of the project operating at a processing rate of 1,500tph is estimated to be in the range of 4-6 GL per annum. Modelling of the amphirols estimated that the additional water release could be as much as 2GL per annum and the water consumption was therefore estimated to be nominally 3GL per annum. A review of this modelling has highlighted that the additional water released by the amphirols for process recovery was overestimated and the 3GLpa water requirement is consequently under estimated. It is likely to be in the range of 4-5 GL per annum when using the amphirols.

The centrifuges enable a significant increase in fine tailings dewatering to be achieved, as it employs the use of a flocculant and increased centrifugal forces to dewater the material to a degree that cannot be achieved in a conventional TSF. The centrifuge testwork undertaken to date has produced a cake with 70% solids concentration, which results in an 83% water recovery from fine tailings, compared to the 80% stated in the EES. The result of this is that the process water consumption for the project is improved with much greater certainty. Based on centrifuge testwork results, the water recovery estimate shows that the 3GL per annum water requirement remains achievable, with ~2.9 GL per annum required for a process plant operating at the maximum 1,500tpa processing rate.

8. NOISE COMPARISON

In the EES scenario, the noise generating sources associated with fine tailings are predominantly associated with the operation of the amphirols. A comparison of the sound power levels generated by the amphirols and the centrifuges is presented in the table below.

Source	Model/Make	Octave Band Frequency							
		63	125	250	500	1k	2k	4k	A
Amphirol (unmitigated)	Mudmaster	115	115	109	107	106	104	98	111
Centrifuge (unmitigated)	Alfa Laval P3-10070	102	101	100	102	96	96	96	104

Each centrifuge plant would consist of three units in operation and one standby unit, not operating, located within a cladded building to provide noise mitigation. The relative noise level difference between the centrifuge and TSF/amphirol solutions, taking into account the sound power, quantity, operating duration and building mitigation, is in the range of 15-20 dB, the centrifuge being the lower noise solution.

A render of the cladded centrifuge building is shown in Figure 12 below. The centrifuge units are located on the enclosed top floor, with a cake discharge conveyor located in the floor below.

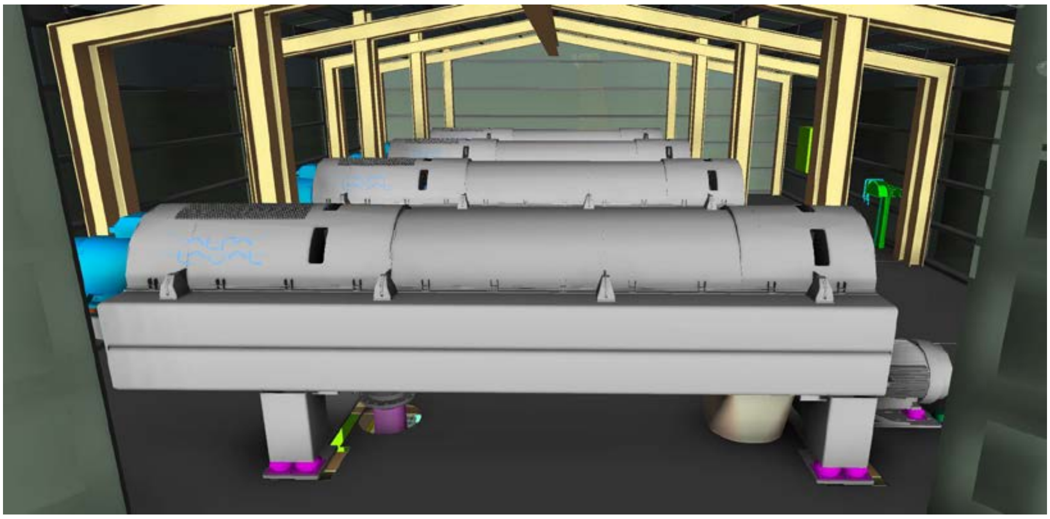

Figure 9 Centrifuges located with cladded building to reduce sound

Based on the above, it is expected that the introduction of the centrifuge plant will result in a lesser noise impact than the amphirol operations but this will be separately assessed by Kalbar's noise experts, Marshall Day Acoustics.

9. AIR QUALITY COMPARISON

The mitigation of dust is a key design consideration. In the EES scenario, one of the main dust generating sources is the extraction and haulage of overburden during mining operations.

The introduction of the centrifuges enables the centrifuge cake to be deposited together with the overburden as backfill, until the backfill design level has been reached, after which rehabilitation operations can commence. This reduces the extent of the exposed areas from what is set out in the EES given there is no longer any need to wait for the in-pit fine tailings TSFs to be fully filled, dried, ripped and blended to be ready for rehabilitation to commence. The removal of the TSFs and introduction of a more continuous rehabilitation process should further reduce dust generation.

Given that the cake stockpile at the centrifuge plant is a damp cake, it is not expected to be a dust generating source. Experience has shown that when the cake is exposed to sunlight and dries, it forms a hard crust that is unlikely to generate any dust when exposed to wind. In addition, the stockpile is continuously drawn down daily and returned to the pit as backfill.

The haul of cake from the centrifuge plant to the mining void will be a new dust generating source, however this is expected to be offset by reduced overburden haul distances of the overburden in mining operations and accelerated mine rehabilitation.

Relative to the EES scenario, the centrifuge cake scenario is expected to improve the dust emissions of the project, but this will be separately assessed by Kalbar's dust expert, Katestone.

10. REHABILITATION OF MINING AREAS

In the EES scenario, rehabilitation commences only once the in-pit TSF has reached its design capacity and the fine tailings have dried sufficiently to be ripped and blended, to form a subsoil surface for the placement of topsoil. The removal of TSFs, and the continuous backfilling of the centrifuge cake with the overburden, negates the delay required for the TSF drying and rehabilitation can commence soon after the final rehabilitation surface level has been reached. The rehabilitation surface on top of the cake/overburden backfill will be identical to the method proposed in the EES, consisting of a manufactured subsoil, followed by topsoil and revegetation.

Overall, rehabilitation can occur in a more continuous manner with the introduction of the centrifuges.

11. CENTRIFUGE COSTS

Compared to the EES scenario, the centrifuge units require increased upfront capital expenditure. The centrifuge cost is partially offset by the removal of the TSF construction, but not withstanding this offset, the additional investment is significant.

Compared to the EES, the direct tailings operating cost of the centrifuge is slightly greater but this is largely offset by the improved operational efficiency of the mining operations, the removal of TSF operating costs and the accelerated rehabilitation of disturbed mining land.

12. ADVANTAGES OF CENTRIFUGE FINE TAILINGS

In summary, the advantages for the Fingerboards project of implementing the centrifuges are:

(a) It provides certainty about water recovery from the fine tailings that is independent of climatic and soil conditions.

(b) It removes the need for the construction of large TSFs and the removal of risk, however low, associated with operating TSFs. There is no need to construct any TSFs for the project in the centrifuge case.

(c) The continuous backfilling of the void without the need to rip and remove fine TSFs before the commencement of rehabilitation operations means that the disturbed mining area is smaller, and rehabilitation can occur sooner after the completion of mining in any particular area.

(d) The continuous mining and backfilling operation significantly reduce overburden haul distance, which in turn reduces noise and dust generation.

(e) Any risk of seepage is removed as the material is fully dewatered to a state that will only retain capillary moisture that cannot seep to the environment.

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