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

---

[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.

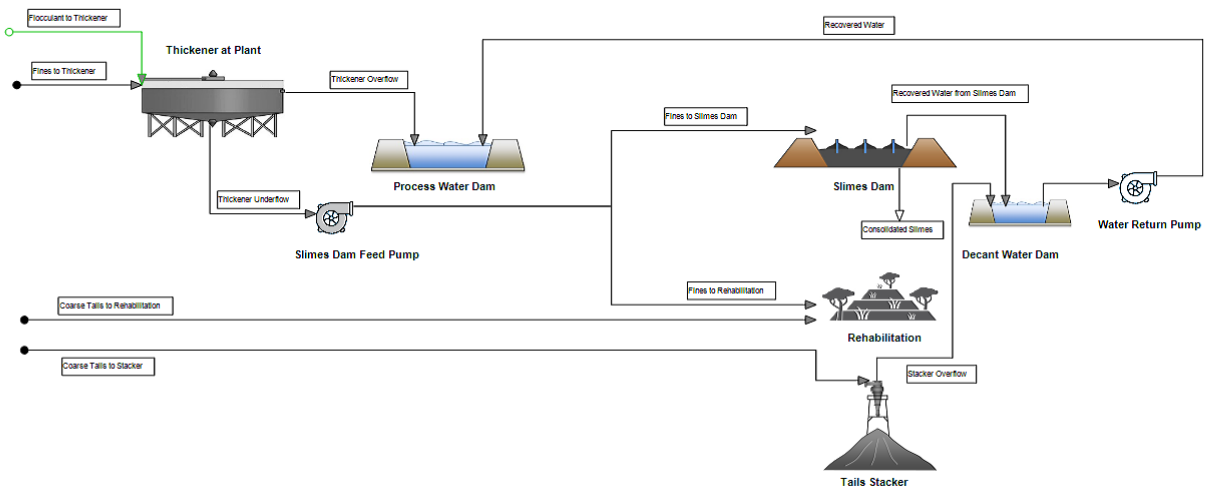

Figure 3 EES tailings flowsheet

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.

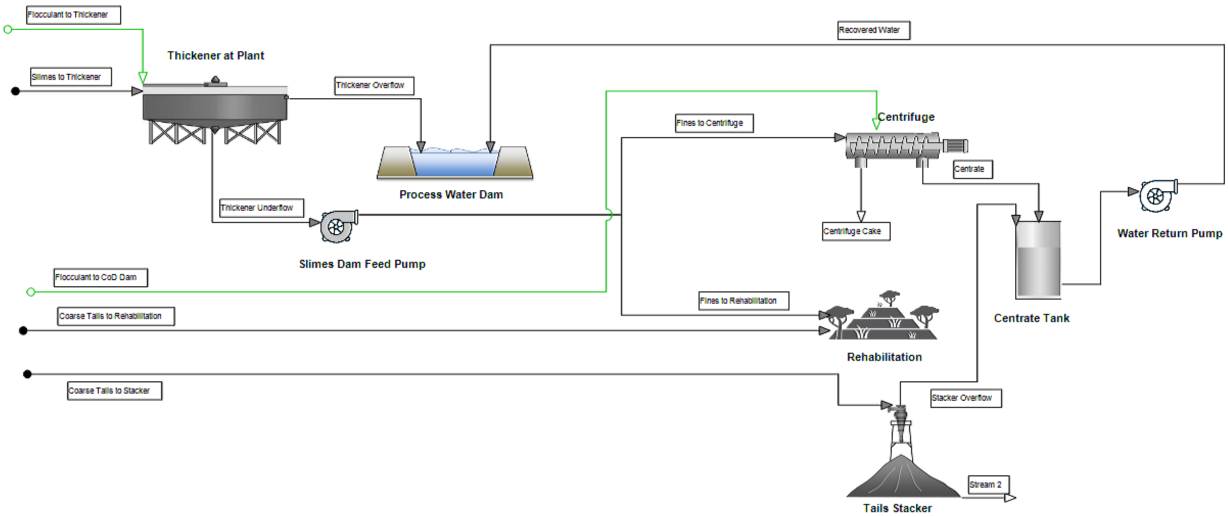

Figure 4 Centrifuge Flowsheet

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.

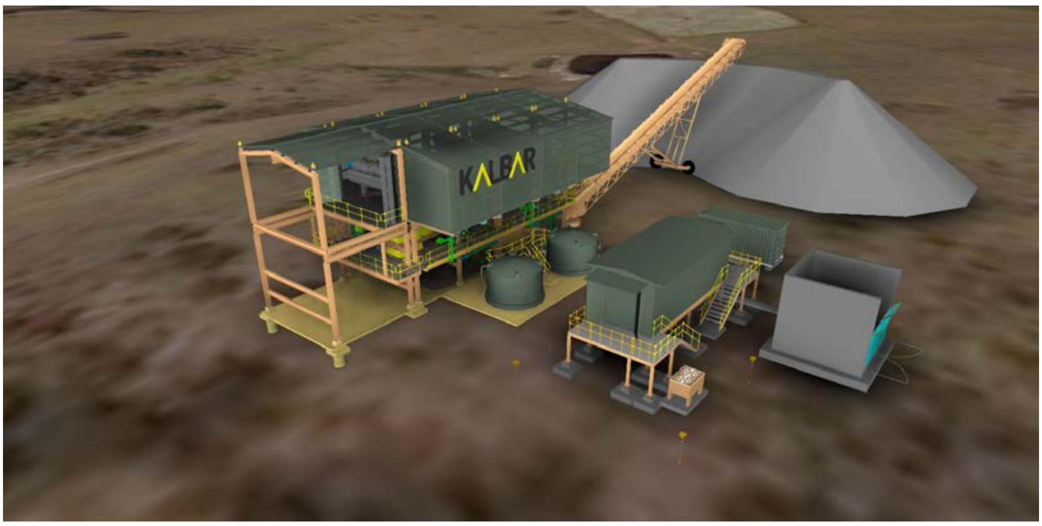

Figure 7 Centrifuge building and cake stockpile

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.

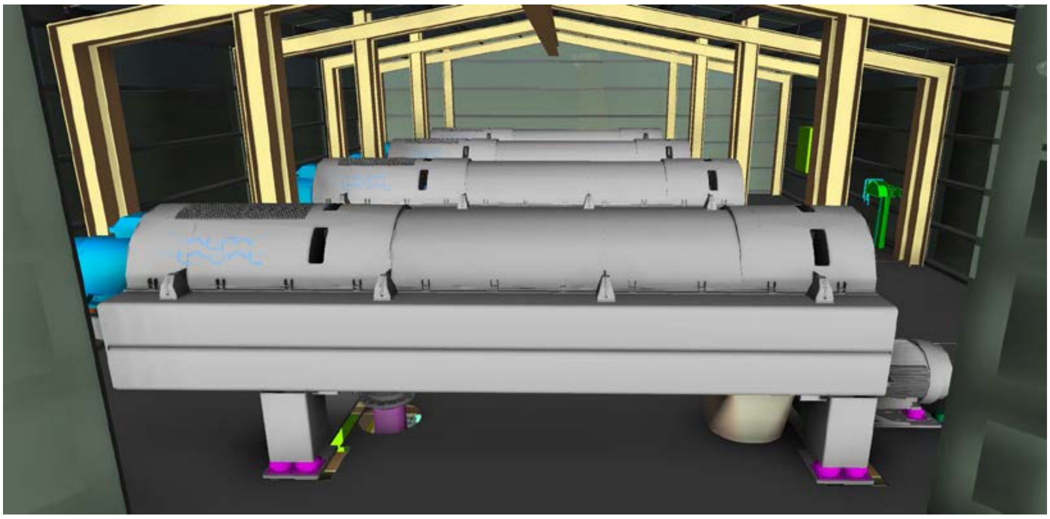

Figure 9 Centrifuges located with cladded building to reduce sound

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.