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Design and construction of a combination soil and water cover on a tailings storage facility in Tasmania

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Abstract

The Main Creek Tailings Dam (MCTD), located at Grange Resources Pty Ltd's (Grange) Savage River Mine in northwest Tasmania, has been in operation since 1985 and is transitioning from an operational tailings storage facility (TSF) to closure. The MCTD is an upstream constructed facility with a maximum height of approximately 83 m. Tailings stored in the MCTD are potentially acid forming (PAF) and require careful management through operation and closure to minimise the risk of the acid and metalliferous drainage (AMD) forming in the TSF.

The site is situated on the west coast of Tasmania, with rainfall significantly exceeding evaporation. Therefore, a water cover would typically be most suitable; however, due to the upstream constructed embankments, a soil cover is required adjacent to embankments to meet long-term stability requirements.

During operations, three trial covers were constructed and instrumented to monitor the performance over a number of years. The information obtained was used to evaluate cover performance and calibrate numerical transient seepage models. The preferred cover based on the trial cover performance was a combination clay and rockfill cover that maintained a high degree of saturation in the clay, minimising oxygen ingress to the underlying tailings, thus reducing the likelihood of AMD formation.

The preferred clay and rock combination cover was assessed and optimised during the detailed design phase by undertaking two-dimensional transient unsaturated seepage modelling in SVFlux, considering a conservative climate scenario.

Construction of the clay component of the combination cover has recently been completed. The construction process, challenges and QA/QC are discussed in this paper.

Keywords: *tailings, AMD, closure cover modelling, closure planning*

1 Introduction

The Savage River opencut magnetite mine is situated on Tasmania's west coast, approximately 100 km southwest of the city of Burnie. The mine has been in operation since 1967 and is currently operated by Grange Resources Pty Ltd (Grange). The Main Creek Tailings Dam (MCTD) was the primary active tailings storage facility on the site from 1985 until recently when the South Deposit Tailings Storage Facility (SDTSF) was commissioned downstream of the MCTD.

The MCTD comprises primarily of valley type storage with a number of embankments to impound the tailings. The main embankment utilises upstream construction methods and has a maximum height of 83 m. The tailings stored within the MCTD are potentially acid forming (PAF); therefore, prevention of acid and metalliferous drainage (AMD) is a key consideration for the closure design.

The closure planning for the MCTD has evolved through the life of the facility involving concept closure planning, construction and monitoring of trial covers, detailed design and construction, which is currently underway.

The closure cover comprises a combination of soil and water cover to minimise oxygen ingress to tailings. Rainfall at the site significantly exceeds evaporation, which maintains a water cover in perpetuity. A soil cover is provided adjacent to embankments to meet long-term stability requirements.

This paper presents the various components of planning undertaken to transition the MCTD from operations into closure.

2 Main Creek Tailings Dam history

MCTD is a zoned earth and rockfill embankment constructed (using conventional downstream construction methods) by previous mine operators between 1982 and 1985 using waste clay and rockfill materials from mine development operations. The main embankment was constructed to RL310 m, giving a maximum height of approximately 60 m.

The main embankment crest was raised 5 m to RL315 m in 1994, as part of the closure works for mine abandonment by the previous operators.

The storage was then reopened, with the embankment raised by upstream construction methods to RL319 m in 2002, RL324.5 m in 2004, RL328.5 m in 2006, RL333 m in 2012 and RL336 m in 2014/15. The closure raise to RL338 m was completed in 2019, which resulted in a total of 23 m height using upstream construction.

Throughout the life of the facility, a number of embankments have been constructed to maintain impoundment. These embankments include the NW Pond Embankment, Spillway Embankment and the Saddle Dam. The Old Tailings Dam (OTD) is situated to the north of the MCTD, the Emergency Tailings Dam (ETD) is situated to the west of the MCTD. The general arrangement of the MCTD is presented in Figure 1.

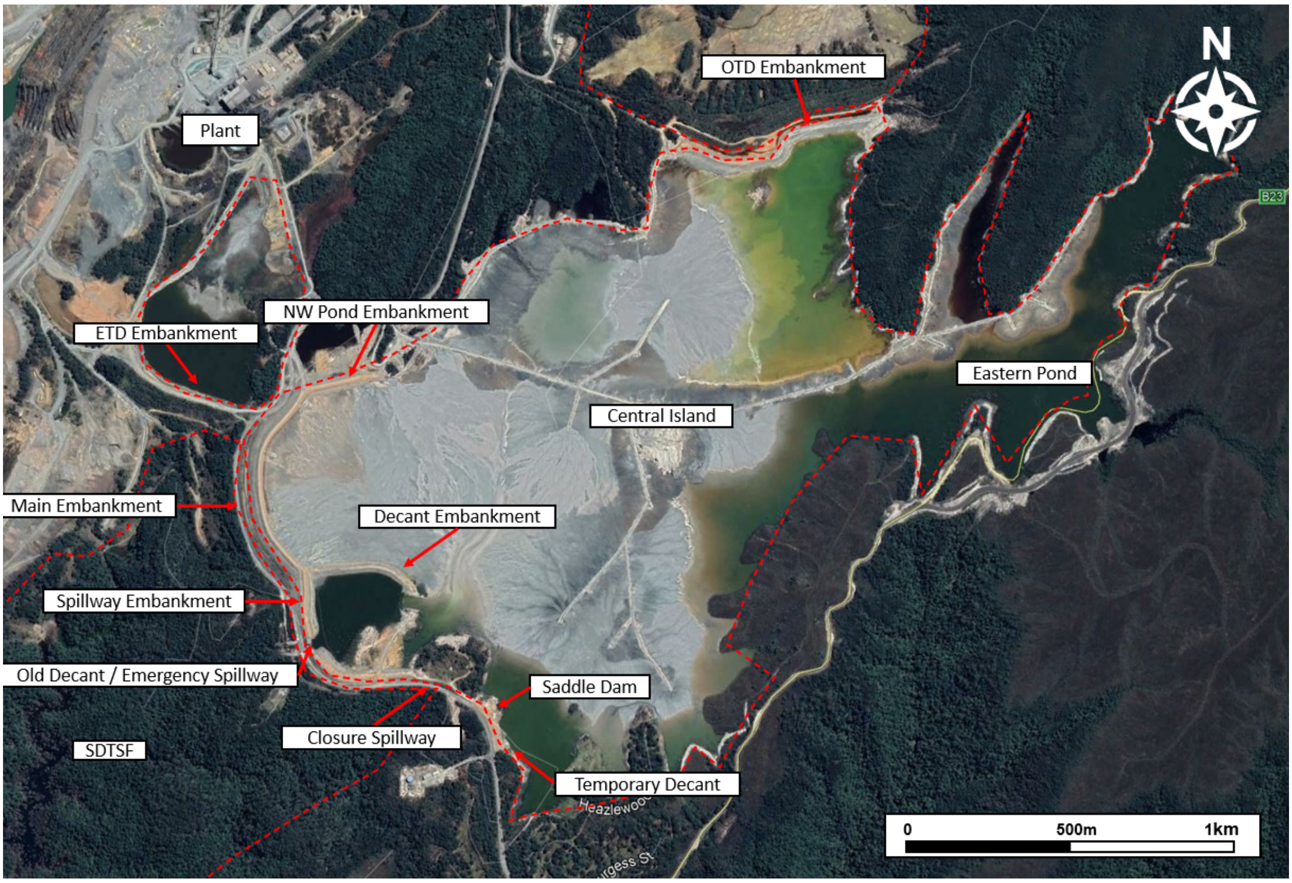

Figure 1 Main Creek Tailings Dam general arrangement (Google Earth 2020)

3 Closure concept

The climate on the west coast of Tasmania is well known for high rainfall and low evaporation, with an approximate 2:1 ratio. The intent of the closure cover is to limit oxygen ingress to the stored tailings at closure to reduce the likelihood of the formation of AMD. The net positive rainfall environment enables a full water cover; however, a full water cover would result in water directly against upstream constructed embankments, which are not designed to be water retaining. Both soil and water cover types suit the climatic conditions when plotted on the global acid rock drainage cover guide, as shown in Figure 2. The closure concept involved a combination cover system comprising a 'dry' or 'soil type' cover 150 m wide adjacent to the upstream constructed embankments with a water cover of 1 m minimum depth elsewhere.

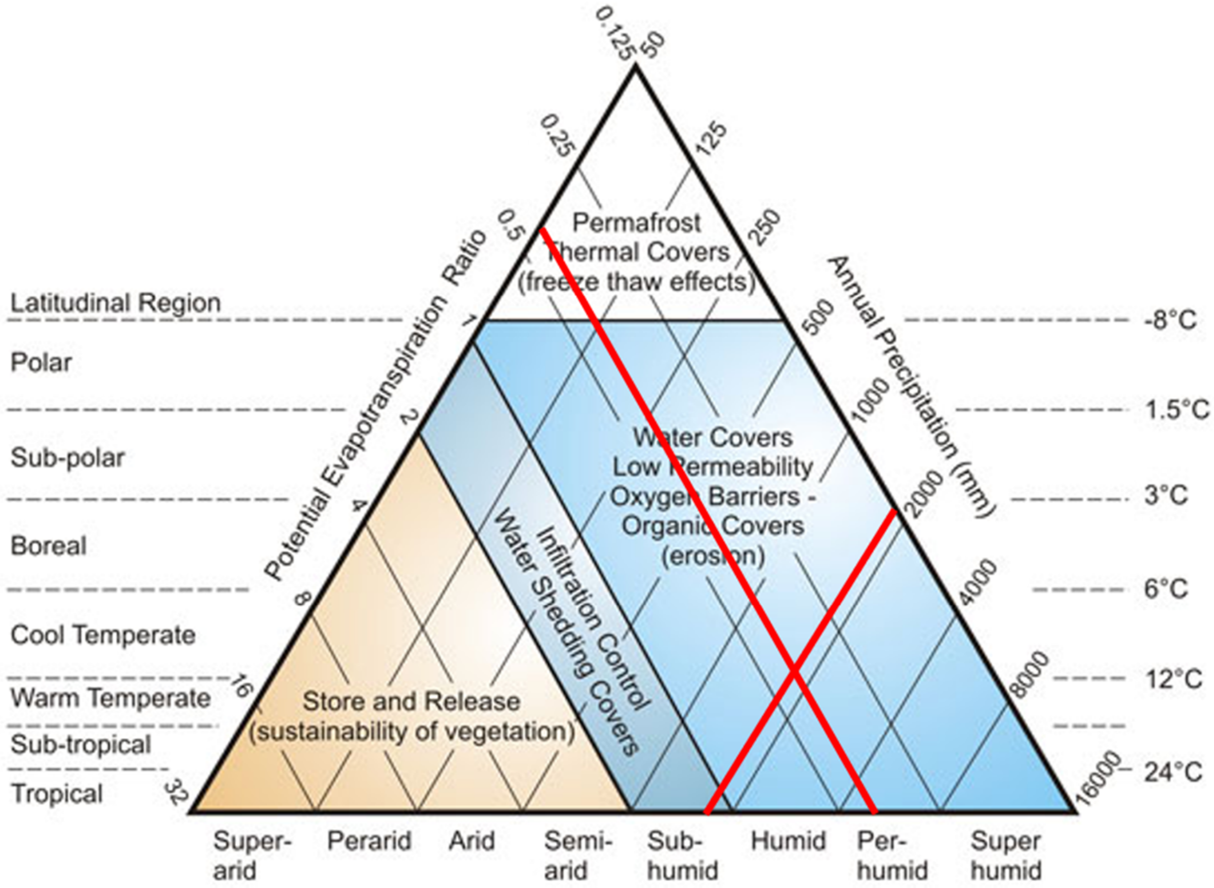

Figure 2 Climate and cover types (INAP 2014)

During the various stages of raising MCTD, the tailings management plan and conceptual closure plan was updated based on the expected life of mine. Premature closure plans were also developed at multiple raise heights such that MCTD could be closed successfully should an unplanned stoppage or closure occur.

4 Trial covers

The long-term performance of the closure cover is critical; therefore, trials with field performance monitoring were undertaken, comprising a section of water-covered tailings and three trial soil covers approximately 40 m wide by 60 m long. These were constructed on the NW Pond, comprising:

- Homogenous clay cover 1.5 m thick – Figure 3.
- Geosynthetic clay liner (GCL) underlying a rockfill protection layer 1 m thick – Figure 4.
- Clay 1 m thick underlying a 1 m thick rockfill protection layer – Figure 5.

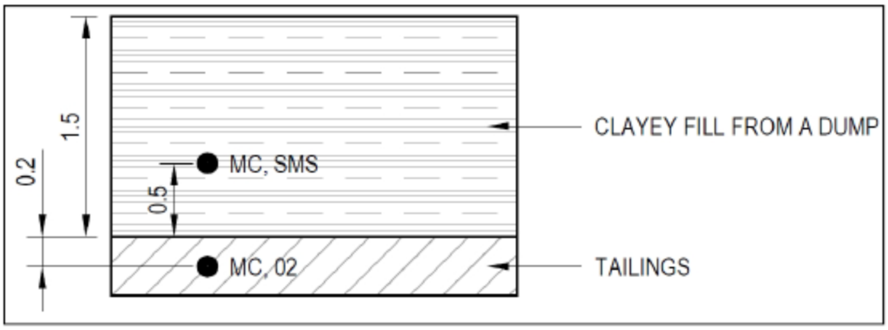

Figure 3 Homogenous clay cover

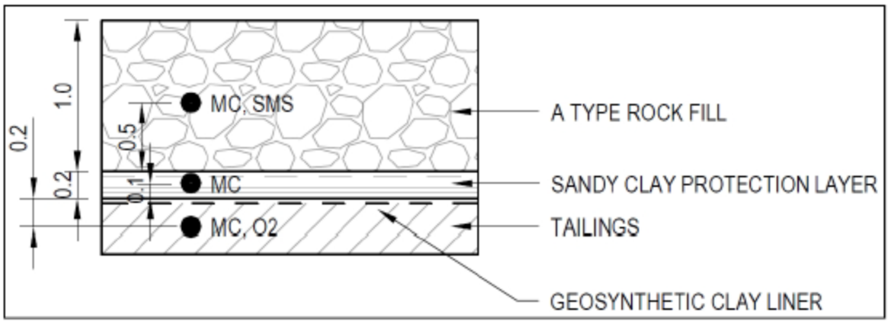

Figure 4 Geosynthetic clay liner cover

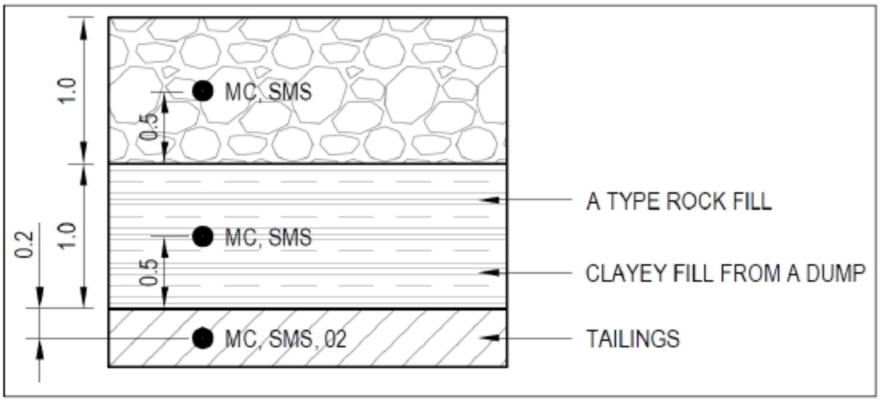

Figure 5 Clay and rockfill cover

The intent of all three covers was to maintain a high level (>80%) saturation within the cover. Instrumentation was installed in the underlying tailings and covers to monitor oxygen, soil matric suction and volumetric water content. Standpipes with vibrating wire piezometers and a weather station were also installed.

Test pits were excavated into the trial covers five years after construction. Material samples were collected for laboratory testing, including soil water characteristic curve and permeability.

The collected data from all three covers were used to calibrate finite element models of the cover in the software package SVFlux. The performance from all three covers was acceptable, with >80% saturation being met at all times; however, the close proximity to a pond (~60 m away) may have impacted saturation levels as the pond level was similar to the surface level of the cover systems, whereas the actual cover will rise at approximately a 1% grade from the final closure pond.

The GCL option was not progressed further, as a 1,000-year design life could not be guaranteed from a manufactured geomembrane.

5 Cover design

Based on the results of the trial cover performance and model calibration, the larger MCTD main embankment was modelled at closure with SVFlux software to determine the optimal cover design for the MCTD. The climate model considered average conditions and also the driest 365-day period on record at Savage River (1242.5 mm from 25/08/1966 to 25/08/2967) to assess the extreme case where cover recharge is low, resulting in worse-case cover saturation. Four covers were modelled in 2D sections as follows:

- 300 m wide – 1 m thick clay cover.
- 150 m wide – 2 m thick clay cover.
- 150 m wide – 1 m clay underlying a 1 m rock cover.
- 150 m wide – 1.7 m clay underlying a 0.3 m rock cover.

The 300 m wide cover enabled the pond to remain further from the main embankment, lowering the phreatic surface within the tailings and embankment and improving stability outcomes; however, the minimum target saturation levels of 80% were not achieved for this case.

A series of 150 m wide covers with a total thickness of 2 m were also modelled as the thicker cover requires a slightly lower saturation level of 70% to achieve a similar reduction in oxygen transfer rate (Miller 1998). The combination clay and rock covers both met the target saturation levels throughout the 365-day model period. The final design was selected as the 1 m clay and 1 m rock cover due to limited clay availability onsite. The rock cover allows for collecting recharge to keep the underlying clay cover at a satisfactory saturation level and provides erosion protection and a growth medium.

Stability of the MCTD and the selected closure cover was assessed and achieved acceptable factors of safety in accordance with Australian National Committee on Large Dams (ANCOLD) guidelines (ANCOLD 2019).

6 Construction

Construction of the closure cover commenced in December 2020 with placement of the clay layer. The construction methodology was unproven to this point. Prior to construction, it was not certain how placing clay over the beached tailings would perform due to the variable nature of the tailings beach and variation of bearing capacity. However, prior experience onsite with constructing access roads over the tailings had showed it was feasible. A safe work method was developed, and to limit the risk of bearing failure and the potential to bog machines in the tailings, this comprised a 1 m thick clay layer, which was placed and compacted in a single lift. The design and specification called for multiple clay layers of 300 mm thickness. Placing a single 1 m thick layer is unconventional; therefore, field and laboratory testing was undertaken at various depths to ensure the clay cover particle size distribution, density and permeability specifications were achieved. In summary, the lab testing showed that minor segregation occurred, with the material being marginally coarser at the bottom of the layer. However, this achieved the required permeability as shown by field and lab permeability testing. The placement methodology was effective through the whole clay placement with only minor bearing failures observed in extremely weak or wet areas of the tailings beach. Grange plans to complete the overlying rock layer once materials become available from the mine. Photos of the construction are presented in Figures 6 and 7. Instrumentation will be installed similar to that used in the trial cover systems to monitor closure performance, particularly the soil cover and tailings saturation levels in addition to reviewing for any increase in pore pressures in the embankment when the pond is allowed to rise to meet the soil cover. MCTD post-closure monitoring will be continued to ensure the close cover is meeting the design intent.

Figure 6 Clay cover placement

Figure 7 Clay cover placement

7 Tailings management

In the years preceding closure, tailings management required careful consideration to ensure that settled density was maximised, while storage capacity was fully utilised and the closure objectives could be met. The key closure objectives to be considered through tailings management were ensuring the large tailings beach maintained during operations was maintained at least 1 m below the future closure pond level to ensure that a minimum 1 m water cover would be established at closure. Tailings deposition modelling was utilised to plan deposition through to closure, allowing Grange to forecast available storage volumes and inform appropriate discharge locations to maximise the storage potential of MCTD while transitioning to a new facility.

8 Associated infrastructure

Prior to transitioning to closure, several key pieces of infrastructure associated with the MCTD were required to be designed and constructed. Two of the key infrastructure items are detailed in the following subsections.

8.1 Closure spillway

The MCTD is designed to meet the ANCOLD (2019) Guidelines on Tailings Dam. The guidelines recommend that for closure all tailings storage facilities (TSFs) can safely pass a probable maximum flood (PMF) event. A new spillway was designed comprising a low flow channel in the centre of a larger 60 m wide open channel spillway. The mine access road crosses the spillway; therefore, the low flow channel was included to pass regular flows up to a 1:140 annual recurrence interval event through a single concrete culvert below the mine access road. The larger 60 m open channel was designed to pass a peak flow rate of 100 m^3/s in the PMF event. The spillway features a concrete nib wall at the inlet to maintain a consistent pond level. The spillway is lined with rip-rap with a minimum D50 of 100 mm, with shotcrete applied to the spillway excavation prior to rip-rap placement to prevent erosion of the in situ material.

8.2 Old Tailings Dam seepage collection bund and pipeline

The OTD is a legacy TSF located upstream of the MCTD. The OTD is a major source of AMD due to its large surface area of exposed PAF tailings. Seepage from the toe of the OTD embankment flowed into the MCTD, which was neutralised by the alkalinity in Grange's tailings slurry during MCTD operations. However, for closure, the continual seepage of AMD into the MCTD pond would have turned the pond acidic, leading to AMD formation in MCTD also.

In order to capture the AMD seepage, the OTD seepage collection bund and transfer pipeline was designed and constructed. The scheme comprised the following:

- A 6 m high earthfill embankment collection bund at the base of the OTD to collect seeps from the OTD at the interface with the OTD embankment and MCTD tailings.
- Surface water diversion drains on the OTD embankment to reduce clean water inflows into the collection bund.
- An intake structure at the OTD seepage collection pond to allow precipitation to settle before entering the transfer pipeline.
- A gravity polyethylene DN280 mm PN10 transfer pipeline from the OTD intake to the SDTSF Storage, with allowance for pressure pigging of the pipeline to enable precipitation cleanout if required.

The items above were constructed in stages from 2014 to 2018, and the scheme is now transferring AMD seepage from the OTD to the SDTSF where it is neutralised through the higher pH active tailings deposition.

9 Conclusion

Planning for closure of MCTD began in approximately 2010, approximately 10 years prior to commencing construction of the closure cover. The planning process undertaken allowed key infrastructure needs to be designed and constructed in a staged manner in the lead up to cessation of tailings deposition and transition to closure. As the knowledge base for closure has continually improved over time, the closure design was also progressively refined. Maintaining premature concept closure plans at various stages ensured the MCTD was operated in a state that could successfully enter a care and maintenance phase or early closure if required. The staged closure planning development approach and closure cover construction have thus far proved to be successful in that the cover has been able to be constructed in accordance with the design specification. At the time of writing, the post-closure performance monitoring was being developed to validate the closure design.

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