NEW BOLIDEN

Tara Mines

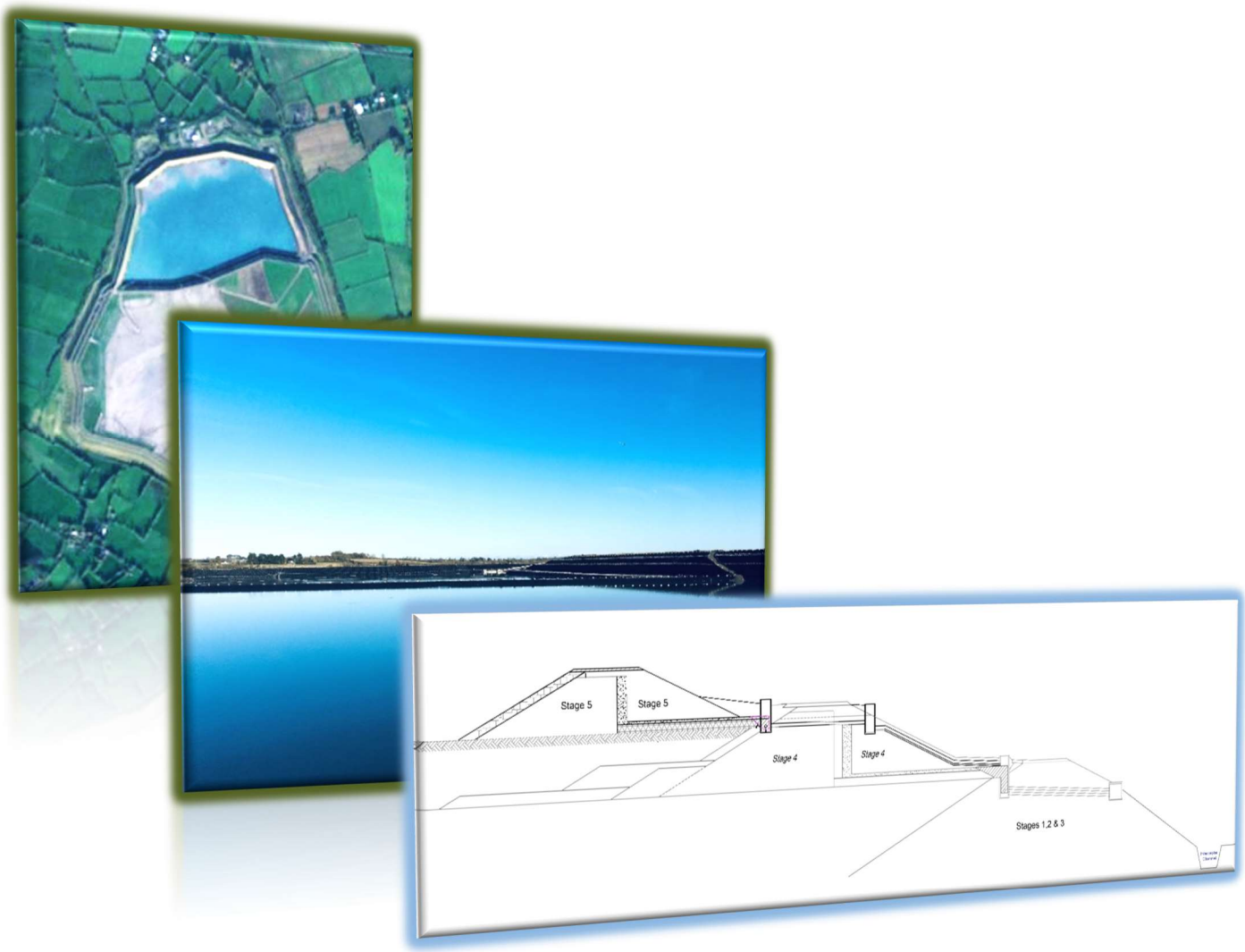
Environmental Impact Assessment Report (EIAR)

Tailings Facility Embankment Buttress

Appendix 1.A

Technical Memo – Buttress Justification

Appeal Reference Number: ABP-315173-22



Submitted: February 2024

NEW BOLIDEN

Boliden Tara Mines DAC

Technical Memo: Proposed Tailings Facility Reinforcement Buttress
Prepared by: Gerd Janssens, Engineer of Record. Boliden Tara Mines (BTM)
Date: November 2022

1 Introduction

The requirement for the construction of a buttress (structure of stone built against a wall to strengthen or support it) around the perimeter of the Tailings Storage Facility (TSF) Stages 1 to 5 has been identified. The buttress will increase the stability of the embankment dam structure to meet the higher standards identified by the Global Industry Standard on Tailings Management (GISTM) issued in 2020.

This technical memo summarises the additional requirements identified in GISTM, the purpose of implementing these requirements, the investigations and analyses undertaken to be able to meet the requirements, and the buttress construction which is required.

2 Background to the proposed works

The Global Industry Standard on Tailings Management (GISTM) has been developed to provide a framework for safe tailings facility management affording operators such as Boliden Tara Mines (BTM) flexibility as to how best to achieve this goal.

The GISTM standard is divided into a series of requirements. Requirement 4.6 mandates the operator to:

> "*Identify and address brittle failure modes with conservative design criteria, independent of trigger mechanisms, to minimise their impact on the performance of the tailings facility.*"

The key terms to understand in this requirement are Brittle Failure and Trigger Mechanism.

- *Brittle failure* occurs when the embankment dam material or foundation suffers a rapid strength loss with minimal initial deformation. Materials which exhibit a large reduction in strength once failure is initiated are referred to as brittle, requiring a relatively large difference in peak and residual strength. The significance of a brittle failure is that it can be very sudden, providing little to no warning, and typically resulting in a larger failure.

- *Trigger mechanisms* are simply the mechanisms which could initiate the brittle failure of the embankment structure. These trigger mechanisms can be due to single or multiple events and which can include elevated water levels, rapid placement of additional fill, movement of foundation, or a seismic event. The trigger mechanisms result in the peak strength of the material being exceeded.

Requirement 4.6 of GISTM specifies that this brittle failure can be addressed through conservative design criteria. One of these design criteria is the stability Factor of Safety (FoS).

The stability of a dam structure is determined by a limit equilibrium stability analysis. This analysis calculates the driving forces leading to instability (typically the weight of the material and steepness of the slope) and compares this to the resisting forces against instability (the strength of the material in the embankment). The ratio of the driving and resisting forces are represented as the Factor of Safety. The higher the Factor of Safety, the greater the stability of the structure.

In conjunction with the GISTM standard, The International Council on Mining and Metals (ICMM) issued the Tailings Management Good Practice Guide. The Good Practice Guide is intended to support the requirements of the GISTM Standard and provide guidance on good governance and engineering practices.

The Good Practice Guide provides the following recommendation on Factor of Safety (FoS):

- Design FoS are not prescribed but should be determined by the Engineer of Record (EOR) and the Design Team and should be endorsed by Independent Review.

- The sensitivities of safe design to material characterisation and site characterisation should be recognised by the EOR and the Design Team and their evaluations should be endorsed by Independent Review. Significant consideration should be given to selecting appropriately conservative material strength parameters for deterministic analysis of the FoS.

Boliden Tara Mines (BTM) have relied on Factor of safety criteria recommended in industry standard guidelines which include the Canadian Dam Association (CDA), International Conference on Large Dams (ICOLD), Australian Conference on Large Dams (ANCOLD), and the European Commission Beast Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries.

Previous industry guidelines did not specifically cover the concept of FoS in the event of brittle failure. BTM have chosen to incorporate the potential for brittle failure in the stability interpretation by selecting a Factor of safety criteria of >/= 1.1 for the residual (liquefied) strength of the tailings.

To update the analysis, BTM first needed to identify the potential for brittle failure and resulting factor of safety, as discussed further in the following section.

It is important to note that the TSF is not currently at risk for instability based on the operational practices in place. The existing design and operation of the TSF was based on the material strength parameters staying within the design range and with operational controls set in place to ensure that these are not exceeded. The potential for triggering liquefaction and brittle failure was, therefore, managed to be within acceptable risk levels based on best practice at the time.

3 Studies Undertaken

The BTM tailings storage facility has always been designed and operated based on the prevailing best industry practice (BAT).

- The original embankments were constructed with an internal drainage system to control the pore water pressures within the embankment. The subsequent upstream raises (Stages 4 and 5) were similarly designed and constructed with internal drainage to control the pore water pressure within the embankment.

- The tailings foundation had wick drains installed prior to upstream raise construction to limit potential build-up of excess pore pressure in the tailings foundation and promote consolidation.

- The rate of construction was controlled and monitored (through Vibrating Wire piezometers) to prevent rapid loading of the foundation tailings.

- The operations and tailings deposition were such that the rate of rise of the facility was controlled and the water level was managed.

- Characterisation of the tailings was undertaken prior to each of the two upstream raises by conducting in-situ site investigation and laboratory testing of the tailings.

These controls eliminated the potential trigger for liquefaction.

In 2019, BTM decided to review the stability of the TSF. This involved a review of the historic site investigations, along with a reassessment of the design. This was undertaken to determine the potential for static and dynamic (seismic) liquefaction of the tailings within the TSF which could have the potential to result in brittle failure referred to in GISTM Requirement 4.6. Liquefaction is the sudden loss of strength due to a build-up of pore pressure within the material.

The 2019 study identified layers within the tailings that had the potential for brittle failure provided there was sufficient mechanisms to initiate the triggering of the liquefaction of the tailings. The study recommended that additional investigation and analysis be undertaken to confirm this. These additional investigation and analysis were initiated in June 2020 with analyses issued in June 2021. The investigations consisted of the following:

- A site investigation included in-situ characterisation of the tailings through cone penetration tests, pore pressure dissipation tests, seismic shear wave velocity measurements, shear vane testing, and collection of undisturbed samples.

- A detailed laboratory investigation program which included standard characterisation testing, but also specialised high end testing to be able to fully assess the liquefaction and brittle failure potential of the tailings.
- Establishment of a constitutive tailings soil model to allow calibration of the in-situ and laboratory test results, and to determine the in-situ state of the tailings.

- Limit equilibrium stability analyses, incorporating all the results and modelling data, to assess the stability based on the defined criteria.

The recommendations of the report, based on meeting the GISTM standard, were as follows:

- A Phase 1 buttress is to be constructed at the downstream toe of Stage 4 embankment to reduce the likelihood of the potential tailings liquefaction (brittle failure).

- A larger phase 2 buttress to follow on from the Phase 1 buttress and would prevent excessive deformation or slope failure in the event of tailings liquefaction.

These recommendations have been endorsed by the Independent Tailings Review Board (ITRB).

4 Description of the Buttress Works

The buttress is required to prevent the initiation of liquefaction of the tailings, as well as limit the deformation if the liquefaction is initiated. The deformation resulting from the tailings liquefaction would be limited to within the tailings material and would not result in an extension of the slip surface through the current Stages 1 to 3 starter dams. A buttress is, therefore, only required on the crest of the Stage 1, 2 and 3 dam embankments where the deformation zone (slip surface) would exit. The crest does need to be widened, however, to accommodate the required buttress size.

Rockfill material has been specified to be placed on the Stage 1, 2 & 3 crest as this has a greater frictional strength than glacial till fill (which is a silty sand to sandy silt material).

The widening of the Stage 1 to 3 embankment dams can be done with the use of glacial till as it is only required to provide support for the rockfill portion of the buttress. Through placement of additional glacial till, the downstream slope will be flattened to a gradient of 2.75H:1V to provide the final closure landform. A drainage layer will be included at the base of the glacial fill to prevent potential saturation of this fill and to tie into the existing internal drainage.

The construction quality assurance and monitoring undertaken during construction will be such that the stability of the existing dam will not be impacted by the placement of additional fill material.

5 Summary

The construction of a buttress around the perimeter of the Stages 1 to 5 of the Tailings Storage Facility (TSF) is required to increase the stability of the embankment dam structure to meet the higher standards identified by the Global Industry Standard on Tailings Management (GISTM) issued in 2020.

The Global Industry Standard on Tailings Management (GISTM) is a new framework for safe tailings facility management, and which requires the operator (BTM) to identify and address brittle failure modes with conservative design criteria, independent of trigger mechanisms, to minimise their impact on the performance of the tailings facility.

BTM undertook additional studies and investigation in 2019 and 2020 to investigate and identify the potential brittle failure modes of the TSF embankment dam. Previous industry best practice was to manage the facility to reduce and eliminate trigger mechanisms which could lead to brittle failure. GISTM require that this is instead managed through the design, which led BTM to recommend the construction of a buttress to ensure the long-term stability in line with best industry practice.

The buttress will consist of widening of the Stage 1,2 and 3 starter dams, and placement of additional fill on the crest of these starter dams.

The proposed buttress design has been endorsed by the ITRB under GISTM.
The proposed buttress has been reviewed by SLR Consulting in its Independent Dam Safety Review Audit, 2022[1].

It is important to note that the TSF is not currently at risk for instability based on the operational practices in place.

[1] SLR consulting,2022. (SLR Ref: 501.064717.00001/R01. Version No: 1. December 2022)