

## REPORT

**MANDALAY RESOURCES  
COSTERFIELD OPERATIONS**  
ABN: 34 006 911 119

**Costerfield Gold Mine**

**Brunswick West Tailings Storage  
Facility Investigation and Design**

**Detailed Design Report**

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PLAN**



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## EXECUTIVE SUMMARY

### General

At the Costerfield Gold Mine, Mandalay Resources Costerfield Operations (MRCO) produces a high-grade gold ore using long-hole stoping with cemented rockfill. The Costerfield Gold Mine currently produces ore from two veins, Youle and Shepherd, at production rates of between 12,000 tonnes to 15,000 tonnes per month. Ore is trucked to the Brunswick Processing Plant via the Brunswick underground portal, where it is stockpiled and blended into the crusher. Tailings produced from the processing have been stored in the Bombay Tailings Storage Facility (TSF) and the Brunswick TSF. The Bombay TSF was recently raised to its final elevation, and is currently active and receiving tailings, and is expected to reach capacity around September 2023. The Brunswick TSF is at capacity, and MRCO have no intentions to further raise the facility. Once the Bombay TSF is at capacity, both these facilities will be closed.

ATC Williams Pty Ltd (ATCW) have been commissioned to undertake the design of a new single stage facility, named the Brunswick West TSF, that will provide tailings storage for up to 5 years. MRCO have indicated their intention to cease underground mining and production of tailings in Q3 2027 (though this date may be extended), and as such, Brunswick West TSF may be the final tailings storage facility commissioned at MRCO.

### Site Conditions

The site of the new Brunswick West TSF is located approximately 500 m north-west of the Brunswick Processing Plant, located within an adjacent farm paddock. The site is roughly triangular in shape, and is confined by Crown Land to the east, MRCO infrastructure and additional farmland to the south, and Bradleys Lane to the west.

The site has a ridge at approximately RL 194.0 m in the centre of the paddock running in a south-easterly direction, from which the natural ground slopes to the north, east and south at a natural grade of up to 5%. The site currently contains two farm water dams at the east and south, the latter of which is situated within a natural drainage channel.

The site currently contains farm infrastructure, trees and a high voltage Single Wire Earth Return (SWER) powerline. Additionally, the boundary of the Brunswick West TSF extends partially into the MRCO Low Grade Run of Mine (ROM) pad. This infrastructure is required to be removed prior to commencement of construction. The site is also located immediately upstream from the Brunswick underground portal.

The local climate of the Costerfield region is considered 'semi-arid'. The climate is generally characterised by cool and wet winters, whilst the summer is often hot and dry.

The regional geology at the Costerfield mine site comprises recent to Holocene age fluvial and colluvial deposits, typically comprising of gravel, sand and silt, overlying Silurian age Costerfield Siltstone, typically comprising thinly bedded siltstone, with minor sandstone and conglomerate.

The Costerfield Mine is in an area of moderate seismicity within Victoria. Within a regional setting, the Costerfield Mine is located on the western side of the Melbourne structural zone, which is bounded by the Mount Williams Fault to the west and the Governor Fault to the east. Locally, the nearest faults are the Moormbool, Costerfield, Black Cat and Mount William Faults, located between 2 and 8km from the Brunswick West TSF site.

### Design Alternatives

Two concepts for storage were considered; a compacted clay core, and a geosynthetic liner. Due to the material properties of the clay at site, a two stage downstream filter would be required for the clay core option, with at least one of the filters required to be formed from imported sand due to the strict particle size requirements.

A high level cost estimate of the two concepts found that the geosynthetic liner option would be cheaper, primarily driven by the high costs of importing significant quantities of sand filters. The geosynthetic option would also provide more control in mitigating potential embankment failure scenarios through the prevention of water migration through the embankment section. The geosynthetic alternative also offers a more simple construction regime. The geosynthetic option was chosen for the design of the Brunswick West TSF.





## Design Concept

The design concept for the Brunswick West TSF is for a single-stage TSF for the storage of tailings for approximately 5 years. The proposed conceptual design consists of;

- Excavation of foundation material within the TSF impoundment to Moderately Weathered (MW) rock to provide borrow materials for construction and to maximise the storage capacity of the TSF;
- Lining of the upstream batter slopes (either with compacted clay or geosynthetic liner) for tailings and decant water storage;
- Construction of perimeter embankments to final height;
- Construction of a decant structure within the TSF; and
- Construction of an external Return Water Pond (RWP).

## Regulatory Design Criteria and Consequence Category

The design of the Brunswick West TSF has been prepared to comply with the relevant ANCOLD Guidelines and Victorian Department of Jobs, Precincts and Regions Earth Resource Regulations (VIC ERR). Specific design requirements for tailings storage facilities are given by ANCOLD “*Guidelines of Tailings Dams*” and VIC ERR “*Guidelines for the design and management of tailings storage facilities*”, which relate to the risk classification of the facility. These classifications determine the level of detail applied to design (specifically storm water storage, spillway, and earthquake design criteria) and operation, maintenance, and surveillance requirements.

The ANCOLD guidelines assign Consequence Categories for Dam Failure and Environmental Spill of contained water. Due to the location of the site relative to the Brunswick underground mine portal, flood protection measures to prevent the inundation of underground with tailings in the event of the dam break have been considered essential to the works. With these mitigation measures in place, a dam break assessment found the critical Population at Risk (PAR) to be 25, primarily associated with the mine personnel at the Brunswick Processing Plant. A Potential Loss of Life (PLL) of 1.0 was also calculated for the critical dam failure.

The severity of damage and loss was found to be Major due to the business and external reputations impacts. As such, a Dam Failure Consequence Category of **High B** has been assigned to the Brunswick West TSF. An Environmental Spill Consequence Category of Low was found, based on the potential release of saline mine water to the environment in the event of a spillway flow, but **Significant** has been adopted for the design.

## TSF Operational Concept

The TSF operational concept will involve deposition from a single point at the northern most point of the facility. Occasional deposition from an additional 4-6 spigot points strategically placed around the facility will help to shape the tailings beach. This arrangement will allow the tailings to beach to shape to a low point at the south-western corner of the facility against the embankments where an inclined decant filter structure will be constructed.

Surface water will enter into the inclined decant structure, comprising of three large heavy duty HDPE pipelines with slots cut into them, and wrapped in a UV resistant filter geotextile, and connected to a pre-cast concrete pit at the base of the embankment. The geotextile will allow water to freely migrate into the pipelines and filter down to the base pit, while preventing tailings from entering. As the tailings rise, the geotextile will clog, primarily allowing surface water to enter in. Water will be pumped out of the pit via a submersible pump and sent to the external RWP.

The intention of the external RWP is to help alleviate issues previously faced with the existing TSFs with water remaining on the facility for extended periods of time while the Brunswick Processing Plant water needs are met, and the Augusta storage dams are full. The external RWP effectively acts as detention basin for the TSF, allowing for water to be continually removed from the TSF even when the Augusta storage dams are at capacity. All water collected within the external RWP is conveyed to either the process plant or Augusta storage dams.





## Operating Levels

The design of the Brunswick West TSF is driven by the embankment height and the operational intent and regulatory water storage requirements. The maximum operating levels have been assigned based on the ANCOLD regulatory requirements for a **High B** dam failure consequence category & **Significant** environmental spill consequence category dam, which include

- Spillway Capacity = Probable Maximum Flood
- Wet Season Storage Allowance = Maximum Operating Pond from Water Balance
- Extreme Storage Allowance = 1 in 100 AEP, 72-hour event plus contingency freeboard

A minimum beach freeboard from the embankment crest to the top of tailings of 0.5 m was also applied to prevent tailings overflow due to localised deposition mounding, and aid in providing suitable storm storage beneath the emergency spillway.

The results of the spillway assessment indicated that a minimum 0.3 m deep, 6 m wide spillway is sufficient to pass the Probable Maximum Flood without overtopping the embankment crest. The spillway has been designed as 0.5 m deep to further reduce and mitigate the risks of embankment overtopping failures.

The Maximum Operating Pond observed from 1,000 realisations of synthetic climate data over the life of Brunswick West TSF was approximately 14,000 m<sup>3</sup>, equating to a pond depth of 0.8 m at the end of filling.

The extreme storm storage allowance for the runoff from a 1:100 AEP, 72-hour storm within the TSF catchment (i.e., confined within the embankments) was approximately 11,000 m<sup>3</sup>, equating to an additional 0.26 m of freeboard required.

The contingency freeboard is equal to wave runup from 1:10 AEP winds plus 0.3 m freeboard. Wave run-up from wind is generally only a concern for large dams with relatively deep bodies of water against the embankment and a long fetch distance from the embankments, which is not applicable for the Brunswick West TSF is relatively small, and wave run-up from wind will be negligible. Contingency freeboard is equal to 0.3m.

Based on this assessment, the following levels are specified:

|   |              |
|---|--------------|
| Maximum Operating Pond =                | RL 198.9 m   |
| Extreme Storm Storage Allowances =      | RL 199.1 m   |
| Contingency Freeboard =                 | RL 199.4 m   |
| Spillway Invert Level =                 | RL 199.5 m   |
| <i>Additional freeboard to spillway</i> | <i>0.1 m</i> |
| Embankment Crest Level                  | RL 200.0 m   |

## Civil Works

The early works for the facility will consist of the removal of existing farm equipment and livestock, removal and re-location of an existing overhead powerline running through the centre of the site, draining of water from the existing farm dams, removal and mulching of trees, and excavation of a portion of the existing low grade ROM pad to re-expose natural ground.

Foundation preparation will consist of initially stripping 0.5m of topsoil across the entire footprint, followed by a further excavation of 0.5m of clayey material for embankment construction, and compaction of the remaining foundation clay to 98% Standard Maximum Dry Density (SMDD). At the previous farm dams and at the ROM pad, the foundations will be stripped to weathered rock.

The impoundment within the facility will be excavated down through less weathered rock to a minimum elevation of RL 180.0m providing the bulk of embankment construction material. The base of the facility will be lined with 1.0m of select compacted clay won from stripping and excavation. An underdrainage network at the base of the impoundment, that is fed into the decant structure will also be constructed to aid in consolidation of the tailings.





Hydraulic performance of the embankments will be provided by a Bituminous Geomembrane (BGM) liner installed on the embankment upstream face, and connected to the base impoundment liner. The embankments will be formed by construction of an upstream clayey subgrade for the placement of the BGM, a transition weathered rockfill zone, and a downstream less weathered rockfill shoulder. The embankments will be constructed to their final downstream closure batter slopes of 4:1 (H:V) and covered with topsoil.

The external RWP will be formed of general earthfill material, and be lined with geosynthetic liner to provide a very low permeability seal for water storage.

### **TSF Conceptual Closure**

A Conceptual Closure Plan for the TSF has been developed as follows:

- A domed (convex), self-shedding cover with a nominal 5% grade.
- The cover layers will comprise a low permeability earthfill material, overlain by inert (i.e., non-acid generating) earthfill and weathered rockfill, and a final layer of topsoil to support revegetation.
- The low permeability earthfill material will be placed directly over the tailings surface and will be
  - A minimum thickness of 0.5 m at the perimeter embankment, and increase in thickness over the tailing surface to the centre of the TSF to form a minimum 5% grade from the centre of the TSF towards the perimeter embankment,
  - The low permeability earthfill material will connect to the Zone 1B Subgrade and BGM liner around the entire perimeter of the TSF to fully encapsulate the tailings,
  - The increasing thickness of the low permeability earthfill material towards the centre of the TSF is designed to support a revegetated surface without intercepting with the tailings below.
- The earthfill and weathered rockfill will be placed over the earthfill material to a minimum thickness of 0.5m, and matching the underlying 5% grade of the landform.
- The topsoil material will be placed over the weathered rockfill to a nominal thickness of 300 mm.

Formation of the initial cap to support the closure landform is dependant on achieving sufficient shear strength (generally a minimum of 15 kPa) in the upper 3 – 5m of tailings deposit to support light weight earthmoving equipment. Based on previous in-situ strength test results on tailings within the Bombay TSF achieving a minimum of 8 – 10 kPa within less than 1 year of deposition ceasing, it is expected that the Brunswick West TSF tailings will have formed a suitable strength crust within 2-3 years after ceasing deposition to support the placement of the initial cap.

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## 1 INTRODUCTION

This report presents the detailed design for the new Brunswick West Tailings Storage Facility (TSF) at Mandalay Resources Costerfield Operations (MRCO) Costerfield Gold Mine, located approximately 8 km north-east of the township of Heathcote in Victoria, Australia.

These works have been carried out at the request of MRCO and in general accordance with ATC Williams (ATCW) proposal 10901.15-P01, dated 8<sup>th</sup> April 2022.

This document presents Revision 3 of the Detailed Design Report for inclusion into the revised Work Plan Submission, with Revision 2 submitted to 3<sup>rd</sup> party review. Changes made within this document as part of the Revision 2 update are presented in Red, and further changes as part of Revision 3 are presented in Blue. Where relevant, reference to Revision 1 of this report will be made.

## 2 SITE DESCRIPTION

The Costerfield Mine is an underground gold and antimony mining operation. The site currently has two tailings storage facilities:

- Bombay TSF (currently receiving tailings), located 500 m north of the Brunswick Processing Plant, and
- Brunswick TSF (at capacity, deposition recently ceased), located to the immediate east of the Brunswick Processing Plant.

A locality plan of the Costerfield Gold Mine is presented in **Figure 1**, with the general Brunswick West TSF area shown in **Figure 2**.

The site of the new Brunswick West TSF is located approximately 500 m north-west of the Brunswick Processing Plant, located within an adjacent farm paddock. The site is roughly triangular, and is confined by Crown Land to the east, MRCO infrastructure and additional farmland to the south, and Bradleys Lane to the west.

The site has a ridge at approximately RL 194.0 m in the centre of the paddock running in a south-easterly direction, from which the natural ground slopes to the north, east and south at a natural grade of up to 5%. The site currently contains two farm water dams at the east and south, the latter of which is situated within a natural drainage channel.

The site currently contains farm infrastructure, trees, and a high voltage Single Wire Earth Return (SWER) powerline. Additionally, the boundary of the Brunswick West TSF extends partially into the MRCO Low Grade Run Of Mine (ROM) pad. This infrastructure is required to be removed prior to commencement of construction.

The existing conditions at the Brunswick West TSF site are presented in **Figure 3**.

## 3 BACKGROUND

### 3.1 Scope of Work

MRCO have engaged ATCW to complete the works for the design of the Brunswick West TSF. These works originally consisted for a Life of Mine assessment and conceptual designs, and have progressed to detailed design.

The scope of work for this projects is as follows:

- Undertaking a geotechnical investigation of the Brunswick West TSF site, aimed at understanding the sub-surface conditions and collection of samples for laboratory testing – separate document;
- Conducting laboratory testing to define and verify the design parameters for construction materials – separate document;



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- Undertake a dam break assessment to define the downstream inundation area, TSF consequence category and required flood protection measures – separate document;
- Conduct a quantitative risk assessment of the facility to estimate the likely methods of embankment failure, and provide suitable risk mitigation measures – separate document;
- Design of the TSF and appurtenant structures, including;
  - TSF embankments, impoundment excavation and emergency spillway.
  - External Return Water Pond (RWP).
  - Clean water diversion drains around the facility.
  - TSF decant structure.
  - TSF underdrainage.
  - Access ramps and flood protection measures.
- Estimation of civil quantities for the construction works.
- Preparation of tender documentation (civil technical specifications and construction drawings) – separate documents;
- Design of the mechanical infrastructure – separate document;
- Preparation of TSF operating manual and dam safety emergency plans – separate documents.

## 3.2 Storage Options Assessment

In tandem with the ATCW Life of Mine Assessment, MRCO internally conducted a storage technology and location options assessment for the Life of Mine tailings storage alternatives for Costerfield.

The current tailings storage options comprised of the Bombay TSF and Brunswick TSF, both which had been raised multiple times through both downstream and upstream methods. This has resulted in a reduction in the suitability for future downstream raises as the cost and volume of material required for construction has substantially increased and expansion of the current embankment toe would require the removal of Crown Land native vegetation.

Initial considerations were made for storage alternatives, and are summarised in Table 1.

**TABLE 1: STORAGE OPTIONS INITIAL ASSESSMENT**

| Option                           | Notes   |
|----------------------------------|---|
| Bombay TSF – Upstream Raising    | <ul style="list-style-type: none"> <li>• Currently operating TSF.</li> <li>• Raising to the final permitted height has just been completed, and a further increase to the footprint and height would require new permitting.</li> <li>• Minimal material volume required for raise, but also would provide minimal storage.</li> </ul>  |
| Brunswick TSF – Upstream Raising | <ul style="list-style-type: none"> <li>• As above for Bombay TSF</li> </ul>   |
| Bombay TSF – Downstream Raising  | <ul style="list-style-type: none"> <li>• Raising to the final permitted height has just been completed, and a further increase to the footprint and height would require new permitting.</li> <li>• Large quantity of rockfill would be required to construct an additional raise, resulting in high financial costs.</li> <li>• Extensive vegetation clearing, including works on Crown Land.</li> </ul> |



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| Option               | Notes   |
|----------------------|---|
| Bombay TSF Cell 3    | <ul style="list-style-type: none"> <li>New cell located on the southern side of the current Bombay TSF, with close proximity to the Brunswick Processing Plant.</li> <li>Located on Crown Land, requiring new lease boundary agreements.</li> <li>Extensive vegetation clearing required.</li> <li>Require WPV and planning permit.</li> </ul>  |
| Underground Backfill | <ul style="list-style-type: none"> <li>Workplan allows for tailings to be utilised for backfilling of underground voids.</li> <li>Requires surface plant infrastructure upgrades.</li> <li>Fine grind size limits the volume of tailings amenable to paste or hydraulic fill.</li> <li>Small stope size makes continuous fill placement not possible.</li> </ul>  |
| Brunswick West TSF   | <ul style="list-style-type: none"> <li>Close proximity to Brunswick Processing Plant.</li> <li>Positive landowner discussions, with potentially three farm paddocks around the site suitable for use.</li> <li>Minimal vegetation clearing required.</li> </ul>   |
| Augusta Central TSF  | <ul style="list-style-type: none"> <li>A repurposed facility on MRCO owned property.</li> <li>Currently utilised for water management, requiring new water dams to be constructed regardless.</li> <li>Permitting may be required.</li> </ul>   |
| Brunswick Open Pit   | <ul style="list-style-type: none"> <li>Potential to sterilise ore.</li> <li>Permitting may be required.</li> <li>Presence of underground portal eliminates this option until underground mining ceases.</li> </ul>  |
| Geotubes             | <ul style="list-style-type: none"> <li>Placement of geotubes within current approved TSF footprint.</li> <li>Aids closure by using tailings to aid final landform shape.</li> <li>Utilises existing TSF water management infrastructure.</li> <li>Solution is stackable.</li> <li>Limited long term capacity, as is depending on existing tailings surface strength, and ultimately limited by the closure landform footprint.</li> </ul> |

Based on the above options, MRCO determined that a new conventional TSF in the farm paddocks to the west of the Brunswick Processing Plant was likely to be the least challenging and most likely to be successful in the timeframe available. The implementation of Geotubes was also identified as a potential short-medium storage alternative should a new TSF become delayed.

MRCO are aware of changing guidelines in respect to tailing management and future regulatory approvals. A heightened focus has been placed on miners and tailings management by regulators, shareholders and company boards due to recent global events. These changes have led to more scrutiny of tailings options and the desire to identify cost-effective alternatives to conventionally managed TSFs. Over the past year, MRCO has been exploring which emerging technologies offer the greatest potential in this regard with a view of embracing the circular economy.

Finding innovative solutions to these challenges will require collaborating with other industries. Some alternative solutions being investigated is as follows:

- Production of topsoil for site closure and rehabilitation purposes;
- Production of soils and/or composts;
- Brick/paver manufacture;
- Civil works; and
- Road construction.

MRCO are currently working with The Circular Mine Consortium to identify which of the above solutions are amenable to our tailings and if not, what uplift or processes are required to allow them to be used.



## 3.3 Life of Mine Options Assessment

### 3.3.1 Preliminary Assessment

In mid-2021, ATCW were engaged by MRCO to undertake a Life of Mine tailings assessment for the Costerfield site. The aim of this assessment was to complete conceptual designs for a 10 year tailings storage life at multiple Greenfields sites around the Costerfield mine site and surrounding area, and to provide preliminary guidance as to which sites should be pursued further. The sites considered were as follows, and are presented in **Map 1**:

- Option 1 Farm paddock immediately south-west of the Brunswick Processing Plant.
- Option 2 Farm paddock approximately 800 m south-east of the Augusta Mine.
- Option 3 Immediately adjacent to the Splitters Creek Evaporation Facility, located approximately 4 km north-east of the Brunswick Processing Plant.

**MAP 1: LIFE OF MINE PRELIMINARY SITE OPTIONS**



At a maximum production rate (advised by MRCO) of 15,000 tpm and an average in-situ density (based on historical reconciliation of previous Costerfield TSFs) of 1.3 t/m<sup>3</sup>, each alternative was required to store approximately 1.38 Mm<sup>3</sup> of tailings.

These sites were assessed as single stage embankments for comparative purposes. No consideration was made for potential site expansion through foundation excavation. A summary of these preliminary options is presented in **Table 2**.

Both Option 1 and Option 2 could store the required tailings, however Option 3 was unable to store the required 10 years of tailings, primarily due to the confined area of the site and underlying topography. Additionally, the location of Option 3 from the Brunswick Processing Plant (approx. 4 km through Crown Land State Forest) ruled this site out.





### 3.3.2 Final Assessment

Since the preliminary assessment was conducted, MRCO advised ATCW that all three sites were unfeasible, either due to location and proximity (i.e., long pumping distances) to the Brunswick Processing Plant or land access issues with the current owner of the farmland sites.

In late September 2021, a location was agreed upon with the landowner within the paddock adjacent to the north-western side of the Brunswick Processing Plant, and to the south-west of the Bombay TSF. This new facility, hereto referred to as the Brunswick West TSF, was assessed as being capable of providing tailings storage for the medium term (4 to 5 years), and would succeed Raise 4 of the currently active Bombay TSF.


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TABLE 2: SUMMARY OF LIFE OF MINE PRELIMINARY OPTIONS

| Option 1  |                                |  |
|---|--------------------------------|---|
| Crest Elevation (m RL)                          | 210                            |   |
| Dam Height (m)                                  | 10m to 21m                     |   |
| Batter Slopes                                   | 2:1 Upstream<br>3:1 Downstream |   |
| Embankment Volume (Mm <sup>3</sup> )            | <b>0.91</b>                    |   |
| Tailings Capacity (Mm <sup>3</sup> )            | <b>1.36</b>                    |   |
| Storage Efficiency (Capacity/Embankment Volume) | <b>1.5</b>                     |   |
|   |                                |   |



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| Option 2  |                                |   |
|---|--------------------------------|---|
| Crest Elevation (m RL)                          | 193                            |  |
| Dam Height (m)                                  | 8m to 21m                      |   |
| Batter Slopes                                   | 2:1 Upstream<br>3:1 Downstream |   |
| Embankment Volume (Mm <sup>3</sup> )            | <b>1.08</b>                    |   |
| Tailings Capacity (Mm <sup>3</sup> )            | <b>1.41</b>                    |   |
| Storage Efficiency (Capacity/Embankment Volume) | <b>1.3</b>                     |   |
|   |                                |   |



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| Option 3  |                                |   |
|---|--------------------------------|---|
| Crest Elevation (m RL)                          | 192                            |  |
| Dam Height (m)                                  | 5m to 20m                      |   |
| Batter Slopes                                   | 2:1 Upstream<br>3:1 Downstream |   |
| Embankment Volume (Mm <sup>3</sup> )            | <b>0.60</b>                    |   |
| Tailings Capacity (Mm <sup>3</sup> )            | <b>0.84</b>                    |   |
| Storage Efficiency (Capacity/Embankment Volume) | <b>1.4</b>                     |   |
|   |                                |   |



### 3.4 Conceptual Design

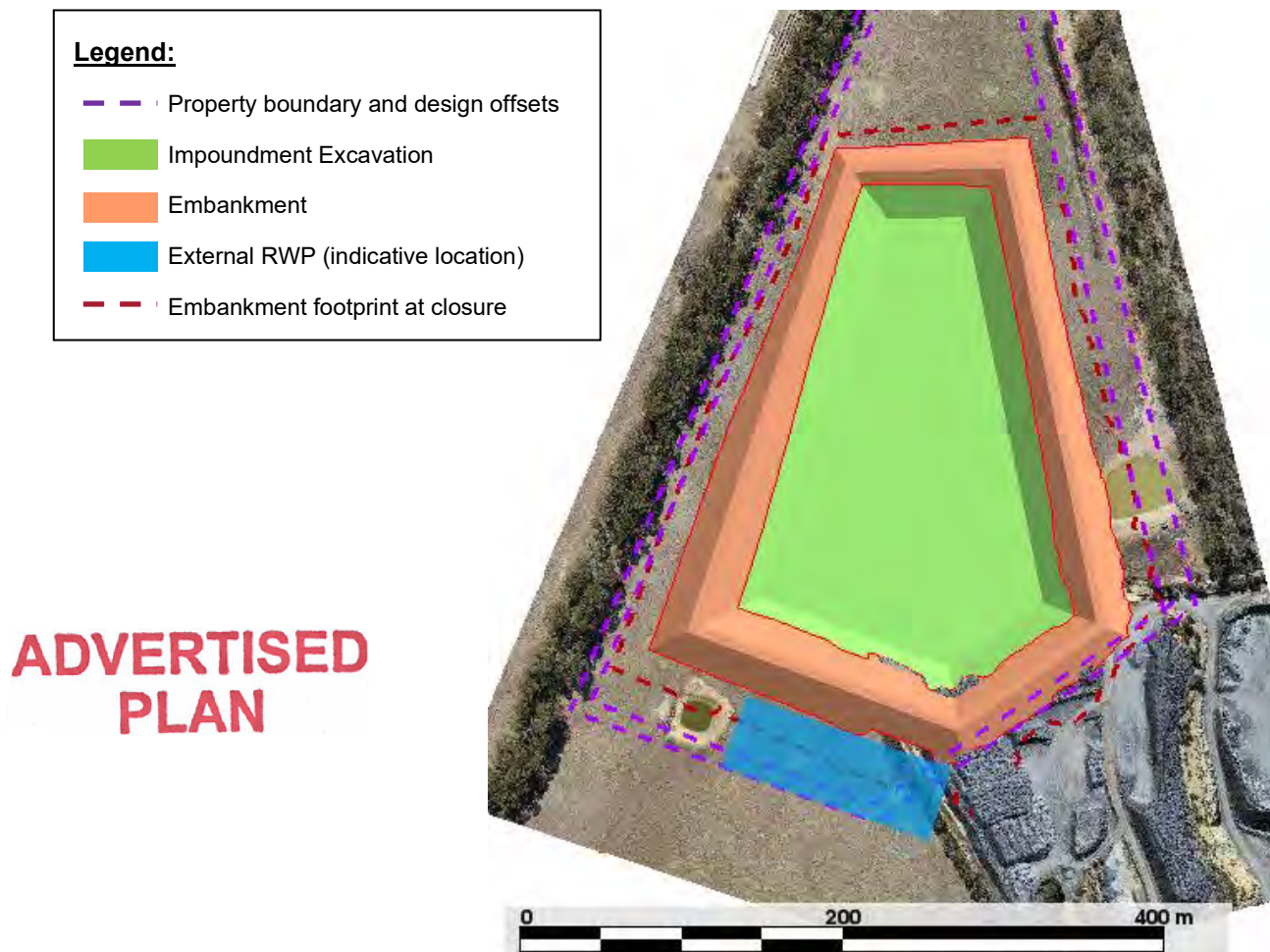
In late 2021, a conceptual design of the Brunswick West TSF was prepared by ATCW. The design concept was for a single stage facility, as the site geometry did not readily facilitate successive staging of the embankments. The proposed conceptual design consisted of:

- Excavation of foundation material within the TSF impoundment to Moderately Weathered (MW) rock to provide borrow materials for construction and maximise TSF storage capacity (nominal RL 185 m);
- Lining of the upstream batter slopes (either with compacted clay or geosynthetic liner) for tailings and decant water storage;
- Construction of perimeter embankments to final height with upstream and downstream batter slopes at 2:1 (H:V) (nominal RL 200.0 m);
- Construction of a decant structure within the TSF; and
- Construction of an external Return Water Pond (RWP).
- Provision of downstream allowance for later construction of closure batter slopes at 4:1 (H:V).

The conceptual design found that the site was able to store approximately 620,000 m<sup>3</sup> of tailings, providing storage for up to 5 years. This conceptual design was used to plan the geotechnical investigations and has formed the basis of this final TSF design.

The conceptual design prepared is presented in **Map 2**.

**MAP 2: BRUNSWICK WEST TSF CONCEPTUAL DESIGN**







## 4 SITE CONDITIONS

### 4.1 Climate

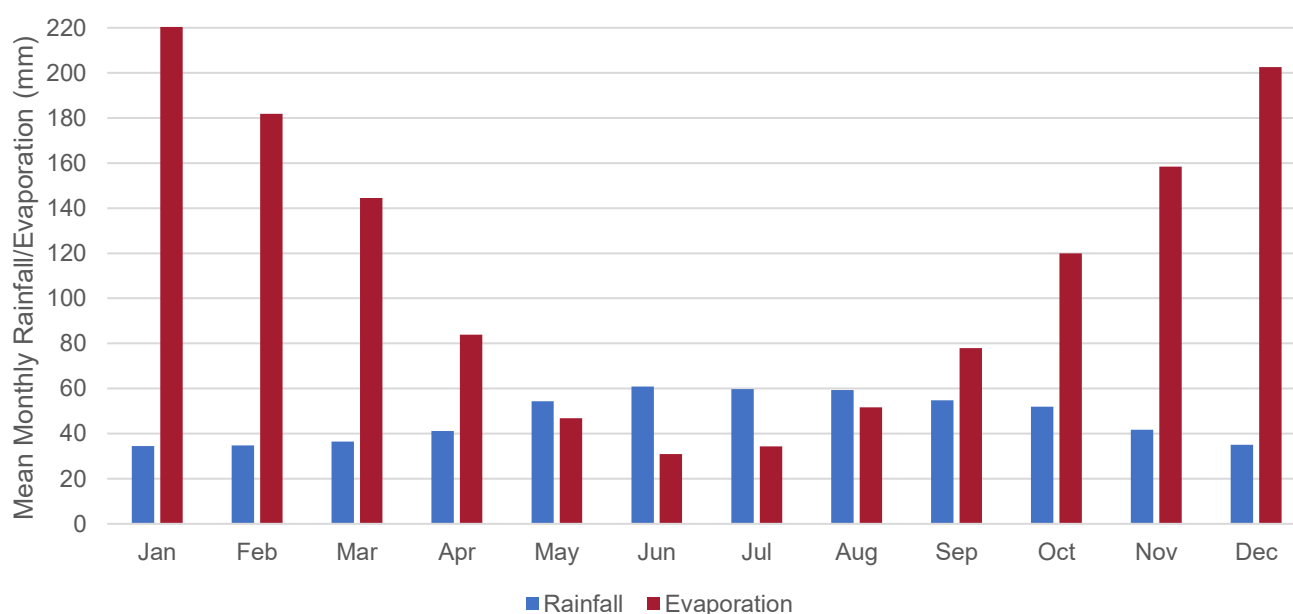
#### 4.1.1 Rainfall and Evaporation

The local climate of the Costerfield region is considered 'semi-arid'. The climate is generally characterised by cool and wet winters, whilst the summer is often hot and dry.

The nearest weather station to the site which has been considered for the Costerfield Site is Heathcote (BOM Station number 088029), located approximately 15 km South-West of the Costerfield Gold Mine. Rainfall has been collected at the Heathcote weather station since 1882. Average annual rainfall is approximately 565 mm, with rainfall peaking between June and August.

The mean monthly rainfall and evaporation is presented in **Chart 1**.

**CHART 1: MEAN MONTHLY RAINFALL AND EVAPORATION (HEATHCOTE WEATHER STATION)**



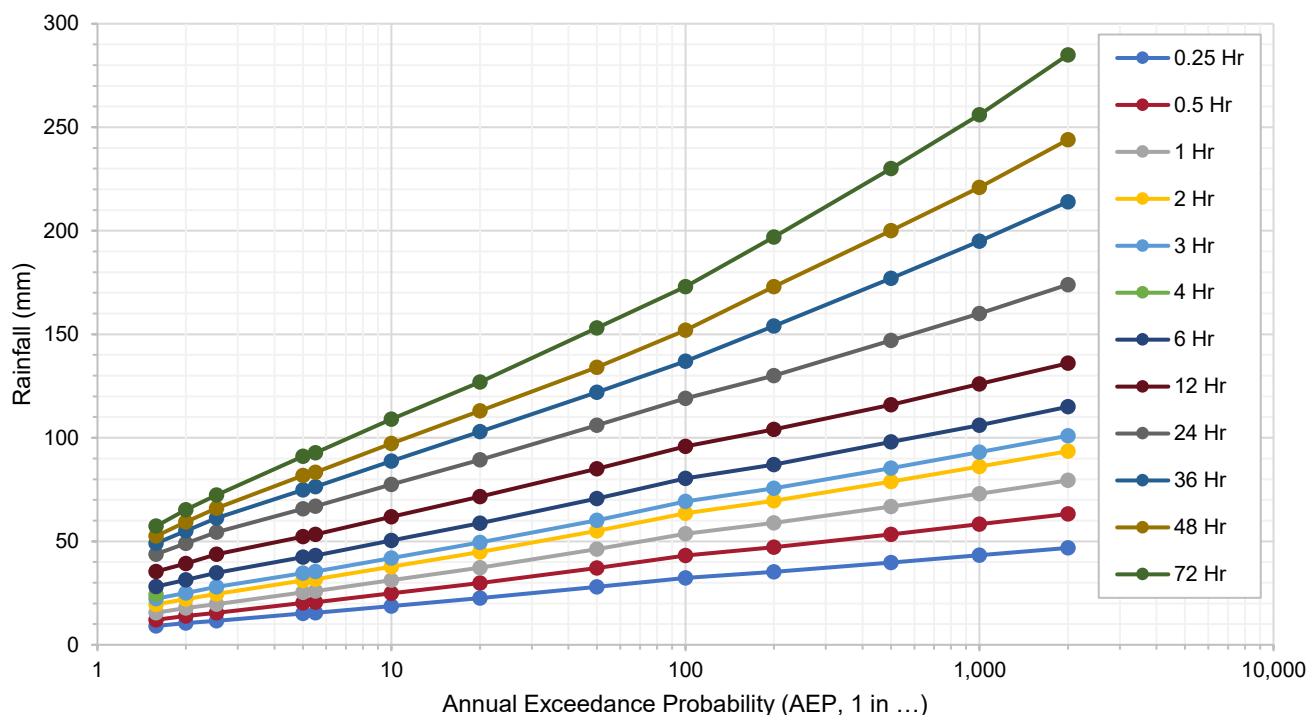
Intensity-Frequency-Duration (IFD) curves used for calculation of design rainfall events have been extracted from the Bureau of Meteorology's Design Rainfall and Data System (2016) for various durations and Annual Exceedance Probabilities (AEP's) ranging between very common (1 in 1.6 years) to 1 in 2,000 years. The IFD curves are presented in **Chart 2**.

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**CHART 2: INTENSITY-FREQUENCY-DURATION CHART (HEATHCOTE WEATHER STATION)**



#### 4.1.2 Wind

The nearest weather station to the site which was considered to have the most relevant wind data is in Redesdale (BOM Station number 0888051), approximately 30 km from the Costerfield Gold mine. The Redesdale weather station has collected continuous data from between June 1993 and August 2019 and has a database of approximately 19,000 observations. Wind rose diagrams of wind direction versus wind speed were used to infer design wind speeds, where relevant.

Wind rose diagrams are based on daily 9 am and 3 pm wind speeds. A review of annual wind rose data indicated that the predominant wind direction is north and south and that sustained (i.e., 10 minute) winds very rarely exceed 40 km/hr. The annual wind rose diagrams for the Redesdale weather station are presented in **Chart 3**.

## 4.2 Topography

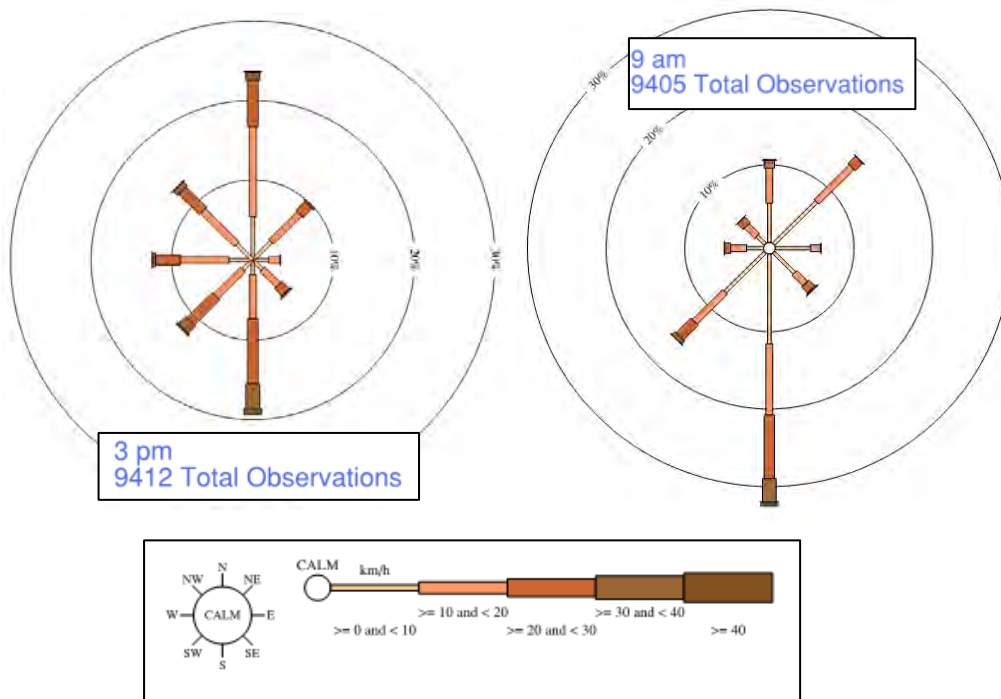
The topography of the Costerfield area consists of rugged hill country, with undulating rises, gentle slopes and localised swales/drainage lines.

Vegetation ranges from mixed species of open forest in the valleys and gentle slopes, with shrubby box gum on the stony gravelly hills, and heath and grasses on the dry slopes and ridges.

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**CHART 3: ANNUAL WIND ROSE DIAGRAMS (REDESDALE WEATHER STATION)**



## 4.3 Geology

### 4.3.1 Site Geology

The Geological Survey of Victoria 1:50,000 scale map sheet of Costerfield (1999) [1], indicates that the near surface geology at the Costerfield Mine site is expected to comprise:

- Recent to Holocene age fluvial and colluvial deposits, typically comprising of gravel, sand and silt; overlying
- Silurian age Costerfield Formation Siltstone, typically comprising thin bedded siltstone, with minor sandstone and conglomerate.

The site sits within the Costerfield Dome, with deep Costerfield Formation Siltstone. The Costerfield Fault runs along the eastern edge of the site through Crown Land.

The Costerfield Mining District is the northern margins of the Darraweit Guim Province, adjacent to the western boundary of the Melbourne Zone of the Lachlan Orogen. The geology of the district consists of Early Silurian, weakly bedded calcareous mudstone with lesser siltstone and sandstone of the Costerfield Formation, estimated to be between 450 and 550 m thick. These are overlain by siliciclastic rocks of the Wapentake Formation, followed by mudstones of the Dargile Formation.

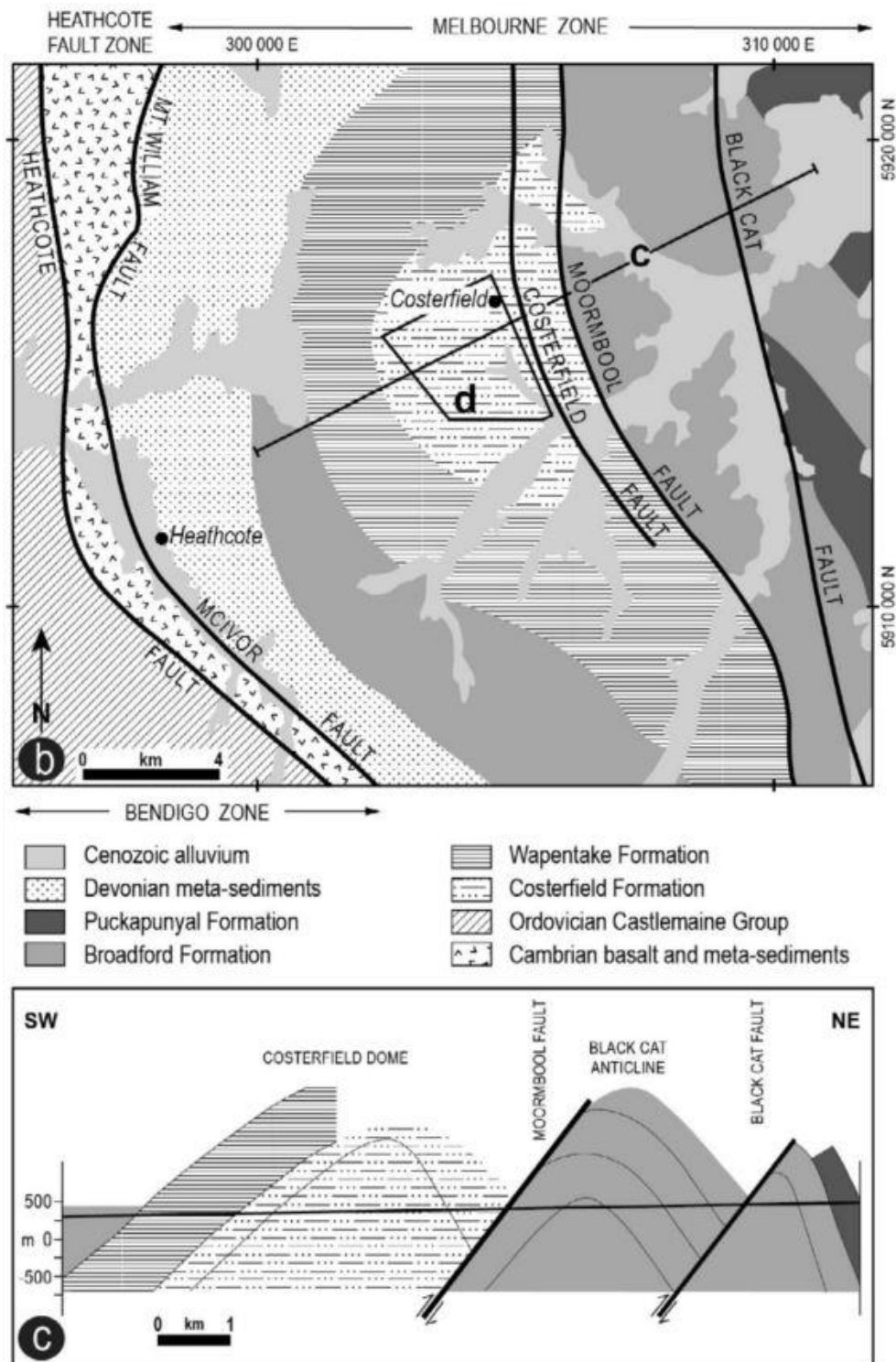
The Costerfield Mine Area lies approximately ~10km east of the Mount William Fault, this fault is the boundary of Melbourne zone and Bendigo zone. The eastern boundary of the Costerfield Mining District is the west-dipping Moormbool Fault. A geological map and section are presented in **Map 3**.

Interpretation of the seismic data indicates that several footwall splays have come off the west-dipping Mount William Fault and that at least one of these may underlie the Costerfield Dome (refer **Map 3**) [2].

At finer detail, this system can be interpreted as including shallow west-dipping, moderately west-dipping and steeply dipping faults. It is believed that these structures formed by east-west shortening during the Middle Devonian Tabberabberan (370–380Ma) Orogeny [2] [3]. Moreover, it seems the most movement along Mount William Fault occurred in the Palaeozoic [4]. Based on Geoscience of Australia, there has been a displacement along the fault in the post Miocene, moreover, the borehole interpretation of Tickell (1977) [4] suggests that the overlying Quaternary section does not appear to be deformed, and he suggest that the most recent movement happened in the Pliocene (~5Ma).



MAP 3: COSTERFIELD MINE AREA GEOLOGICAL MAP



## 4.3.2 Geological Activity

As part of the Probabilistic Seismic Hazard Assessment (PSHA) conducted by ATCW for the Costerfield site [5], a review of all recorded seismic events surrounding the site was conducted. Appendix A of the PSHA [5] lists earthquakes within 40 km of the area with a magnitude above 1.0. Of these events, only ten were larger than magnitude 3.0. The maximum magnitude listed within 124 km of Costerfield is MP 4.0 at Seymour. Only one event was closer than 10 km from the site with a magnitude 1.4 on 19<sup>th</sup> June 2017, which was not reported as felt. The closest event with magnitude



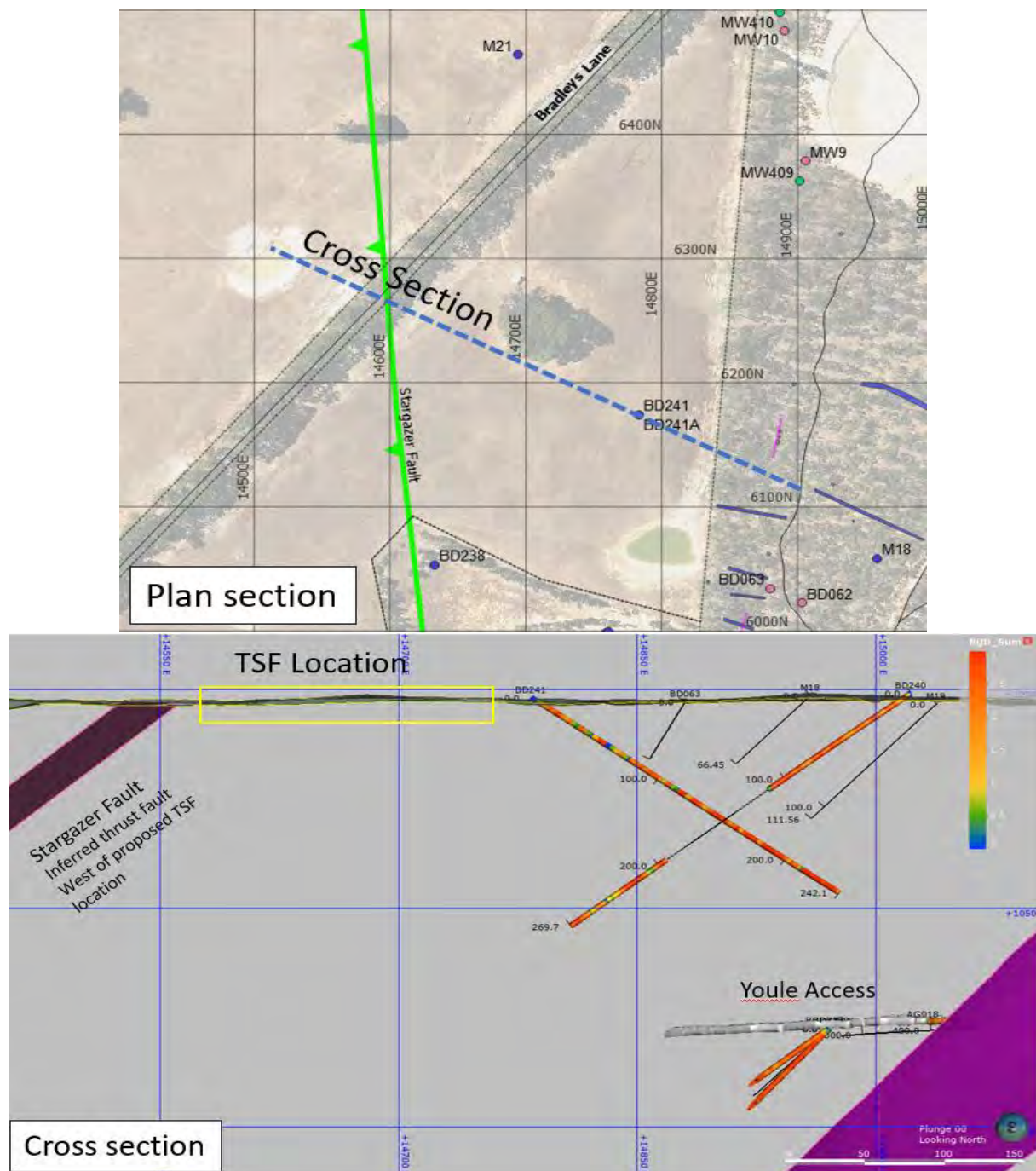
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3.0 or higher was an ML 3.1 about 10 km from Costerfield, near Puckapunyal on 28<sup>th</sup> October 1980. Only eight events were recorded before 1976, when the surrounding seismic network was first installed. It was concluded that the level of geological activity in the immediate area of the Brunswick West TSF is very low.

In late 2021, a regional diamond drilling campaign conducted by MRCO identified a potential geological structure from a single borehole, MM019. This borehole was conducted approximately 2.5km south of the Brunswick West TSF site, dipping at approximately 50°. At a drilling depth of approximately 164m, a change in stratigraphy was identified. From this borehole, MRCO inferred a potential minor geological structure, named the “Stargazer” fault, that, if continuous to surface level, could daylight within the downstream shell of the Brunswick West TSF embankment. MRCO's projection of this potential structure is presented in **Map 4**.

**MAP 4: INFERRED STARGAZER STRUCTURE INTERACTION WITH BRUNSWICK WEST TSF SITE**







Extensive exploration drilling works previously conducted by MRCO to the immediate south have not found evidence of this structure, with the geological structure inferred from a single borehole. Additionally, ATCW geotechnical investigations of the Brunswick West TSF (refer **Section 9.2**) site found no evidence of surface expression or fault gouging as a result of geological activity. Given the lack of evidence to support the presence of this geological structure, it is considered that there is a high probability the Stargazer fault is not present beneath the footprint of the Brunswick West TSF. It is likely this identification only shows an offset in stratigraphy, with no connection to the Mount William fault.

Given the low activity in the area, fault location and depth, and lack of surface expression, it is highly unlikely that this potential geological structure will impact the construction and operation of the Brunswick West TSF.

## 4.4 Hydrogeology

The regional hydrogeology of the area encompassing the Costerfield Gold Mine consist of two aquifers:

- **Shallow Alluvial Aquifer:** This is a perched groundwater system that exists within the confines of modern-day creeks and valleys and forms the minor aquifer for the region.
- **Regional Basement Aquifer:** This is a fractured rock aquifer, formed by an upper weathered rockfill layer and lower fresh rock with significant fractures associated with major faults in the region.

An annual environmental review of the groundwater at the Costerfield site was undertaken by Golder Associates [5] in 2021, which reviewed the groundwater monitoring from the last 5 years (2016 to 2021), and the dewatering undertaken at the site. Golder identified that, prior to mid-2017, monthly mine dewatering was relatively stable at between 30 and 60 megalitres per month (ML/month). This value peaked in early 2019 at 80 ML/month and has decreased over the previous 3 years to around 40 ML/month.

A review of the groundwater levels from the past 5 years concluded that the lower aquifer (the Regional Basement Aquifer) is influenced by both rainfall trends and mine dewatering activities, while the upper aquifer (the Shallow Alluvial Aquifer) only showed a response to rainfall trends only. This indicates the groundwater levels within the upper aquifer is not impacted by mine dewatering activities and, subsequently, shows no hydraulic connection with the lower aquifer.

The bores within the upper aquifer around the Costerfield mine area were often seen as dry during periods of below average rainfall and recharged quickly following large rainfall events.

Lower aquifer bores in the immediately vicinity of the Brunswick area have shown groundwater levels consistently declining in a response to mine dewatering. Bores located further away from the area show little response, indicating a low hydraulic connectivity with the strata outside the mined area.

From the results of the environmental review, Golder have developed a cone of drawdown resulting from dewatering activities, showing a 'tight' cone of depression in a north-south orientation along the Costerfield and Moormbool faults. Estimated groundwater contours around the Brunswick West TSF site show the drawn down groundwater levels as approximately RL 110 to 120m (i.e., up to 60 m below the base of the planned Brunswick West TSF excavations). Groundwater monitoring bores installed as part of the Geotechnical investigations (refer **Section 9.2**) have not observed any standing water, and corroborate these results.

In 1996, Golder Associates completed an initial assessment of the long term pit water quality for the Brunswick pit [7]. As part of this assessment, an estimate of the recharge rates back into the Brunswick pit (in which the Brunswick Underground Portal is located) were made, and indicated that, once dewatering ceases, the groundwater levels will return to around RL 176 to RL 180 m. It is estimated that the recharge will be rapid within the first year of dewatering ceasing, recharging from RL 153.0 to RL 171.7 m, before slowing down to around 1.0 m per year thereafter.





## 4.5 Underground Mining

MRCO have provided ATCW with the anticipated underground working within the area at the completion of mining. The underground workings consist of the following;

- Brunswick Underground Workings (current inactive), and the Brunswick Decline, located directly beneath the Brunswick Processing Plant area and connects to the surface via Brunswick Portal to provide access to both Youle and Cuffley.
- Youle Underground Workings, located approximately 1.2 km north of the Brunswick Processing Plant, which are currently being mined with an expected lowest point at approximately -394 m RL.
- Cuffley Underground Workings, located immediately north of the Augusta mine, which is currently inactive.
- Augusta Underground Workings (currently inactive), and Augusta Decline, which connects surface via the Augusta portal and also provides access to Cuffley.
- Numerous historical Underground Workings, including:
  - workings towards the north near Youle with four historic mine shaft entrances towards the north of Bombay TSF (not connected to Youle),
  - workings near Augusta and Cuffley, with one historic mine shaft entrance slightly north-west of Augusta, and
  - Brunswick pit (currently inactive) and historic underground workings.

These models indicate that no underground works are to be conducted directly beneath the site. The nearest impact identified is the Brunswick-Youle underground access, which runs north-south beneath Crown Land from the Brunswick Processing Plant towards Bombay TSF. The elevation of this access is approximately -30 m RL, around 200 m away from the lowest point of excavation of the Brunswick West TSF. Underground blasting activities occurring at Youle are also not expected to impact the Brunswick West TSF, given the significant distance between the two and that the TSF features no upstream constructed elements that may be impacted by vibrations. As such, no interaction is expected between the Brunswick West TSF and the underground mining works.

Mandalay have informed ATCW that underground mining operations are expected to cease at the end of September 2027. From this date, the Brunswick Underground Portal will be sealed, and dewatering will stop, allowing the groundwater to recharge.

## 4.6 Seismicity

In May 2020, ATCW conducted a Probabilistic Seismic Hazard Assessment (PSHA) of the Costerfield Site, which is presented in ATCW report 109014.08-R01 [5]. This assessment involved a desktop review and characterisation of all historical seismic sources (local and regional) and development of a Ground Motion Model.

The Costerfield Mine is in an area of moderate seismicity within Victoria. Within a regional setting, the Costerfield Mine is located on the western side of the Melbourne Structural zone, which is bounded by the Mount Williams Fault to the west and the Governor Fault to the east. Locally, the nearest faults are the Moornbool, Costerfield, Black Cat and Mount William Faults, located between 2 and 8km from the Brunswick West TSF site.

A summary of the site Peak Ground Acceleration (PGA) as a function of Annual Exceedance Probability (AEP) determined from the PSHA is presented in **Table 3**. De-aggregation of the earthquake hazard by magnitude and distance was also undertaken in this study [5] for the 2,000, 5,000 and 10,000 AEP events, which are also presented in **Table 3**.

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**TABLE 3: COSTERFIELD SEISMIC HAZARD ASSESSMENT RESULTS SUMMARY**

| Annual Exceedance Probability | Peak Ground Acceleration | Mean Distance (km) | Mean Magnitude ( $M_w$ ) |
|-------------------------------|--------------------------|--------------------|--------------------------|
| 1 in 475                      | 0.034 g                  | -                  | -                        |
| 1 in 1,000                    | 0.088g                   | -                  | -                        |
| 1 in 2,000                    | 0.138 g                  | 22.5               | 6.1                      |
| 1 in 5,000                    | 0.238g                   | 15.6               | 6.2                      |
| 1 in 10,000                   | 0.347g                   | 12                 | 6.3                      |

A maximum earthquake magnitude of  $M_{max} = 7.5$  was considered for the PSHA study [5], which will be adopted as the maximum earthquake magnitude for this design.

## 5 DESIGN GUIDELINES AND STANDARDS

The following is a list of pertinent regulatory and engineering best practice documentation upon which this design had been based:

- Australian National Committee on Large Dams (ANCOLD) – Guidelines on the Consequence Categories for Dams” (2012) [8].
- Australian National Committee on Large Dams (ANCOLD) – Guidelines on Tailings Dams (2019) [9]
- Australian National Committee on Large Dams (ANCOLD) – Guidelines for Design of Dams and Appurtenant Structures for Earthquake (2019) [10]
- Australian National Committee on Large Dams (ANCOLD) – Guidelines on Risk Assessment (2022) [11].
- Victorian Department of Jobs, Precincts and Regions Earth Resource Regulations (VIC ERR), “Technical Guideline Design and Management of Tailings Storage Facilities” (2017) [12]
- Environmental Protection Authority Victoria (EPA), “Waste Disposal Categories – Characteristics and Thresholds” (2020) [13].
- Victorian Department of Environment and Primary Industries (VIC DEPI), “Strategic Framework for Dam Safety Regulation” (2014) [14].

## 6 CONSEQUENCE CATEGORY ASSESSMENT

### 6.1 Overview

An assessment of the Consequence Category for the Brunswick West TSF has been undertaken in accordance with the ANCOLD Guidelines for Consequence Categories [8], the ANCOLD Tailings Guidelines [9], and Victorian Government Tailings Guidelines [12] (which are in turn derived from ANCOLD). As outlined in these guidelines, two consequence categories are assessed for design purposes:

- The Dam Failure Consequence Category. This is an assessment of the potential failure modes of the TSF and the consequences to public safety, the environment and public infrastructure as the result of a dam failure. The result of this assessment is used to determine the following:
  - Emergency Spillway Design Criteria;
  - Embankment Seismic Design Criteria; and
  - TSF Surveillance inspection scope and frequency.





- The Environmental Spill Consequence Category. This is determined by considering only the effects of a spill from the TSF during a flood or extended extreme wet weather period without the TSF itself failing. The result of this assessment is used to determine the following:
  - Water Storage Freeboard Design Criteria, including:
    - Wet season storage allowance;
    - Storm storage capacity; and
    - Contingency freeboard requirements.

The Consequence Category of a TSF is determined as a matrix of the Severity of Damage and Loss occurring because of a dam failure/environmental spill, and the Population at Risk (PAR) downstream of the facility.

It should be noted that the Consequence Category is independent of the likelihood of failure and purely looks at the consequences of failure. The likelihood of each failure mode is discussed further in **Section 7**.

## 6.2 Severity Level Impact Assessment

An assessment of the Severity of Damage and Loss for a Dam Failure Scenario has been undertaken in accordance with the ANCOLD Guidelines on Consequence Categories [8], and is presented in **Table 4**. This assessment has been based on advice provided to ATCW by MRCO, with reference made to the previously adopted Severity of Damage and Loss for the Brunswick TSF.

**TABLE 4: ASSESSMENT OF SEVERITY OF DAMAGE AND LOSS DUE TO DAM FAILURE (FROM ANCOLD [8])**

| Damage and Loss                               |   | Cost Estimate  | Severity Level |        |       |         |
|---|---|----------------|----------------|--------|-------|---------|
|   |   |                | Minor          | Medium | Major | Catast. |
| Total Infrastructure Costs                    |   |                |                |        |       |         |
| Residential                                   | Potentially 2 houses destroyed.                                     | <\$10M         | X              |        |       |         |
| Commercial                                    |   | <\$10M         | X              |        |       |         |
| Community Infrastructure                      | Damage to Heathcote-Nagambie Road.                                  | <\$10M         | X              |        |       |         |
| Dam Replacement or Repair                     | Repair of Breach.   | \$10M - \$100M |                | X      |       |         |
| Impact on Dam Owner's Business                |   |                |                |        |       |         |
| Importance to the Business                    | Essential to maintain and continue operations.                      |                |                |        | X     |         |
| Effect on services provided by owner          | No services (i.e. water or power supply) provided by business, N/A. |                |                |        |       |         |
| Effect on continuing credibility              | Extreme Discontent.   |                |                |        | X     |         |
| Community reaction and political implications | Extreme Discontent.   |                |                |        | X     |         |
| Impact on financial viability                 | Severe to crippling in the long term.                               |                |                |        | X     |         |
| Value on water in the storage                 | Not applicable to tailings dams, N/A.                               |                |                |        |       |         |





| Damage and Loss           |   | Cost Estimate | Severity Level |        |       |         |
|---------------------------|---|---------------|----------------|--------|-------|---------|
|                           |   |               | Minor          | Medium | Major | Catast. |
| Health and Social Impacts |   |               |                |        |       |         |
| Public Health             | Release of Type C Contaminated Waste. Relatively isolated site, primarily impact personnel on site.<br> |               |                |        |       |         |

Based on the results of **Table 4**, a Severity of Damage and Loss for a Dam Failure scenario has been assessed as “Major”. This is consistent with the Severity of Damage and Loss for the Brunswick TSF, assessed by ATCW during the latest raise in 2020 **[15]**. The Brunswick West TSF is in a similar regional setting as the Brunswick TSF and would result in similar damages and loss.





The Severity of Damage and Loss for an Environmental Spill scenario has been assessed as “Medium”, owing to the release of potentially contaminated mine water and impact to the natural environment.

## 6.3 Population At Risk (PAR)

### 6.3.1 Dam Break Modelling

As part of the design of the Brunswick West TSF, a dam break assessment has been conducted for the facility. This assessment [16] looked at both Sunny Day Failure (SDF) and Flood Day Failure (FDF) case at four critical embankment sections

- Northern side of the facility at the junction connecting the eastern and western embankments. Determined as the most critical in terms of flow propagating to the north of the facility.
- Eastern embankment, southern extent situated over a historical farm dam and immediately adjacent to the ROM pad and Brunswick Pit ramp entrance. Determined as a critical section for flows propagating east and towards the Brunswick Processing Plant and Brunswick Underground Portal. Exact failure location determined based on the expected foundation conditions over the historical farm dam.
- Southern embankment, southwest extent corresponding with largest embankment height and immediately adjacent to the ROM pad. Determined as a critical section for flows propagating south and towards the low grade ROM Pad and Brunswick Underground Portal. Exact failure location determined based on maximum embankment height and expected foundation conditions over previous clean water diversion drains and the low grade ROM Pad.
- Western embankment, central extent to the north of the operational pond, adjacent to an empty paddock and Bradleys Lane. Determined as a critical section of flows propagating west and inundating Bradleys Lane.

For each embankment section, the no-mitigation and mitigation cases with respect to flooding impacts were considered. The results of this assessment will inform the Dam Safety Emergency Plan (refer **Section 22.4**).

Based on discussions with MRCO, the dam break outflow have been conservatively modelled assuming a Newtonian (i.e., water) flow regime, with complete mobilisation of all above natural ground-stored tailings. No accounting for the potentially reduced tailings mobilisation due to residual shear strengths or the attenuated outflow regime due the rheological properties of the mobilised tailing have been included.

From these assessments, an estimation of the critical Population at Risk (PAR) has been undertaken to estimate the Dam Failure Scenario, which considers the population which would be directly exposed within the downstream environment, as well as considerations for the likelihood of people evacuating the area.

Failure modes for both the SDF and FDF cases were considered as overtopping failures, with the freeboard between the embankment crest and the tailings/water within the facility being consumed, leading to a release of stored tailings and water, which erodes the embankment and propagates failure of the embankment.

In regard to the propagation of the adopted failure mode, it is recognised that the as-designed embankment is inherently geotechnically stable (refer **Section 16.5**) with batter slopes flatter than the residual angle of repose for rockfill and is constructed entirely by downstream methods. As such, a sudden release failure (such as those observed at other tailings dams around the world in recent years) is considered non-credible.

It is noted that the dam break assessment considers the consequences of failure as opposed to the likelihood of it occurring, though some consideration does need to be made to the most likely failure progression methods to allow for a realistic and suitably conservative assessments to be undertaken. The failure progression scenarios for the SDF and FDF cases are summarised below:





- **Sunny Day Failure**

- Static settlement of the embankment occurs post-construction due to poor quality controls and saturation (loose, uncompacted materials), which is un-noticed and not remedied by mine personnel.
- At the end of filling, a suitably large earthquake occurs, causing a significantly large amount of seismic deformation, as well as completely liquefying the tailings.
- The post-construction static settlement and seismic deformation of the embankment exceeds the remaining freeboard, leading to operational water and liquefied tailings to mobilise over the lowered embankment crest.
- The liquefied tailings and water progress quickly over the embankment crest and down the slope, eroding the rockfill material, causing an unravelling failure of the embankment and releasing tailings and water.

- **Flood Day Failure**

- The TSF emergency spillway loses capacity or becomes blocked completely (due to incorrect or over-deposition, placement of pipes across the spillway mouth, etc.).
- A suitably large storm event exceeds the reduced spillway capacity/consumes the remaining freeboard and progresses over a localised low-spot in the embankment crest.
- The water flow progresses quickly over the embankment crest and down the slope, eroding the rockfill material, causing a run-away failure of the embankment and releasing tailings and water.

Given that both failures methods are concerned with overtopping leading to unravelling erosion of embankment fill materials, the breach parameters of the TSF were estimated using the Froehlich Empirical Equations [17]. The embankment was conservatively assumed to breach to full height, with the breach base width and development time estimated based on the Froelich equations.

Detailed results and flood mapping from the Dam Break Assessment are presented in ATCW report 109014.15-R02-1 [16]. The most critical scenario identified was a Sunny Day Failure breach of the Eastern Embankment, due to its proximity to the Brunswick Underground Portal and Brunswick Processing Plant, and relatively sudden failure mechanism (seismic induced). As such, these results have been used to determine the critical PAR for the facility. While the FDF case at the same location would result in similar breach times, the preceding events for this failure (extremely large storm) would result in the Brunswick Processing Plant area being evacuated, most likely removing the PAR for this scenario.

The estimation of PAR from the dam break has been undertaken in consideration of the flood protection measures that will be constructed as part of the Brunswick West TSF (refer **Section 11.6.9**).

For the critical dam break scenario, approximately 290,000 m<sup>3</sup> of tailings and 10,000 m<sup>3</sup> of water were released over a period of approximately 16 minutes.

#### 6.3.2 Estimation of Population at Risk

The downstream population within the inundation area, broken down into weekdays and weekends, and day and night hours, are summarised in **Table 5**.

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**TABLE 5: POPULATION WITHIN POTENTIAL DOWNSTREAM INUNDATION AREA**

| Location                    | Weekday |       | Weekends |       |
|-----------------------------|---------|-------|----------|-------|
|                             | Day     | Night | Day      | Night |
| Underground                 | 30      |       |          |       |
| Brunswick Plant ROM Pad     | 1       | 1     | 1        | 1     |
| Processing Plant            | 9       | 4     | 3        | 3     |
| Gold Room                   | 1       | 1     | 0        | 0     |
| Mill Offices                | 9       | 1     | 1        | 1     |
| Mill Workshop               | 3       | 2     | 0        | 0     |
| <i>Total</i>                | 23      | 9     | 5        | 5     |
| 964 Heathcote-Nagambie Road | 1       | 2     | 2        | 2     |
| 966 Heathcote-Nagambie Road | 2       | 2     | 2        | 2     |
| Heathcote-Nagambie Road     | 2       | 1     | 2        | 1     |

In addition to the above, traffic counts from Heathcote-Nagambie road (provided to ATCW by MRCO) have indicated approximately 641 vehicles per day. These numbers have not been broken down into hourly counts and have therefore been assumed as 80% during the day (512) and the remainder at night (129). The transient PAR assigned to Heathcote-Nagambie road has been assessed as per **Equation 1**.

### EQUATION 1: TRANSIENT PAR

$$\text{number of vehicles} * \text{expected passengers per vehicle} * \frac{\text{length of road inundated}}{\text{vehicle speed} * 12\text{hrs}}$$

A 1 km stretch of Heathcote-Nagambie road is within the inundation area, with a posted speed limit of 100 km/hr. If it is conservatively assumed that all vehicles are near capacity (4 occupants), the following transient PAR values are estimated:

- Day time – 1.7 (rounded to 2)
- Night time – 0.4 (rounded to 1)

These PAR values (rounded up) have been included in the downstream population numbers summarised in **Table 5**.

#### 6.3.3 PAR Outcomes

The flood inundation maximum depth, maximum velocity, depth-velocity product and arrival time for the critical scenario are presented in **Map 5** to **Map 8**, respectively.

The dam break assessment found that, with the proposed flood protection measures in place, significant amounts of flowing tailings/water can be prevented from entering the Brunswick Underground Portal. Without these measures in place, the mobilised tailings and water would progress directly towards the Brunswick Underground Portal, inundating the underground mine works, primarily the Brunswick Decline and the Youle Underground Workings. All mine personnel within these underground work areas would be considered as PAR.

Given the depth and lengths of the underground workings from the surface (up to 500m below surface and up to 1.2 km away), there would be little to no awareness of the prevailing conditions at the surface in the event of a dam break. Warning times and evacuation notices would need to be relayed from the surface, however this may be insufficient given the single access tunnel towards the Youle underground workings. As such, a dam break flow into the underground and towards Youle would have a very high probability of loss of life, and these flood protection measures are considered as vital whilst tailings are stored above ground and this downstream at-risk population exists.





With the flood protection measures in place, the released tailings and water flows both north and south in roughly equal proportions. Flow towards the north enters the Bombay TSF perimeter drains and surrounds the facility. The released material is not expected to flow further north than the Bombay rock garden and does not reach the Youle ventilation shaft or numerous historic mine shaft openings this area due to the natural topography dipping towards the south.

The released material towards the north will inundate Heathcote-Nagambie road for a stretch of approximately 1km to depths of up to 0.5m and velocities of up to 1.6 m/s, with a maximum depth-velocity product of 0.7 m<sup>2</sup>/sec. As such, vehicles on Heathcote-Nagambie road at the time are considered as PAR

Once over Heathcote-Nagambie road, the flow progresses along Tin Pot Gully towards the south-east. One house (996 Heathcote-Nagambie road) is impacted by released material, with the flood wave arriving within 37 minutes of first release, however the flow depths and velocities are relatively small (max D-V product of 0.1 m<sup>2</sup>/sec) . The other two residential properties are expected to be unimpacted. As such, the external residential properties are not considered as PAR.

Once the dam break flow material reaches the Augusta mine water dams, it is largely contained within the natural drainage channel of Tin Pot Gully, and is not considered a significant threat.

The released material to the south is diverted to the east around the northern flood protection bund. The flow then enters into the Brunswick processing plant area, inundating the high-grade ROM, RO plant and cement plant, tailing processing plant, mill offices, mill workshop and carpark. This area is a natural low point, and the flow is therefore not expected to enter the Brunswick pit. A small amount of released material will flow within the Brunswick TSF northern perimeter drains, and eventually progressed east towards Heathcote-Nagambie road. All personnel within the Brunswick Processing Plant are considered as PAR

As such, for the purposes of Consequence Category Assessment, the peak PAR occurs during the weekday day time, and is equal to 25; 23 from the Brunswick Processing Plant, and 2 from Heathcote-Nagambie Road. This falls within the 10-100 range for the Dam Failure.

For the Environmental Spill Scenario, the release of water from the facility will be controlled via the spillway and will direct towards the previously constructed perimeter drains and natural drainage channels. The PAR is therefore expected to be < 1.

#### 6.3.4 Estimation of Potential Loss of Life

An estimation of the Potential Loss of Life has been undertaken for the assessed Sunny Day failure dam break scenario. A full estimation of the PLL for each scenario is further discussed in the Dam Break Report [16].

For estimating PLL, ANCOLD [8] recommend using the methods as described by Graham [18]. These methods were developed based on case studies of historical dam failures, as the author notes there is no available procedure for predicting the exact number of fatalities that may arise from a dam failure.

The loss of life resulting from a dam failure is highly influenced by three factors:

1. The number of people within the downstream inundation area,
2. The total amount of warning time available for evacuation, and
3. The severity of the flooding.

The number of people within the downstream inundation area is equal to the PAR defined in **Section 6.3.3**, which is 23 within the Brunswick Processing Plant, and 2 at Heathcote-Nagambie Road.

Graham [18] recommends that the total amount of warning time available is equal to time since the initiation of an evacuation (which is dependent on an observation a failure progressing) plus the time taken for the arrival of dangerous flood water.

The time when dam failure warnings would be initiated for earthfill dams is dependent on the failure progression for the dam break scenario, and number of people around the dam that may observe the failure initiating. Given the proximity of the TSF to the Brunswick Processing Plant, a failure would be classified as “many observers at dam”. As discussed in **Section 6.3.1**, the failure progression is an overtopping failure initiated by seismic events, however no specific guidance is provided for this type of failure progression. This will therefore be somewhere between an overtopping failure (0.25 hrs





before dam failure) and a delayed seismic failure (2 hrs before dam failure) , as defined by Table 2 of Graham [18]. ATCW have therefore adopted a time when dam failure warnings would be initiated as 0.5 hrs. This is added onto the flood wave arrival times (0.25 hrs for the Brunswick Processing Plant area, and 0.5 hrs for Heathcote-Nagambie road, refer **section 6.3.3**), resulting in total warning times of 45 minutes for the Brunswick Processing Plant area, and 1 hour for Heathcote-Nagambie road.

Graham [18] recommended the use of the flood severity-based method for estimating loss of life. Flood severity is classed into the following categories:

- Low – No buildings washed off their foundations; flood depths less than 10ft, (3.3m), or  $D*V$  less than  $4.6 \text{ m/s}^2$ .
- Medium – Buildings are destroyed, but trees or building debris remains for people to seek refuge on; flood depths in excess of 10ft (3.3m), or  $D*V$  greater than  $4.6 \text{ m/s}^2$ .
- High – Near instantaneous failure of a dam in seconds, resulting a flood wave completely sweeping the area clean, with no evidence of human presence.

Based on the results of the dam break assessment, with a peak  $D*V$  of up to  $5 \text{ m}^2/\text{sec}$ , it is evident that the flood severity would be classified as “Medium”.

The final parameter required to estimate PLL is the downstream population understanding of the flood severity, classified as either “Vague” (warning issuers have not seen an actual dam failure, or do not comprehend the magnitude of the flooding), or “Precise” (warning issuers have an excellent understanding of the flooding due to observations of the flooding). This parameter is primarily concerned with people at risk very far (multiple kilometres) downstream which can receive plenty of warning of the flood magnitude. Given the proximity of the critical areas to the Brunswick West TSF, a classification of “Vague” has been adopted.

For a Medium flood severity, warning time of 45 minutes to 1 hour, and a Vague understanding of the flood severity, Graham [18] recommends a fatality rate (fraction of the PAR that become PLL) in the range of 0.01 to 0.08, with a recommended value of 0.04. When applied to the PAR of 25, this is equal to a PLL of 1.0.

## 6.4 Assessed Consequence Category

Based on the Severity of Loss and Damage for each failure scenario (refer **Section 6.2**) and the Population at Risk (refer **Section 6.3**), the Assessed Consequence Category for the Dam Failure (in green) and Environmental Spill (in Blue) for the Brunswick West TSF is presented in **Table 6**.

**TABLE 6: ASSESSED CONSEQUENCE CATEGORY (FROM ANCOLD [9])**

| Population at Risk | Severity of Damage and Loss |             |             |              |
|--------------------|-----------------------------|-------------|-------------|--------------|
|                    | Minor                       | Medium      | Major       | Catastrophic |
| < 1                | Very Low                    | Low         | Significant | High C       |
| > 1 to < 10        | Significant                 | Significant | High C      | High B       |
| > 10 to < 100      | High C                      | High C      | High B      | High A       |
| > 100 to < 1,000   | Note 1                      | High B      | High A      | Extreme      |
| >1,000             |                             | Note 1      | Extreme     | Extreme      |

Assessing the Brunswick West TSF consequence category based on incremental PLL, in accordance with ANCOLD [8], would also result in a consequence category of “High B” (based on a PLL of between 1.0 falling between  $\geq 1$  and  $< 5$ ).

## 6.5 External Return Water Pond

The Victorian Department of Environment and Primary Industries (VIC DEPI) [14] classify a private dam as potentially hazardous and subject to dam safety regulation if;





- has a wall that is 5 metres or more high above ground level at the downstream end of the dam and a capacity of 50 megalitres or more; or
- is on a waterway and has an ANCOLD Consequence Category of Significant or above.

The external RWP has a maximum height at the northern end of approximately 4.5 m above the natural surface, and has a capacity of less than 50 ML. The RWP would also be expected to have a Consequence Category in line with the environmental spill consequence category of the TSF (release of potentially saline water resulting in Medium damage, with <1 PAR), and would be classified as Low. As such, the external RWP is not classed as a potentially hazardous dam, no further assessment is required for the facility.

## 6.6 Interaction From a Breach of the Existing Facilities

As is shown in **Figure 2**, the two existing TSFs at Costerfield are situated relatively close to the Brunswick West TSF site. The Bombay TSF is approximately 100 m immediate north-east, and the Brunswick TSF is approximately 500 m to the south-east. Given the close proximity, there exists the potential for these facilities to undergo a failure and interact with the Brunswick West TSF.

The Brunswick TSF is located downstream of the new Brunswick West TSF, with the natural ground elevation at approximately RL 185 m, compared to RL 189 m at the Brunswick West TSF site. The topography around the Brunswick TSF slopes to the east following natural drainage lines. If a breach of the Brunswick TSF were to occur at the north-western corner of the facility, the initial flood wave would be expected to progress slightly upstream, but would quickly begin to follow the natural topography and flow down the natural drainage lines to the east. As such, a failure of the Brunswick TSF will not interact with the Brunswick West TSF.

The Bombay TSF is also located slightly downstream of the Brunswick West TSF, with natural ground elevation at RL 190 m, compared to RL 191.5 m at the closest point of the Brunswick West TSF. The topography slopes towards the north-east, with a natural topographical high point around 200 m to the south of Bombay TSF. It is envisaged that the worst-case scenario would be a breach occurring at the south-west corner of the Bombay TSF. The failure would occur as a relatively rapid breach of the upstream raised portions of the Bombay TSF (two raises, or approximately 6.0 m), followed by erosion and gradual failure of the downstream raised portions, with the highest risk for damage occurring as a result of the initial rapid breach.

ATCW experience with dam break modelling suggests that the material released from a breach of an upstream raised embankment will quickly spread out over flatter natural topography. The initial flood wave would flow over the natural ground south of Bombay TSF and against the northern half of the eastern embankment downstream toe, flowing partially uphill at a depth of around 2 m, before retreating and following the topography to the north-east. This will result in erosion of the upper topsoil layer and some of the rockfill at the downstream toe. However, the robust design of the Brunswick West TSF embankment (4:1 downstream batter slopes) means that this erosion is highly unlikely to initiate an embankment failure and knock-on dam breach of the Brunswick West TSF.

It is therefore concluded that the existing TSFs at the Costerfield site will contribute a negligible increase to the risk embankment failure of the Brunswick West TSF, and the level of risk is considered acceptable.

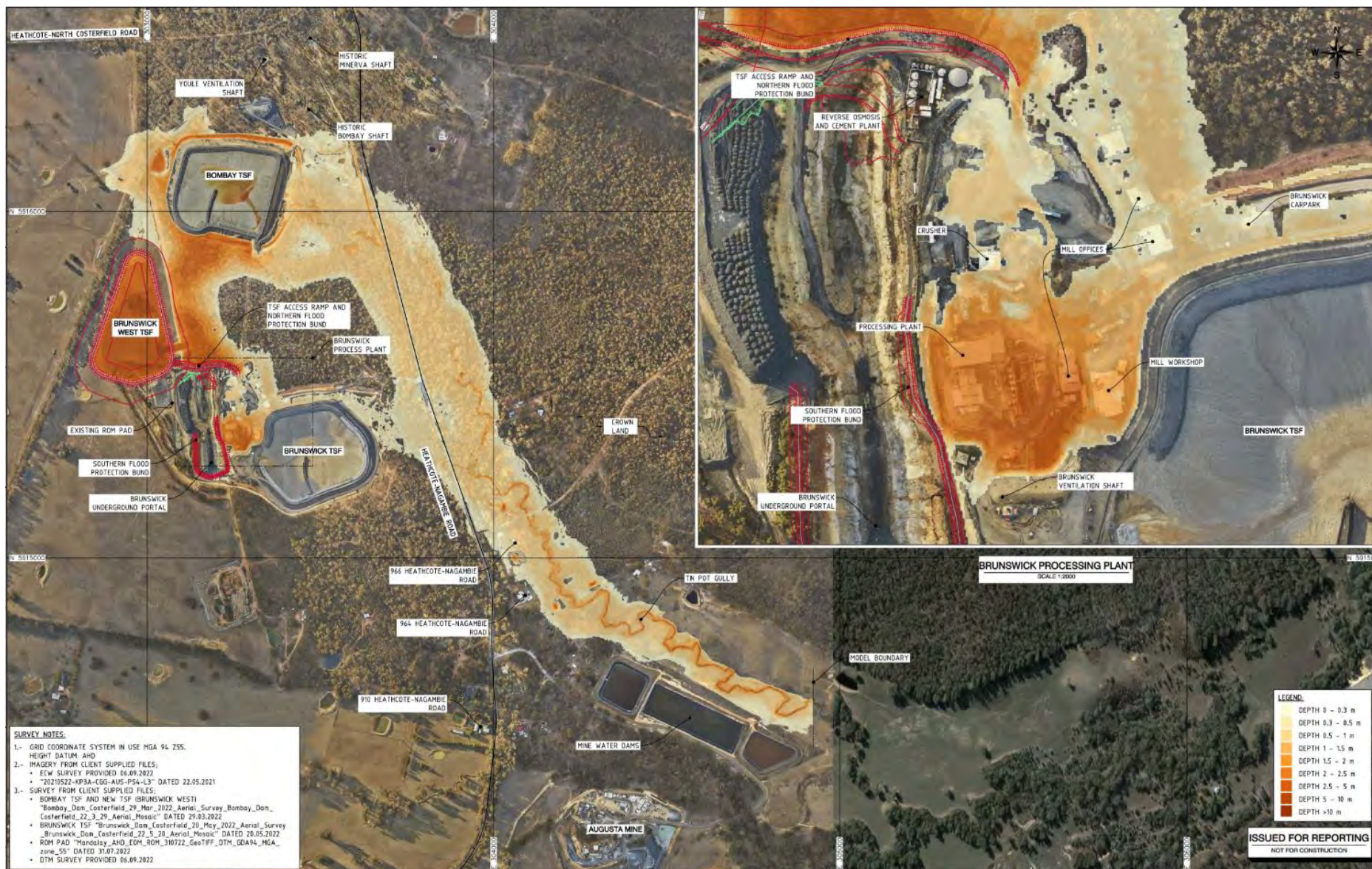
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MAP 5: EASTERN EMBANKMENT SUNNY DAY BREACH – MAXIMUM DEPTH

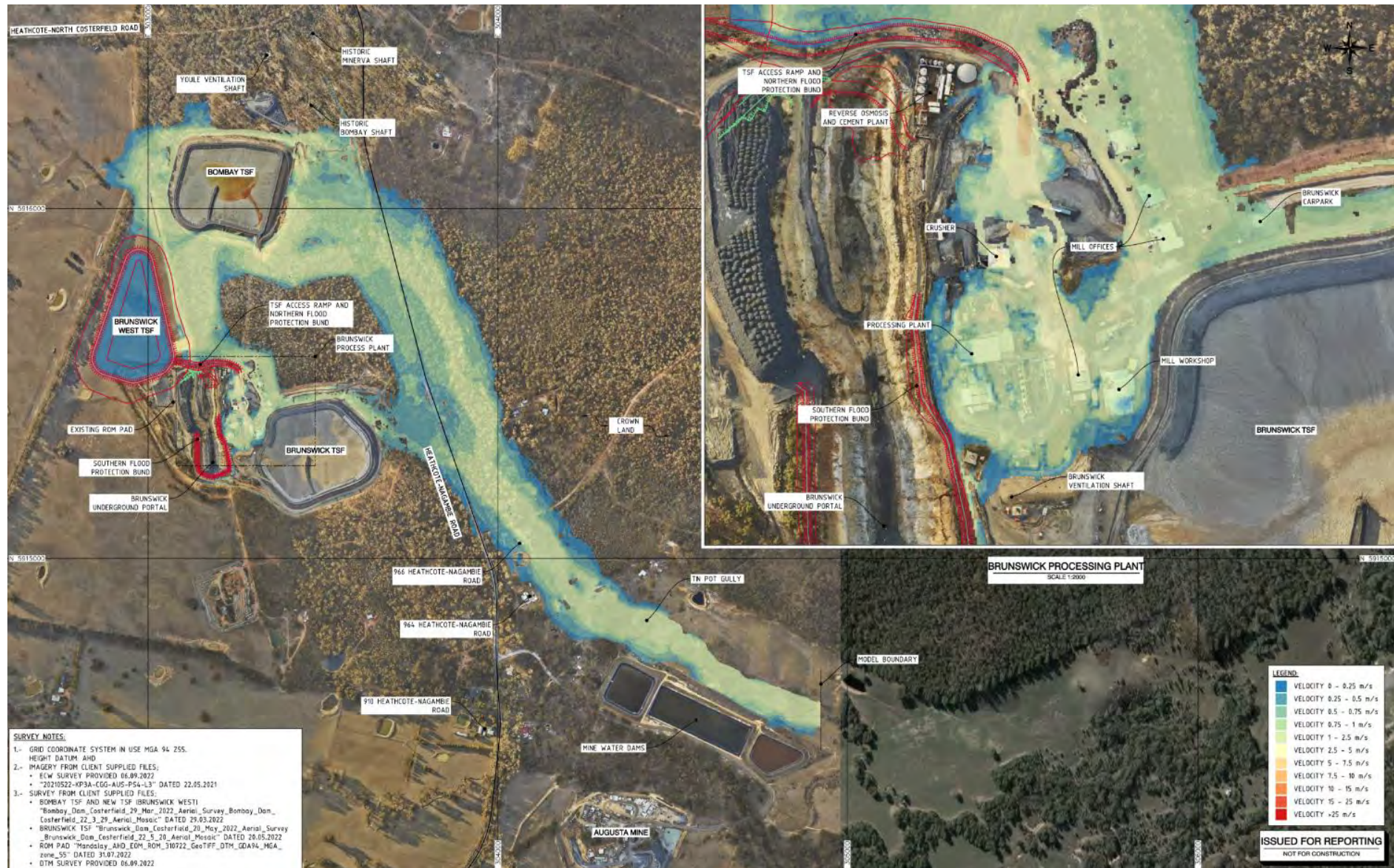




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MAP 6: EASTERN EMBANKMENT SUNNY DAY BREACH – MAXIMUM VELOCITY

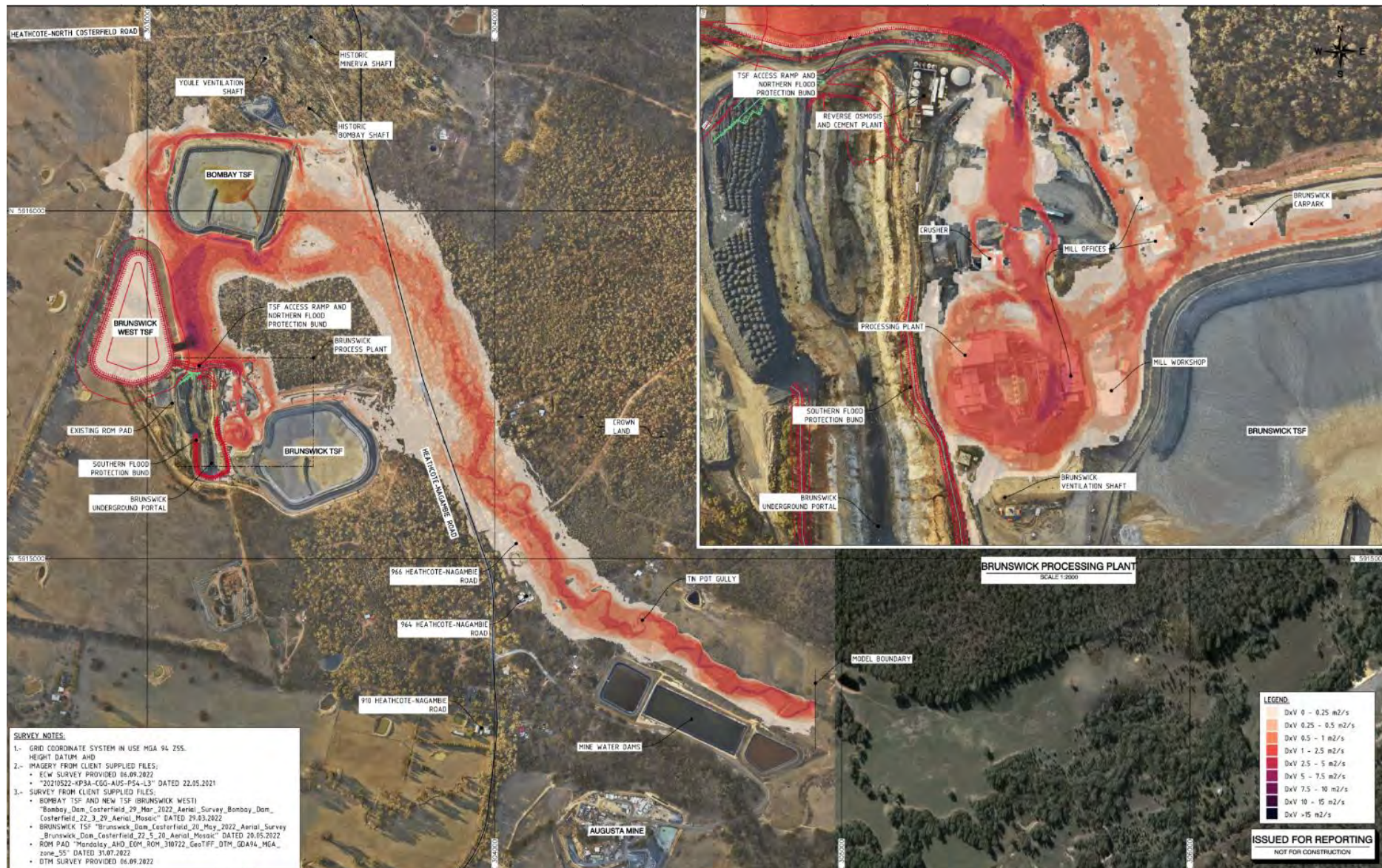




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**MAP 7: EASTERN EMBANKMENT SUNNY DAY BREACH – MAXIMUM DEPTH-VELOCITY PRODUCT**

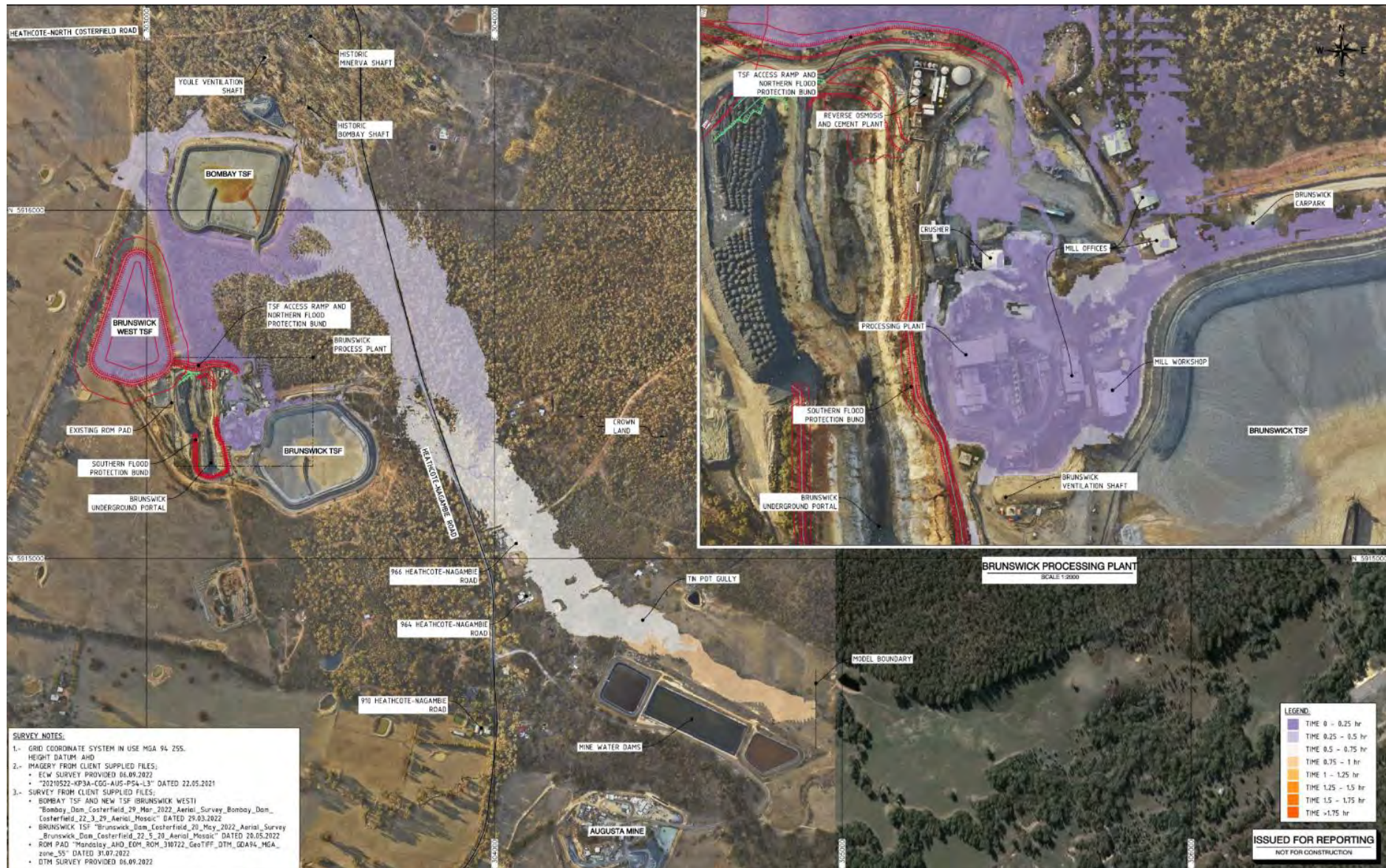




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MAP 8: EASTERN EMBANKMENT SUNNY DAY BREACH – ARRIVAL TIME







## 7 DAM FAILURE MODE AND RISK ASSESSMENT

### 7.1 Overview

The ANCOLD Guidelines on Risk Assessment [11] recommend that for High Consequence Category dams, a quantitative risk assessment be conducted to quantify and evaluate the risk tolerability of the facility. As part of the design for the Brunswick West TSF, ATCW conducted a Credible Failure Mode Assessment (CFMA) for the facility, which is documented in ATCW report 109015.15-R03 [19]. The purpose of this assessment was to identify all potential failure modes and progression paths that would result in a catastrophic failure of the TSF, leading to a release of tailings and water.

The process for this assessment is summarised below;

1. Identify all potential failure modes for the facility that would result in a release of material, based on ATCW and MRCO experience and judgement, and drawing on databases of failure modes that have occurred at other facilities globally;
2. Document the failure progression (sequential steps required for a failure to occur), and the controls in place to mitigate a potential failure;
3. Undertake a qualitative screening of all the failure modes by categorising them as either “Potentially Credible” or “Non-Credible”;
4. Conduct a quantitative analysis of the potentially credible failure modes to assign an overall probability of failure; and
5. Assess the overall level of risk for the facility, considering the probability of failure and the Potential Loss of Life (PLL).

The initial identification and qualitative screening process was undertaken by ATCW, and provided to MRCO for review and internal discussion.

MRCO have completed an internal workshop of the failure modes and risk register, which have refined the initial screening conducted by ATCW.

### 7.2 Potential Failure Modes & Qualitative Screening

A list of Potential Failure Modes (PFMs) that could result in a breach was compiled to initially assess the likelihood of a failure occurring. These failure cases can broadly be categorised as a failure due to:

- Geotechnical Piping,
- Overtopping of the embankment crest, or
- Embankment Instability.

Additionally, as part of the dam break modelling [16], a combined settlement and erosion failure was identified as potentially credible to provide verification of a potential sunny day embankment failure.

The PFMs and the failure progression for each scenario for the Brunswick West TSF are presented in **Appendix A**.

Following the identification of the PFMs, a list of all possible controls for the failure modes that can be implemented at the Design, Construction and Operational stages was documented. Based on these controls, each PFM was designated as either “Potentially Credible” or “Non-Credible”.

Potentially Credible PFMs were considered as scenarios that could be envisaged as possible, even with all controls in place. Non-Credible PFMs were considered as scenarios that are incredibly unlikely to occur with all controls in place, or scenarios are illogical in context of the facility. In the context of the Brunswick West TSF, this may be “failure through an upstream raise” when the facility is to be constructed entirely by downstream methods.

Following the qualitative screening process, the following PFMs were considered as Potentially Credible and considered for Quantitative Assessment:





## **Geotechnical Piping**

- Geotechnical Piping through the embankment – Cracking caused by loss of support from downstream shoulder.
- Geotechnical Piping through the embankment – Cracking caused by loose/poorly compacted layers in the upstream zones.
- Geotechnical Piping through the Embankment – Caused by transverse seismic cracking.
- Geotechnical Piping into the Foundations.

## **Embankment Overtopping**

- Embankment Overtopping due to loss/impairment of emergency spillway.
- Embankment Overtopping due to crest scour from pipeline burst.
- Embankment Overtopping due to poor deposition management – Spillway Blockage.
- Embankment Overtopping due to poor deposition management – Decant Blockage.
- Embankment Overtopping due to poor deposition management – Over deposition.
- Embankment Overtopping due to build-up of excess tailings bleed water.
- Embankment Overtopping due to higher than expected operating pond levels.
- Embankment Overtopping due to single/multiple large storms that exhaust freeboard and exceeds spillway capacity.
- Embankment Overtopping due to reduced spillway capacity from seismic induced crest settlement.
- Embankment Overtopping due to scour from failure of Spillway Erosion Protection Rip-Rap.

## **Embankment Instability**

- Embankment Instability due to incorrect material characterisation – Embankment fill materials.
- Embankment Instability due to incorrect material characterisation – Foundation materials.
- Embankment Instability due to high phreatic surface.
- Embankment Instability due to inadequately constructed embankments.
- Embankment Instability due to inadequately prepared foundations.

## **Combined Settlement and Erosion**

- Embankment erosion failure due to cumulative static settlement and seismic deformation.

## **7.3 Quantitative Assessment**

### **7.3.1 Overview**

The failure modes identified as “Potentially Credible” in **Section 7.2**, as well as relevant comparison base cases, have been numerically analysed to assess the likelihood of each failure mode occurring. Failure has been analysed for the critical stage over the life of the TSF, which generally corresponds to the end of filling scenario at the maximum operating pond level.

A summary of the assessment methodology for each failure mode is provided below, with full derivations of the probabilities and factors of safety are documented in the CFMA report [19].

## **Geotechnical Piping**

Failure of an embankment due to geotechnical piping requires a series of events to occur sequentially and remain in place until a failure mode can develop and cause a failure.





The geotechnical piping process can be summarised as follows:

1. Initiation – A concentrated leak in the embankment allows for water to begin to mobilise through the compacted Zone 1B.
2. Continuation – An assessment as to whether the compacted Zone 3A downstream zone will prevent piping from continuing further.
3. Progression – An assessment as to whether:
  - a. the soil within which the pipe is forming will support the roof of the pipe,
  - b. if the pipe will collapse and seal the pipe, or
  - c. the upstream zones will limit flow.
4. Detection & Intervention – An assessment as to whether signs of internal erosion are detected, but intervention methods are unable to halt the erosion process.
5. Breach – An assessment of how the initial piping failure will cascade into a catastrophic failure that will lead to the release of stored material.

Fell et al [20] provide a comprehensive toolbox for the estimation of the probabilities of piping at each stage of the process, which has formed the basis of this assessment. These methods were developed based on analysis of historical embankment failures and expert judgement behind the importance and impact of the relevant factors.

These assessments were primarily developed for water storage dams, where a free water body is continually present at the upstream face of the embankment, and can contribute to a high seepage gradient if erosion begins. These methods remain applicable for tailings retaining embankments once the erosion process has begun, but consideration must be given to the effect of the tailings in the initiation process. This often leads to discrediting of foundation failure, as piping failure through the foundations can only occur while the tailings remain below the foundation level, and wont lead to an embankment failure.

For the Brunswick West TSF, piping failures would require exposed water against the embankment upstream face, and would require the initial condition of a significant flaw in the synthetic liner that goes un-noticed for a long period of time.

### **Embankment Overtopping**

Failure of an embankment due to overtopping failures has been assessed as water flowing uncontrolled over the embankment rather than through the spillway. This has been assessed as estimating the probably of the initial conditions that would lead to stormwater not flowing through the spillway, followed by the AEP of the storm event to cause the failure.

Estimation of the preceding events (for example, probability of partial/complete spillway blockage from operation personnel activities) was often empirically estimated to give an order-of-magnitude estimate of the probability of an event occurring. This has been undertaken using the mapping scheme developed by Barniech et al, as presented in the ANCOLD risk assessment guidelines [11].

The magnitude of the storm event to cause an overtopping failure has been estimated as follows:

- In cases where the emergency spillway is active (either at partial or full capacity), the numerical routing methods as used in the spillway design (refer **Section 13.2.4.1**) were used to determine the storm depth and critical duration that would exceed the spillway capacity. From this, the AEP of the storm event was determined based on the estimations of extreme rainfall depths (refer **Section 13.2.2**)
- In cases where the emergency spillway is bypassed (i.e., completely blocked off), the storm depth of the 72hr storm event to exceed the remaining freeboard was estimated, which then informed the AEP of the storm event.

### **Embankment Instability**

Failure of an embankment due to instability has been undertaken by considering the as-designed embankment stability as a base case scenario, and assessing the impact to the overall factor of safety by applying one or more detrimental conditions occurring. Estimation of the probability failure is





difficult, as there are no definitive methods for relating embankment factor of safety with a probability of failure.

The base case as-designed embankment stability at the end of filling scenarios have been adopted from the stability assessment, and assessment of the potential failure undertaken following the design methodology (refer **Section 16**). [Estimation of the likelihood of failure has been determined using the methods described by Silva et al \(2008\) \[21\].](#)

## **Combined Settlement and Erosion**

Failure of the embankment from a combined settlement and erosion failure was assessed by considering cumulative static settlement post construction followed by seismic deformation of the embankment leading to the release of liquefied tailings and operational water. This has been assessed by consideration of the sequential steps required to initiate failure. This has considered the estimated probabilities as per the mapping scheme developed by Barneich et al [11], as well as embankment deformation estimated by the AEP of the seismic event.

### 7.3.2 Results

The estimated likelihood of occurrence (probability or factor of safety) for each of the Potentially Credible PFM's is summarised in **Table 7**. These probabilities represent the overall probability of failure, and are inclusive of the preceding conditions and the triggering event.

Full derivations of the probabilities and factors of safety are documented in the CFMA report [19]

**TABLE 7: POTENTIAL FAILURE MODES ESTIMATED PROBABILITY OF OCCURANCE**

| Failure Mode  | Estimated Probability          | Consequences of Failure (PLL) |
|---|--------------------------------|-------------------------------|
| Geotechnical Piping   |                                |                               |
| Through embankment - Cracking caused by loss of support from downstream shoulder            | 3.8 x 10 <sup>-10</sup>        | Sunny Day Failure<br>PLL = 1  |
| Through embankment - Cracking caused by loose/poorly compacted layers in upstream clay zone | 7.9 x 10 <sup>-12</sup>        |                               |
| Through embankment – Cracking caused by transverse seismic cracking                         | 5.0 x 10 <sup>-11</sup>        |                               |
| Into foundations  | 3.8 x 10 <sup>-10</sup>        |                               |
| Embankment Overtopping  |                                |                               |
| Loss of spillway capacity   | 1.3 x 10 <sup>-9</sup>         | Flood Failure<br>PLL = 0.01   |
| Crest scour from pipeline burst   | 5.0 x 10 <sup>-10</sup>        |                               |
| Poor deposition management - Spillway Blockage  | >> 1.0 x 10 <sup>-10</sup> (1) |                               |
| Poor deposition management - Decant Blockage  | >> 1.0 x 10 <sup>-9</sup> (1)  |                               |
| Poor deposition management - Over deposition  | >> 1.0 x 10 <sup>-8</sup> (1)  |                               |
| Build-up of excess tailings bleed water   | >> 1.0 x 10 <sup>-10</sup> (1) |                               |
| Higher than expected operating pond levels  | >> 1.0 x 10 <sup>-10</sup> (1) |                               |
| Single/multiple large storms that exhaust freeboard and exceeds spillway capacity           | >> 5.0 x 10 <sup>-11</sup> (1) |                               |
| Reduced spillway capacity from seismic induced crest settlement                             | >> 1.0 x 10 <sup>-10</sup> (1) |                               |
| Scour from failure of Spillway Erosion Protection Rip-Rap                                   | 2.0 x 10 <sup>-9</sup>         |                               |
| Embankment Instability  |                                |                               |
| Incorrect material characterisation - Embankment fill materials                             | 1.0 x 10 <sup>-11</sup>        | Sunny Day Failure             |
| Incorrect material characterisation - Foundation materials                                  | 1.0 x 10 <sup>-11</sup>        |                               |





| Failure Mode  | Estimated Probability   | Consequences of Failure (PLL) |
|---|-------------------------|-------------------------------|
| High phreatic surface   | 1.0 x 10 <sup>-13</sup> | PLL = 1                       |
| All combined design element failures above                                  | 3.0 x 10 <sup>-13</sup> |                               |
| Inadequately constructed embankments  | 1.0 x 10 <sup>-10</sup> |                               |
| Inadequately prepared foundations   | 6.0 x 10 <sup>-12</sup> |                               |
| Combined Settlement and Erosion Failure                                     |                         |                               |
| Erosion failure due to cumulative static settlement and seismic deformation | 1.0 x 10 <sup>-9</sup>  | Sunny Day Failure<br>PLL = 1  |

Note (1) Failure modes requiring storm events larger than the PMP denoted with ">>" suffix, indicating the probability is well below this assessed value.

It can be seen that the estimated probabilities of failure are generally very low, with the highest probability around  $10^{-9}$ . The mitigation measures that have been included in the design have significantly lowered the likelihood of failure and provide a suitable level of risk management.

## 7.4 Risk Assessment

The ANCOLD Guidelines on Risk Assessment [11] provide guidance for the tolerability of public safety risks for the general community and workers associated with the facility, and considers the relationship between the annualised probability of failure and the potential number of fatalities due to dam failure. This is presented as an F-N chart, or the ANCOLD Societal Risk Guidelines. This chart presents the individual F-N pairs for each of the failure cases considered, as well as the combined F-N curve for the Brunswick West TSF, and is presented in **Chart 4**.

This chart presents the individual F-N pairs for each of the failure cases considered, as well as the combined F-N curve for the Brunswick West TSF.

This chart can be split into two regions;

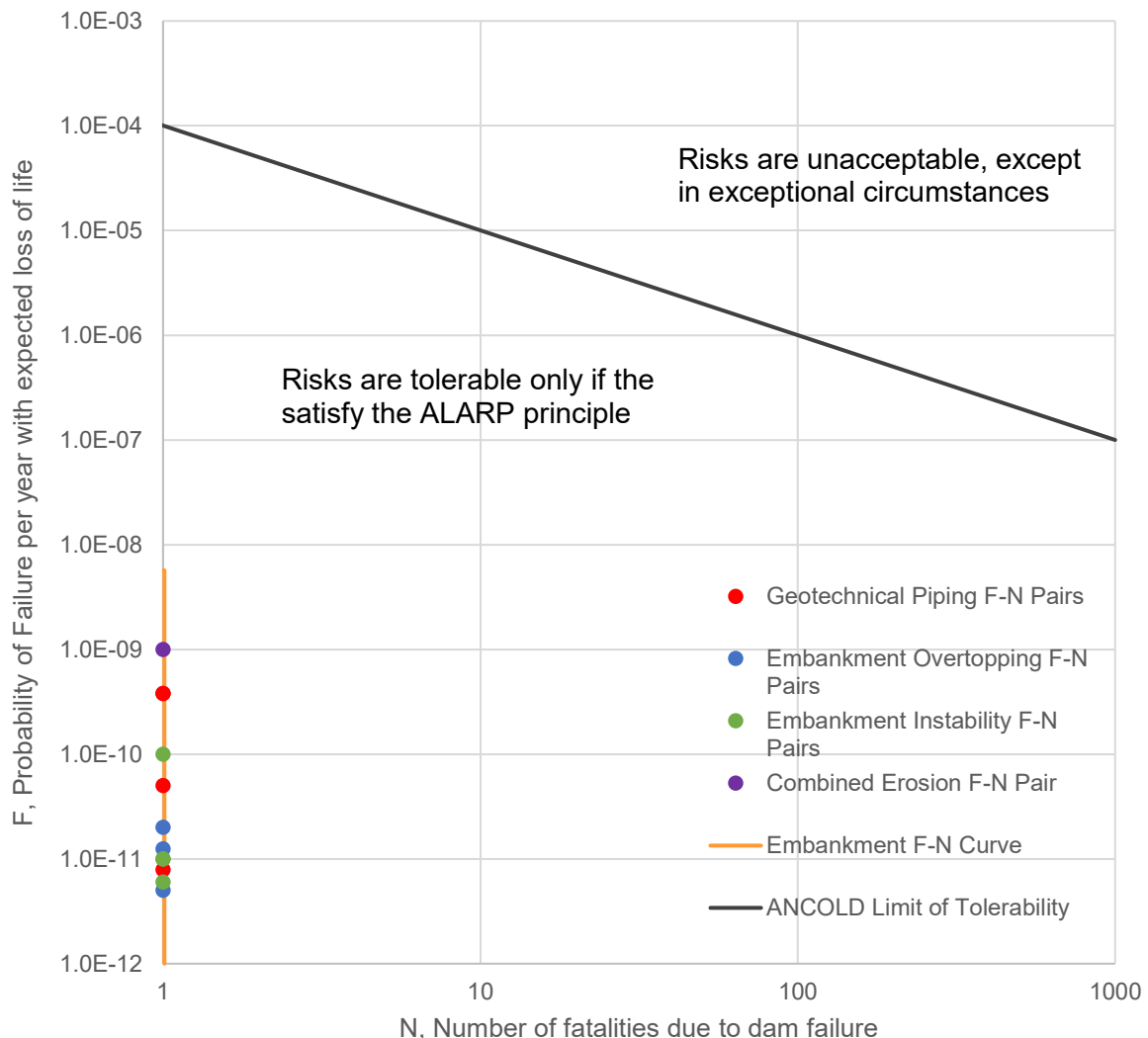
- Risks are unacceptable, except in exceptional circumstances.
- Risks are tolerable only if they satisfy the "As Low As Reasonably Practicable (ALARP)" principle.
  - This is delineated from the above region by the "Limit of Tolerability" line.

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**CHART 4: PROBABILITY OF FAILURE VS NUMBER OF FATALITIES – NEW DAMS**



**Note:** ANCOLD provides the Limit of Tolerability line to a lower bound N value of 1. For fractional N values (i.e.,  $N < 1$ ), the F-N pairs have been presented at  $N = 1$ , with the probability values adjusted to compensate.

It can be seen from **Chart 4** that the F-N pairs for the assessed failure cases and the cumulative embankment F-N curve plots well below the ANCOLD Limit of Tolerability for new dams, and are within the region where the risk can be considered as tolerable if they satisfy the ALARP principle.

The key ALARP considerations for the proposed Brunswick West TSF are summarised below:

- The residual societal risk for the Brunswick West TSF design is roughly 4 orders of magnitude below the ANCOLD Limit of Tolerability for new dams.
- The proposed design for the Brunswick West TSF satisfies best practice design for the facility, and has been designed to meet and exceed the minimum requirements of ANCOLD. Key risk control measures from the TSF design are summarised below;
  - Inclusion of the BGM liner to control initiation for geotechnical piping.
  - Formation of the embankment downstream slopes to 4:1 (H:V), resulting in a significant Factor of Safety against embankment instability.
  - Excavation of the emergency spillway beyond the depth of the PMP peak flood height to control water overtopping the embankment crest.





- The proposed design also incorporates two flood diversion bunds to aid in the prevention of material (tailings and/or water) inundating the Brunswick Underground Portal in the events of a dam failure to remove the PLL from the Dam Break scenario. While the additional costs to construct these bunds is not insignificant, these flood protection measures have been considered as necessary to ensure the safety of the mine workers within the underground network.
- Construction of the Brunswick West TSF is proposed to have full time construction QA/QC to ensure the design specifications are met, including foundation preparation, material specifications, and material placement and compaction.
- An Operation, Maintenance and Surveillance Manual (OMS) will be prepared and implemented prior to commissioning of the Brunswick West TSF, in accordance with the operating requirements of ANCOLD.
  - This document will describe the routine inspections required for key elements of the facility, and subsequent actions to be conducted to limit the potential progression of embankment failure.
  - Surveillance and instrumentation monitoring requirements will also be documented, to be conducted regularly, and reviewed annually as part of the dams engineer inspections.
- A Dam Safety Emergency Plan (DSEP) will also be prepared and implemented prior to commissioning of the Brunswick West TSF, in accordance with the operating requirements of ANCOLD.
  - This document will describe the procedures to be followed by personnel in the inundation zone based on trigger levels of key elements of the facility. These trigger levels are defined on a traffic-light system, from lowest (within normal operating levels) to highest (failure is imminent), and provides instruction on the required actions to take at different levels.
  - Timely evacuation of mine personnel from the Brunswick Processing Plant area when approaching the highest trigger level will further reduce the PLL in the event of a Dam Break .
  - As part of the operation of the facility, the DSEP will be regularly tested to ensure mine personnel within the inundation zone are sufficiently trained on the actions to take at different trigger levels.
- The incremental costs and level of effort associated with further engineering risk reduction works for the proposed Brunswick West TSF would be significant compared to the relatively small to negligible further risk reduction that could be achieved.

As such, ATCW consider that the design of the Brunswick West TSF satisfies the ALARP principle, and that the residual risks imposed to the community and mine personnel due to the presence of the Brunswick West TSF are tolerable, and the facility meets the requirements of ANCOLD for the management and tolerability of risk.

## 7.5 Risk Register

As part of the CMFA process, a risk register was developed in collaboration with MRCO for the Design, Construction, Operation and Closure stages of the facility, and is presented in **Appendix A**. This risk register is a non-exhaustive list and should be continually updated throughout the various stages of the facility.

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## 8 DESIGN CRITERIA

Based on the assigned Consequence Category outlined in **Section 6**, the ANCOLD Guidelines [9] & [10] required minimum design criteria is summarised in **Table 8**.

Additional embankment design criteria not outlined by the ANCOLD Guidelines [9] & [10] are summarised in **Table 9**.

Additionally, the Tailings Storage Facility Data Sheet for the Brunswick West TSF, as recommended by VIC ERR [12], is provided in **Appendix B**.

**TABLE 8: TSF REQUIRED MINIMUM DESIGN CRITERIA**

| Criteria Description                                | Criteria Requirement  |                    |  |
|---|---|--------------------|--|
| Dam Failure Consequence Category                    | <b>HIGH B</b>   |                    |  |
| Embankment stability minimum Factor of Safety (FoS) | <b>Loading Condition</b>  | <b>Criteria</b>    | <b>Material Strength Parameters</b>  |
|   | Static Short Term   | FoS $\geq$ 1.3     | Undrained Strength   |
|   | Static Long Term  | FoS $\geq$ 1.5     | Drained (effective) or Undrained strength (as appropriate for cohesive materials)  |
|   | Post Liquefaction (Safety Evaluation Earthquake)  | FoS $\geq$ 1 – 1.2 | Post-liquefied strength /residual strength for material that are potentially liquefiable. 20% reduction in peak shear strength for the materials that are not liquefiable. |
| Seismic Criteria                                    | Operational Basis Earthquake (OBE) 1:475 to 1:1,000 AEP event<br>Safety Evaluation Earthquake (SEE) 1:5,000 AEP event<br>(adopted 1:10,000 AEP) |                    |  |
| Minimum Spillway Critical Design Storm              | 1:100,000 AEP Critical Duration Storm + Wave run-up for 1:10 AEP wind, or Probable Maximum Flood (PMF)  |                    |  |
| Environmental Spill Consequence Category            | <b>LOW, but have adopted SIGNIFICANT</b>  |                    |  |
| Maximum Operating Pond                              | Determined by semi-quantitative risk analysis methods, or 1:100 Notional AEP wet season runoff (fall back method)                               |                    |  |
| Minimum Extreme Storm Storage                       | 1:100 AEP, 72 hr flood  |                    |  |
| Contingency Wave Freeboard Allowance                | 1:10 AEP Wind   |                    |  |
| Additional Freeboard                                | 0.3 m   |                    |  |

**TABLE 9: ADDITIONAL DESIGN CRITERIA**

| Item                        | Criteria           | Comment   |
|-----------------------------|--------------------|---|
| <b>TSF Embankments</b>      |                    |   |
| Crest Elevation             | RL 200.0m (AHD)    | Determined based on the current maximum approved raise height for Bombay and Brunswick TSF. |
| Crest Width                 | Min 6.0m           | To provide vehicle access along embankment crest  |
| Crest Grade                 | 3%, 1-way into TSF | To provide drainage and limit run-off down downstream batter slope.                         |
| Internal Zone Minimum width | 3.0m               | For ease of construction through layered material placement                                 |



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| Item                                    | Criteria   | Comment   |
|---|--|---|
| Downstream Batter Slopes                | 4:1 (H:V)  | To provide suitable closure slopes for the facility.  |
| Embankment Lining Requirements          | Minimum 1.0m of 1x10 <sup>-9</sup> m/s clay, or equivalent   | VIC ERR Requirements [12]   |
| Impoundment Lining Requirements         | Minimum 1.0m of 1x10 <sup>-9</sup> m/s clay, or equivalent   | VIC ERR Requirements [12], which are derived from the EPA Guidelines for landfills for containment of Category C Contaminated Soils [13]. |
| TSF Excavation Base                     | RL 180.0m  | Limited by expected groundwater levels once dewatering ceases   |
| <b>External Return Water Pond</b>       |  |   |
| External RWP Concept                    | Facilitate continual removal   | Designed to temporarily hold decant and storm water pumped from the TSFs to prevent delays in removal of water from the TSFs              |
| External RWP Size                       | To store 1:100 AEP, 72hr runoff from the TSF + 7 days bleed, OR<br>To store 7 days' worth of pumping from the TSF with no removal from the RWP | To allow for continual pumping off the TSFs to maximise evaporative drying potential  |
| Embankment Height                       | < 5.0 m  | To be treated as a non-hazardous private dam as per VIC DEPI [14]   |
| Embankment Crest Width                  | 4.0m   | To facilitate construction and access on crest.   |
| Embankment & Excavation Upstream Batter | 3:1 (H:V)  | To allow for smooth drum operation to prepare for geosynthetic liner installation.  |
| Embankment Downstream Batter            | 2.5:1 (H:V)  | To provide suitable closure slopes for the facility.  |
| <b>Diversion Drains</b>                 |  |   |
| Design Capacity                         | 1:100 AEP, Critical Duration   | Determined by Risk Assessment methods for a High B Consequence Category Dam   |
| Buried Culverts Flow Depth              | Maximum 70% of Internal Diameter   | To prevent pressurised pipe flow.   |
| <b>Decant Structure</b>                 |  |   |
| Tailings Discharge Solids Concentration | 45% - 50%  | Based on capacity of High Rate Thickener  |
| Decant Structure Filter                 | Tailings D <sub>85</sub> = 75 µm   | Based on PSD tests of Brunswick Processing Plant slurry samples conducted in 2022.  |
| <b>Access Ramps</b>                     |  |   |
| Crest Width                             | Min 6.0m   | -   |
| Grade                                   | LV – Max 12%<br>Haul – Max 8%  | Provide safe access for light vehicles (LV) and Haul trucks   |
| Drainage                                | 2% Crossfall (1-way or 2-way, as appropriate)  | To provide suitable surface drainage  |

It is noted in **Table 8** that, based on a Dam Failure Consequence Category of **High B**, the Brunswick West TSF is required to be designed for a minimum Safety Evaluation Earthquake (SEE) Annual Exceedance Probability (AEP) of 1 in 5,000, however ATCW have adopted a 1 in 10,000 AEP for the SEE. As identified **Section 6.3.1**, the critical failure progression path for a Sunny Day Failure is attributed to vertical seismic deformation. As such, ATCW have adopted the 1 in 10,000 AEP event for the SEE to demonstrate that the facility is suitable robust to withstand larger seismic events





Additionally, the assessed Environmental Spill Consequence Category for the Brunswick West TSF was **Low**, however ATCW have adopted **Significant**. The primary implication that upgrading the Environmental Spill Consequence Category has on the design of the Brunswick West TSF is the required storm storage freeboard (1:100 AEP 72Hr Storm, plus 1:10 AEP Wind plus 0.3 m freeboard for Significant, compared to storm storage requirements determined by risk assessment for Low). The increased freeboard requirements have been adopted as a contingency against potential unforeseen issues that cannot be accounted for in the design, and is considered a suitably conservative approach for a new facility. The impact to the overall storage capacity of the Brunswick West TSF has been determined as very low, approximately 80 days at the end of the storage life. If this additional storage space is required once the Brunswick West TSF is nearing capacity, the increased freeboard can be revised and reduced in line with the assessed consequence category of Low in the context of the operational life of the Brunswick West TSF.

## 9 GEOTECHNICAL DATA

### 9.1 Previous Assessments & Identified Gaps

#### 9.1.1 Previous Assessments

Several Geotechnical Investigations and Laboratory testing schedules have been previously undertaken at Costerfield which remain relevant for the design of the Brunswick West TSF.

#### **Bombay TSF Cell 2 Starter Investigation (2009)**

As part of the design of the Cell 2 starter embankment, a geotechnical investigation was undertaken by ATC Williams in 2009, and is documented in ATCW report 109014R03 [20]. The aims of this investigation were as follows:

- Assess the subsurface conditions beneath the Cell 2 starter embankment foundations. Including clay and weathered rock depths,
- Assess the material within the impoundment area for suitability for re-use as borrow material in embankment construction, and
- Determine the ease of excavation of the subsurface material within the proposed excavation area of Cell 2.

The works consisted of the drilling of ten boreholes within the embankment footprint and impoundment area, undertaking Standard Penetration Tests and Falling Head Permeability tests within the boreholes, excavation of 12 test pits, and laboratory testing on samples collected from the investigations.

#### **Tailings Characterisation (2009)**

Further laboratory testing of the properties of the tailings produced at the Costerfield Gold Mine was undertaken as part of the Cell 2 starter embankment design [23]. Flocculated tailings slurry samples were sent for laboratory testing, consisting of:

- Particle Size Distribution, including hydrometers,
- Atterberg Limits,
- Soil Particle Density,
- Moisture/solids content (as received),
- Initial Settled Density (tray settlement),
- Shrinkage Limit Density, and
- Falling Head Permeability.

#### **Bombay TSF Cell 2 Construction (2009)**

Construction of the Bombay Cell 2 starter embankment consisted of a foundation excavation for waste rock borrow, which is documented in ACTW report 109014R06 [24]. This foundation excavation is





similar to what is proposed for the Brunswick West TSF, and provides insight into the potential depth of excavation that can be achieved in highly and less weathered siltstone rock utilising large earthmoving equipment (CAT D11 bulldozers and large excavators).

#### **Brunswick TSF First Raise Detailed Design (2014)**

In 2014, URS undertook a detailed design of the Brunswick TSF [25]. As part of this assessment, a geotechnical investigation was undertaken to characterise the existing Brunswick TSF and underlying foundations. This investigation is relevant as some of the materials proposed for use in construction of the Brunswick West TSF are similar and sourced from the same locations as those used for the Brunswick TSF.

This assessment consisted of drilling four boreholes, undertaking Standard Penetration Tests and Falling tests within the boreholes, excavation of eight test pits, and collection of samples of embankment material for laboratory testing. The laboratory testing consisted of the following:

- As received Moisture Content,
- Atterberg Limits and Linear Shrinkage,
- Emerson Class Dispersions,
- Particle Size Distribution,
- Particle Size Distribution with Hydrometer,
- Constant Head Permeability Test,
- Standard Compaction, and
- Effective Stress Triaxial Test

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#### **Brunswick TSF Raise 3 Detailed Design (2020)**

In 2020, ATCW undertook the design of raise 3 of the Brunswick TSF, documented in ATCW report 109014.07-R01 [15]. As part of this assessment, ATCW undertook a desktop review of laboratory testing previously undertaken on the existing earthfill embankments, in-situ clays, compacted clay core, and rockfill material.

This desktop review provides a point of comparison for the material strength parameters found as part of the current laboratory testing.

#### **Bombay TSF Raise 4 Detailed Design (2021)**

In 2021, ATCW undertook the design of raise 4 of the Bombay TSF, documented in ACTW report 109014.12-R04 [26]. As part of this assessment, a series of Cone Penetrometer Testing with Pore Pressure measurements (CPTu) were undertaken on the desiccated tailings, as well as laboratory testing on collected samples of in-situ tailings, to facilitate the raise partially over tailings.

The results of this investigation provided indicative parameters for tailings peak and post-seismic shear strengths.

#### **9.1.2 Identified Knowledge Gaps**

Based on a review of the previous investigations undertaken and review of the site overall, ATCW have identified the following knowledge gaps at the Costerfield Gold Mine and the current TSF's:

- Lack of detailed knowledge of the tailings delivery systems, and inability to suitably pump thickened tailings to the TSFs.
- Will be addressed through undertaking rheological testing of tailings slurry and detailed design of pumping infrastructure for both tailings and return water. **As of Revision 2 of this document, rheology testing has been completed, with results to be discussed in the following sections. ATCW are currently engaged with MRCO to complete the detailed design of the slurry transportation systems for Brunswick West TSF. The outcomes of this design will inform the necessary pumping requirements from the tailings pump station to ensure tailings slurry can be transported to the deposition points at the design solids**





concentration, as well as define the requirements for operation and maintenance of the pumping infrastructure.

- Lack of detailed knowledge of the tailings settling properties at higher discharge solids concentration. Limited design of the facility based on previous data undertaken on a lower bound sample.
  - Will be addressed through expanded tailings slurry testing, and used to validate the design based on the lower bound sample. **As of Revision 2 of this document, tailings settling tests have rheology testing have been completed, with results to be discussed in the following sections, and incorporated into the TSF design.**
- Limited knowledge of depth of free-dig excavation through foundation rock possible at this site, and was inferred based on Bombay TSF cell 2 starter excavation.
  - Has been addressed through geotechnical investigations borehole drilling within the embankment footprint to define the rock weathering profile, as well as a review of MRCO previous commissioned studies into rock excavatability undertaken for the Brunswick pit.
- Knowledge of foundation clays and embankment clayey materials previously based on results of investigation from nearby Brunswick TSF.
  - Has been addressed through detailed laboratory testing of remoulded and undisturbed clay samples.
- Earthfill and rockfill strength profiles previously based on angle of repose of uncompacted material.
  - Has been addressed through review of published literature of earthfill and rockfill strength profiles.

## 9.2 Current Investigations

### 9.2.1 Overview

To facilitate the design of the Brunswick West TSF, ATCW conducted a geotechnical investigation of the site to characterise the site and collected samples to further characterise the in-situ foundations of the TSF. The objectives of the investigations were:

- Characterise the sub-surface strata within the embankment foundations and TSF impoundments;
- Determine the in-situ properties of the natural clays and rock within the embankment foundations;
- Assess the material properties of the clays and rockfill within the proposed TSF impoundment excavation.

An overview of works undertaken is summarised in the following sections, and the results of the investigation and laboratory testing are documented in ATCW report 109014.15-R01 [27].

**Supplementary to the site investigations, ATCW have also conducted laboratory testing of tailings slurry produced by the Brunswick Processing Plant. The objectives of this investigation were to characterise the rheological and settling properties of the tailings slurry. An overview of works undertaken is summarised in the following sections, and the results of the slurry laboratory testing is documented in ATCW report 109014.17-R01 [28].**

### 9.2.2 Test Pits

The test pits were undertaken on 28<sup>th</sup> February 2022 by two Geotechnical Engineers from ATCW and were excavated with a Volvo ECR305CL Excavator from the nearby Bombay TSF construction works. The weather on the day was warm and sunny, with light cloud cover.

The test pit investigation consisted of the following works;





- Excavation and geotechnical logging of 22 test pits across the site to investigate the depths of topsoil, natural clays, and Extremely Weathered (EW) rock, and
- Collection of various (17 in total) bulk disturbed samples of representative material for laboratory testing.

Test pits were excavated until excavator refusal on rock, at depths varying between 0.7 m and 2.9 m.

### 9.2.3 Drilling

The drilling works were undertaken between 16<sup>th</sup> May 2022 and 1<sup>st</sup> June 2022, with undisturbed tube samples collected on 14<sup>th</sup> June 2022 with 3 ATCW Geotechnical Engineers providing supervision, direction and logging of the boreholes across different days of the drilling works. The boreholes were drilled by Geotechnical Testing Services (GTS), utilising a truck mounted drill rig.

The drilling investigation consisted of the following works;

- Drilling of 12 boreholes across the site, consisting of
  - Auguring by solid continuous flight auger to 2.6m to allow for installation of casing, or until effective refusal, then
  - Rock Coring by NMLC coring techniques to the target depths determined on site by the ATCW Geotechnical Engineer,
- Undertaking SPT's within the natural clay and Extremely Weathered rock, with the depths and testing intervals determined on site by the ATCW Geotechnical Engineer,
- Installation of three Groundwater Monitoring Bores (GWMB).
- Collection of Undisturbed Tube Samples (U50) at 6 locations and depths determined by the ATCW Geotechnical Engineer for laboratory testing.

In conjunction with the drilling works, ATCW also conducted falling head permeabilities at various depths and locations determined on site by the ATCW Geotechnical Engineer.

Nine boreholes between 7.1 m and 11.1 m in depth were drilled within the anticipated foundations of the embankment. A further three were drilled within the proposed impoundment area to depths between 10.5 m and 14.5 m. The augured upper part of the boreholes were approximately 100mm in diameter, while the lower cored sections were approximately 80mm in diameter.

Since installation, the installed GWMB's have not observed any water and have remained dry.

### 9.2.4 Laboratory Testing

Laboratory testing was carried out at ATCW's NATA accredited laboratory. The laboratory testing was undertaken in two parts, which are outlined below:

#### Part A – Bulk Sample Material Classification

Part A of the testing focused on classification and characterisation of the natural clays and extremely weathered rock collected during the test pits. These comprised of the following works:

- Natural Moisture Content on all bulk samples (17);
- Atterberg Limits on all bulk samples (17);
- Particle Size Distribution on bulk samples (13);
- Particle Size Distribution on select bulk samples of clay (4).

The results of this laboratory testing informed the samples selected for further laboratory testing.

#### Part B – Select Material Characterisation, Remoulded Testing & Undisturbed Tube Sample Testing

Part B of the testing focused on determining the engineering properties for design of the Brunswick West TSF on representative samples of natural clays and extremely weathered rock collected during the test pits. These tests aimed to derive the design envelope for materials used for construction. These comprised of the following works;





- Emerson Class dispersions on a range of select clay samples (8);
- Soil Dry Density/Moisture Content Relationship curves on representative combined weathered rock and clay samples (3);
- Compacted Permeability on representative combined weathered rock and clay samples (3);
- Undrained multi-stage Triaxial Tests on a critical combined clay sample under remoulded conditions, undertaken at 3 different confining pressures (1 test);
- Density of Undisturbed Tube Samples on clay samples;
- Undrained Single Stage Triaxial Tests on two select undisturbed tube clay samples, undertaken at 2 different confining pressures (2 tests).

## 9.2.5 Tailings Slurry Laboratory Testing

To facilitate the design of the slurry transportation system for the Brunswick West TSF, and validate the facility design, laboratory testing was carried out at ATCWs NATA accredited laboratory. 75L of tailings slurry was provided to ATCW at an as-received solids concentration of 24.83%, as well as 20L of process water and 1kg of flocculant.

The laboratory testing comprised of the following works;

- Estimation of Solids Concentration (1)
- Electrical Conductivity on both the Tailings (1) and Process Water (1)
- Atterberg Limits on the tailings solids (1)
- Soil particle density of the tailings solids (1)
- Particle Size Distribution on the tailings solids (1)
- Rheology testing undertaken at varying solids concentrations (5)
- Initial Settled Density tests undertaken at varying solids concentrations (4)
- Shrinkage Limit Density test on the tailings solids (1)

## 10 TAILINGS DESIGN CONSIDERATIONS

### 10.1 Tailings and Surface Water Management Strategy

The proposed tailings deposition strategy for the Brunswick West TSF will be a slight modification from the current strategy employed at the Bombay and Brunswick TSFs. Deposition will primarily occur from a single spigot at the northern-most point of the facility. Occasional deposition from an additional 4-6 spigot points strategically placed around the northern end and sides of the facility will help to confine surface water around the decant structure at the south-western corner.

The primary deposition will be run for a fixed amount of time (typically 1 to 1.5 weeks), after which deposition from the additional spigots will occur for a short amount of time (typically 1-2 days each) to aid in re-shaping the beach. Determination of the deposition times from each spigot will need to be verified through routine inspections of the tailings beach and assessment of the filling performance of the facility.

The operational intent is to maintain the low point of the tailings beach at the inclined decant system located at the south-western corner of the TSF. It is proposed that the inclined decant system will consist of three PN20 DN800mm HDPE pipes with regularly spaced slots to allow decant water to enter. To prevent tailings entry, the pipes will be wrapped in a UV stabilised filter geotextile and secured to a concrete slab installed on the embankment upstream face.

The three decant pipes will connect to a single precast concrete pit at the base, joining all three pipe sections. Water will be recovered from within the decant pit via a submersible pump (Flygt BS 2750 drainage pump, capacity 15 L/sec), installed within the central decant pipe, with the pump activated by





automated water level sensors. The pump will transfer decant water over the embankment crest to the external RWP. Details of the Decant Structure system are discussed in **Sections 11.6.5** and **13.4**.

Water from the RWP will be returned to the Brunswick Processing Plant for reuse, and will become the primary source for process water. The intention of the external RWP is to help alleviate issues previously faced with the existing TSFs with water ponding in the facility for extended periods of time. The external RWP acts as detention basin for the TSF, allowing for water to be continually removed from the TSF, whilst also being able to supply process water to the Brunswick Processing Plant.

The external RWP will also be used to store surface water from the inactive Bombay TSF and Brunswick TSFs. Rainfall accumulation in these facilities will be regularly pumped to the external RWP to maintain these facilities as dry as possible to assist in preparation for closure, and aid in manage the risk of these facilities storing excess surface water.

Initial sizing of the facility was undertaken to contain the following over the normal operating pond;

- Runoff from the 1:100 AEP, 72hr Storm over the Brunswick West TSF, Bombay TSF and Brunswick TSF, plus
- 7 days worth of bleed water.

## 10.2 Tailings Properties

### 10.2.1 Geotechnical

Tailings produced by the Brunswick Processing Plant have been characterised as part of the 2022 tailings slurry testing [28]. A summary of these results is presented in **Table 10**. Similar testing conducted in 2009 [23] is also presented as reference.

The Initial Settled Density (ISD) is the density of the tailings as they settle and release bleed water due to sedimentation soon after discharge. The Shrinkage Limit Density (SLD) is the maximum tailings density that can be attained through the action of evaporative drying alone and can be visually observed by the development of cracks on the tailings beach. Attainment of the SLD will depend on the rate of rise of the tailings and the initial settled density of the tailings.

**TABLE 10: TAILINGS SLURRY GEOTECHNICAL PROPERTIES**

| Test                          |               | Units            | 2022 Results   | 2009 Results         |
|-------------------------------|---------------|------------------|--|----------------------|
| Solids Content (As Received)  |               | %                | 24.83%   | 65%                  |
| pH                            |               | -                | 6.8 (at 53% solids)  | -                    |
| electrical Conductivity       |               | µS/cm            | 260 (at 53% solids)  | -                    |
| Atterberg Limits              | LL            | %                | 28   | 29                   |
|                               | PL            | %                | 17   | 13                   |
|                               | PI            | %                | 11   | 16                   |
| Particle Size Distribution    | -75 µm (Silt) | %                | 83   | 84                   |
|                               | -2 µm (Clay)  | %                | 22   | 22                   |
| USCS Classification           |               | -                | CL or OL   | CL                   |
| Particle Density              |               | t/m <sup>3</sup> | 2.77   | 2.82                 |
| Initial Settled Density (ISD) |               | t/m <sup>3</sup> | 0.91 (at 40.0% solids)<br>0.98 (at 45.8% solids)<br>0.98 (at 50.0% solids)<br>1.03 (at 54.8% solids) | 0.81 (at 35% Solids) |





| Test                          | Units             | 2022 Results   | 2009 Results         |
|-------------------------------|-------------------|--|----------------------|
| Bleed Water                   | m <sup>3</sup> /t | 0.77 (at 40.0% solids)<br>0.53 (at 45.8% solids)<br>0.34 (at 50.0% solids)<br>0.22 (at 54.8% solids) | 0.93 (at 35% solids) |
| Shrinkage Limit Density (SLD) | t/m <sup>3</sup>  | 1.65   | 1.76                 |

## 10.2.2 Geochemical

As part of the design for the Brunswick TSF First Raise in 2014 [25], URS collected three samples of historical tailings from near the surface of the existing Brunswick TSF for Geochemical testing. The date of origin of these historical tailings is unknown. As part of the Bombay Cell 2 Design Report in 2009 [23], it was noted that “*Brunswick Dam has reached capacity some time ago, with some of the tailings being reprocessed, and that, at the time of preparing this design, Bombay Dam Cell 1 is very close to capacity*”, which implies deposition into the historical Brunswick TSF most likely ceased around the mid 2000’s.

In addition to the historical Brunswick TSF Tailings, URS had also previously collected four tailings samples for geochemical testing from the Bombay TSF in 2011, most likely from freshly deposited tailings from Lift 1 of the facility. URS considered these samples (Bombay 2011) as likely to be representative of the tailings properties going forward. In consideration of the historical deposition sequencing of tailings within the facilities, and that there has been very little change to the ore body and processing methods since 2011, ATCW are also in agreeance that the Bombay 2011 tailings are more representative of the future tailings properties

The intent of the Geochemical testing was to determine if the tailings within the impoundment were categorised as contaminated waste. A summary of the Geochemical testing results, extracted from the URS Brunswick TSF First Raise Report [25], are presented in **Table 11** and **Table 12**.

The VIC ERR Tailings Guidelines [12] define tailings as high risk for contamination (in the event of a dam breach) based on the contaminant concentrations, and/or sulphidic tailings with the potential to cause acid and metalliferous or saline drainage. Decant water is also defined as high risk for contamination with a total cyanide concentration exceeding 1 milligram per litre, and/or a pH outside the range 5 to 9. The concentration levels are derived from the EPA [13] Guidelines for a Category C Waste (Non-corrosive acids and alkaline waste). These concentrations are also presented in **Table 11** and **Table 12** as a comparison.

**TABLE 11: SUMMARY OF GEOCHEMICAL TESTING – CONCENTRATION BY DRY WEIGHT**

| Compound   | VIC ERR & EPA Limits (mg/kg) | Brunswick TSF 2014 (mg/kg) |          |          | Bombay TSF 2011 (mg/kg) |          |          |          |
|------------|------------------------------|----------------------------|----------|----------|-------------------------|----------|----------|----------|
|            |                              | Sample 1                   | Sample 2 | Sample 3 | Sample 1                | Sample 2 | Sample 3 | Sample 4 |
| Arsenic    | 500                          | 856                        | 814      | 366      | 272                     | 267      | 294      | 282      |
| Cadmium    | 100                          | <1                         | <1       | <1       |                         |          |          |          |
| Chromium   | 500                          | 9                          | 9        | 17       |                         |          |          |          |
| Copper     | 5,000                        | 28                         | 32       | 28       | 10                      | 8        | 9        | 9        |
| Cobalt     | 500                          | 13                         | 10       | 5        |                         |          |          |          |
| Lead       | 1,500                        | 33                         | 19       | 34       | 385                     | 502      | 510      | 450      |
| Mercury    | 75                           | 0.3                        | 0.2      | 15.1     |                         |          |          |          |
| Molybdenum | 1,000                        | <2                         | <2       | <2       |                         |          |          |          |
| Nickel     | 3,000                        | 35                         | 35       | 18       |                         |          |          |          |
| Tin        | 500                          | <5                         | <5       | <5       |                         |          |          |          |





| Compound                                | VIC ERR & EPA Limits (mg/kg) | Brunswick TSF 2014 (mg/kg) |          |          | Bombay TSF 2011 (mg/kg) |          |          |          |
|---|------------------------------|----------------------------|----------|----------|-------------------------|----------|----------|----------|
|   |                              | Sample 1                   | Sample 2 | Sample 3 | Sample 1                | Sample 2 | Sample 3 | Sample 4 |
| Selenium                                | 50                           | <5                         | <5       | <5       |                         |          |          |          |
| Zinc                                    | 35,000                       | 82                         | 64       | 73       | 37                      | 32       | 32       | 33       |
| Cyanide                                 | 2,500                        | 28                         | 104      | 395      |                         |          |          |          |
| Fluoride                                | 10,000                       | 340                        | 430      | 340      |                         |          |          |          |
| Monocyclic Aromatic Hydrocarbons        | 70                           | <70                        | <70      | <70      |                         |          |          |          |
| Polycyclic Aromatic Hydrocarbons        | 100                          | <100                       | <100     | <100     |                         |          |          |          |
| Total Petroleum Hydrocarbons (C6 to C9) | 650                          | <10                        | <10      | <10      |                         |          |          |          |
| Total Petroleum Hydrocarbons (>C9)      | 10,000                       | <50                        | <50      | <50      |                         |          |          |          |
| Aldrin + Dieldrin                       | 1.2                          | <0.05                      | <0.05    | <0.05    |                         |          |          |          |
| DDT + DDD + DDE                         | 50                           | <0.05                      | <0.05    | <0.05    |                         |          |          |          |
| Chlordane                               | 4                            | <0.05                      | <0.05    | <0.05    |                         |          |          |          |
| Heptachlor                              | 1.2                          | <0.05                      | <0.05    | <0.05    |                         |          |          |          |
| Other Organochlorine Pesticides         | 10                           | <10                        | <10      | <10      |                         |          |          |          |

**TABLE 12: SUMMARY OF GEOCHEMICAL TESTING – LEACHABLE CONCENTRATION**

| Compound | VIC ERR & EPA Limits (mg/L) | Brunswick TSF 2014 (mg/L) |          |          | Bombay TSF 2011 (mg/L) |          |          |          |
|----------|-----------------------------|---------------------------|----------|----------|------------------------|----------|----------|----------|
|          |                             | Sample 1                  | Sample 2 | Sample 3 | Sample 1               | Sample 2 | Sample 3 | Sample 4 |
| Arsenic  | 0.7                         | 0.8                       | 0.4      | 1.3      | 0.03                   | 0.04     | 0.03     | 0.02     |
| Cadmium  | 0.2                         | <0.05                     | <0.05    | <0.05    |                        |          |          |          |
| Chromium | 5.0                         | <0.1                      | <0.1     | <0.1     |                        |          |          |          |
| Copper   | 200                         | <0.1                      | <0.1     | <0.1     | <0.01                  | <0.01    | <0.01    | <0.01    |
| Lead     | 1.0                         | <0.1                      | <0.1     | <0.1     | <0.01                  | <0.01    | <0.01    | <0.01    |
| Mercury  | 0.1                         | <0.001                    | <0.001   | <0.001   |                        |          |          |          |
| Selenium | 1.0                         | <0.05                     | <0.05    | <0.05    |                        |          |          |          |
| Zinc     | 300                         | 0.4                       | <0.1     | 0.3      | 0.24                   | 0.18     | 0.16     | 0.09     |
| Cyanide  | 8                           | 0.007                     | 0.723    | 0.261    |                        |          |          |          |
| Fluoride | 150                         | 0.4                       | 0.2      | 0.3      |                        |          |          |          |

It can be seen from the results of the Geochemical testing that the maximum concentration limits defined by VIC ERR [12] were only exceeded for the arsenic content from the Brunswick tailings, which were believed to have been deposited in the mid 2000's. The more recent samples collected from Bombay TSF (deposited around 2010-2011) had arsenic concentrations lower than the maximum concentration limits. As discussed above, the Bombay tailings are considered to be more representative of the future tailings that will be deposited into Brunswick West TSF.





Previous geochemical assessment [25] of the tailings produced from the Brunswick Processing Plant had not considered them as Potentially Acid Forming (PAF). Given that no significant change is expected in the tailings mineralogy since collection of the Bombay TSF 2011 tailings, the tailings to be stored within Brunswick West TSF are also not considered as PAF.

The pH levels for the Brunswick TSF (2014) tailings samples were recorded at between 7.6 and 8.2. No pH data is available for the Bombay TSF (2011) tailings.

Based on the above results, it is expected that the tailings to be stored within the Brunswick West TSF can be considered as low risk for contamination.

## 10.3 Tailings Bleed

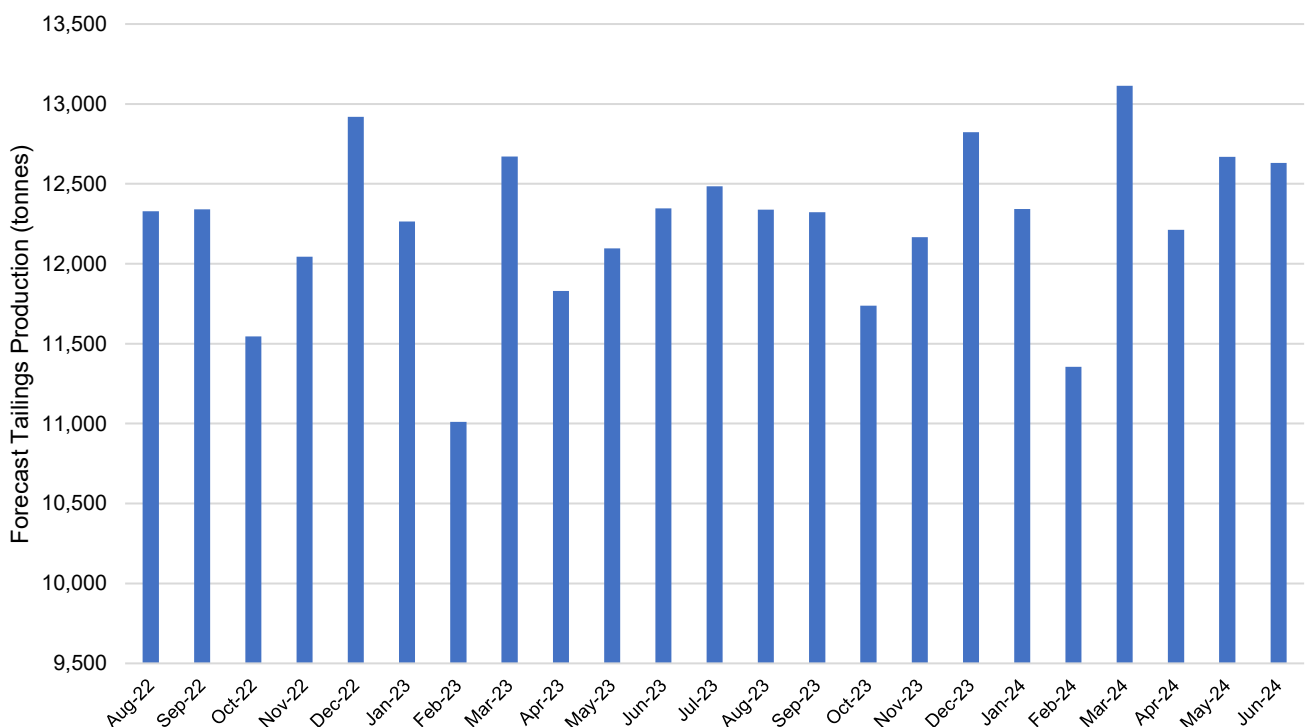
As discussed in **Section 10.2.2**, the anticipated tailings composition for the Brunswick West TSF is expected to remain very similar to the historical tailings produced by the Brunswick Processing Plant, given there have been no material change to the orebody characteristics or processing methodology.

Bleed produced by tailings will have elevated salt concentrations when compared with fresh water, but will not be inherently different to the concentrations historically experienced for both Brunswick and Bombay TSF's. The water collected on the TSF's is recycled to the Brunswick Processing Plant, and MRCO have not indicated to ATCW that they have historically experienced any production issues with this water re-use. As such, no material issues are expected from the tailings bleed water or supernatant concentrations.

## 10.4 Tailings Production

MRCO have provided ATCW with forecast tailings production values for August 2022 to June 2024, which are presented in **Chart 5**.

**CHART 5: FORECAST TAILINGS PRODUCTION**



The current forecast date for the end of filling of Bombay TSF and commencement of deposition into Brunswick West TSF is October 2023. The production rates in **Chart 5** are only forecast until June 2024, whereas the Brunswick West TSF is expected to provide storage until at least 2027. For this assessment, the average daily production rate from October 2023 to June 2024 has been used, which equals 419 tonnes/day.





## 10.5 Tailings Density

The Overall Insitu Density (OID) is used to estimate the storage capacity of the facility. In a sufficiently large and well operated TSF, the density of the tailings will approach the SLD as the action of evaporative drying is sufficient to remove water from the deposited tailings. For the Brunswick West TSF, the relatively small beach area and confined embankment shape means there will not be enough time for each deposited layer of tailings to reach the SLD, even with good deposition practices.

Estimations of the OID have been undertaken based on the tailings surface area, forecast throughput rates, evaporation potential, and deposition properties at 45% solids. Through evaporative drying alone (not accounting for underdrainage), an OID of approximately 1.3 t/m<sup>3</sup> is estimated at the end of filling, which has been adopted for the design of then Brunswick West TSF.

## 10.6 Tailings Beach Slope

The adopted design tailings beach slope has been based on a review of the beach slopes achieved for both the Bombay and Brunswick TSF. This indicates a concave beach profile, whereby the tailings are generally quite steep in the initial upper beach and flatten out further down towards the decant pond. This profile is typical and is generally due to operational fluctuations in thickener performance, feed rate, flocculant behaviour and day to day changes in depositional practices. For this assessment, ATCW have adopted the beach profiles observed at the existing facilities, which are as follows:

- 1.5% Beach slope for 50m length, then
- 0.6% Beach slope for the remaining length.

## 10.7 Tailings Operational Freeboard

ANCOLD Guidelines [9] require that a minimum Operational Freeboard be maintained between the top of the tailings and the adjacent embankment crest to minimise the potential for backflow of tailings and overtopping because of tailings mounding at the discharge points.

A minimum beach freeboard from the embankment crest of 500 mm has been adopted to aid in prevention of tailings backflow onto the embankments and emergency spillway, and to allow sufficient storm storage (refer **Section 13.3**). This results in a maximum tailings head of beach level of RL 199.5 m.

## 10.8 Tailings Delivery and Deposition

As discussed in **Section 10.1**, it is proposed that tailings will be deposited primarily via a single spigot at the northern-most point of most point of the facility. Occasional deposition from an additional 4 to 6 spigot points strategically placed around the facility will help to confine surface water around the decant structure.

ATCW are currently engaged with MRCO for the upgrade of the tailings transportation systems, which includes the current Bombay TSF and the Brunswick West TSF. The details of the mechanical infrastructure will be forthcoming upon completion of that study.

## 10.9 Tailings Beach Monitoring

To ensure the tailings design assumptions are being met, routine monitoring of the Brunswick West TSF tailings surface will be required. MRCO currently conduct aerial drone surveys of their existing TSF's on a quarterly basis. MRCO have committed to extending this survey to include the Brunswick West TSF to capture the development of the tailings beach as deposition continues. This survey data will be collected and reviewed regularly as part of the annual inspections for the facility. This will allow for estimation and monitoring of the following aspects;

- Overall in-situ density of the tailings (incremental and cumulative),
- Achieved beach slope,





- Estimated quantity of surface water,
- Estimated beach areas for surface runoff, and
- Forecast remaining capacity.

## 11 FACILITY DESIGN

### 11.1 Existing Conditions

The current conditions of the Brunswick West TSF site are presented in **Figure 3**.

The site is roughly triangular, and is confined by Crown Land to the east, MRCO infrastructure and additional farmland to the south, and Bradleys Lane to the west. The site has a ridge at approximately RL 194.0 m in the centre of the paddock running in a south-easterly direction, from which the natural ground slopes to the north, east and south at a natural grade of up to 5%.

The site currently contains farm infrastructure, trees, a high voltage Single Wire Earth Return (SWER) powerline, as well as three Groundwater Monitoring Bores installed as part of the geotechnical investigations [27]. Additionally, the boundary of the Brunswick West TSF extends partially into the MRCO Low Grade Run of Mine (ROM) pad. This infrastructure is required to be removed prior to commencement of construction.

### 11.2 Selection of Design Alternative

#### 11.2.1 Original Design

In the early design stages, ATCW considered a zoned earth and rockfill embankment. The embankment was to consist of a downstream shoulder of compacted rockfill, a compacted, inclined clay core keyed into the natural foundations clays, and an upstream protective rockfill zone. The compacted clays and rockfill would be won directly from the impoundment and foundation excavations.

As discussed in the ATCW Geotechnical Report [27], dispersion testing undertaken on the natural clays with distilled water found an Emerson Class Number of 2 and 3, indicating dispersive clays. Similar testing undertaken on the natural clays by URS in 2011 [25] found similar results with distilled water with an Emerson Class Number of 2. Testing undertaken by ATCW in 2009 [20] utilising site decant water (significantly higher salinity) found the clays to be slightly dispersive, with an Emerson Class Number of 4.

These results all indicate that the natural clays around the Costerfield site are susceptible to dispersion with clean water. The inclusion of these clays in the original zoned earth and rockfill design would introduce a significant risk of an internal erosion and piping failure when combined with extended rainfall, which is considered as a credible failure scenario for these types of embankments. To control and mitigate the risks associated with the dispersive clays, at least one of the following measures would be required:

- Construction of filter zones downstream of the inclined clay core (sand filter to protect the clay, followed by a gravel filter to stabilise the sand) to control erosion. The design of these filters requires very strict particle grading requirements, with the material needing to be imported from external quarries.
- Addition of lime or gypsum to reduce the dispersive behaviour of the clays. These additives can be quite expensive when considering the large quantities required for the entire embankment and would require extensive mixing and control of the clay at the borrow source.

Additionally, compacted permeability testing on the high plasticity clays found a hydraulic conductivity in the range of  $5.0 \times 10^{-7}$  m/s, at least 1 order of magnitude below the VIC ERR [13] requirements of a minimum of 1.0 m thick clay liner of  $1.0 \times 10^{-9}$  m/s (or equivalent).





## 11.2.2 Refined Design Alternatives

Based on the above properties of the clays, ATCW had developed two separate alternatives for the design of the embankment:

### Clay Core Alternative:

This alternative would utilise the 2-stage downstream filters described above. From upstream to downstream, the embankment would feature the following:

- 2.0m wide upstream compacted rockfill zone to provide protection for the clay core from cracking and desiccation through evaporation. This material would be won from the impoundment excavation works of the foundation rock.
- A 3.0m wide compacted, inclined clay core to provide the low permeability, seepage control zone within the embankment. This material would be won from stripping of the impoundment and foundation preparation works and would need to exclude the use of high plasticity clays.
- A 2.0m wide sand filter, followed by a 4m to 5m (nominal) wide sandy, gravelly rockfill filter to provide filtration for the dispersive clays. The sand materials would need to be sourced from external quarries, whilst the gravelly filter could potentially (subject to additional design checks) be sourced from weathered rock within the impoundment excavation.
- A downstream compacted rockfill shoulder to form the mass of the embankment. This material would also be won from the impoundment excavation works of the foundation rock.

The overall embankment would have a crest width of 8.0m, and would be entirely constructed utilising a Civil Earthworks contractor.

### Geosynthetic Liner Alternative:

This alternative would forgo utilising the compacted clay core as the low permeability zone and replace this with a Bituminous Geomembrane (BGM) Liner. From upstream to downstream, the embankment would feature the following:

- The BGM liner installed on the upstream face of the embankment and remain exposed.
- A 3.0m wide compacted clayey gravel/gravelly clay subgrade for the BGM Liner. This material would be won from stripping of the impoundment and foundation preparation works, and would include all clay and clayey sand and gravel material encountered, provided that the maximum particle size at the surface is limited to 30 mm to prevent BGM damage. This subgrade layer would also need to extend down the impoundment excavation face.
- A downstream compacted rockfill shoulder to form the mass of the embankment. This material would also be won from the impoundment excavation works of the foundation rock.

With the reduction in the number of earthworks zones, the embankment would have a crest width of 6.0m, with a Civil Earthworks contractor constructing the embankment and preparing the subgrade, followed by a specialised lining installation subcontractor for the BGM.

The relative pros and cons of both alternatives is summarised in **Table 13**.

**TABLE 13: EMBANKMENT ALTERNATIVES PRO'S AND CONS**

| Description                                   | Clay Core  | Geosynthetic Liner  |
|---|--|---|
| Embankment susceptibility to erosion failures | Installation of downstream filters will help significantly lower the probability of an erosion piping failure, but seepage through the embankment may still occur. | If properly installed and welded, with no major holes/flaws, the BGM should eliminate (or at least significantly reduce) the probability of an erosion piping failure through prevention of seepage through the embankment. |
| Phreatic Surface Control                      | Clay core of $1 \times 10^{-9}$ m/s will manage phreatic surface, but will still allow significant seepage and development of phreatic surface through section.    | Improved control over the phreatic surface through impermeable liner of hydraulic conductivity in range of $1 \times 10^{-12}$ m/s  |





| Description                                  | Clay Core   | Geosynthetic Liner   |
|--|---|--|
| Embankment Construction                      | Excluding High Plasticity clays required.<br>Controlled placement and compaction of the clay to 98% SMDD, with frequent field density testing.          | All clay materials would be suitable for use and could be blended with gravelly material.<br>Would only require compaction to around 95% SMDD, with less frequent field density testing. |
| TSF Storage Capacity                         | -   | Minor (~7-8 months) increase in storage capacity through narrower embankment crest.  |
| Costs (on items that differ between designs) | Clay core - \$30/m <sup>3</sup> , with ~26,000 m <sup>3</sup><br>Imported Filters - \$100/m <sup>3</sup> with ~36,000 m <sup>3</sup><br>Total - \$4.38M | Earthfill subgrade - \$25/m <sup>3</sup> , with ~45,000 m <sup>3</sup><br>BGM Liner - \$35/m, with ~38,000 m <sup>2</sup><br>Total - \$2.45M   |
| Reliability on External Suppliers            | Reliant of commercial sand/gravel quarries for production of suitable filter materials  | Reliance on the acquisition of suitable BGM liner, and potential supply chain risks (through this can be partially alleviated through early ordering of material)                        |
| Reliability on External Sub-Contractors      | None  | Specialised lining installation sub-contractor required to deploy, weld and test the BGM liner, as well as a dedicated QA/QC program for the installation                                |

Based on the factors outlined above, MRCO have elected to utilise the BGM Liner Alternative for the design of the Brunswick West TSF Embankments.

## 11.3 Facility Overview

The TSF embankments will be constructed to RL 200.0m, which has been inferred as the maximum allowable height of the facility based on the current approved elevation limits for the nearby Bombay TSF (RL 200.4m). Construction of the Brunswick West TSF will generally consist of the following:

- Early works preparation of the site, including the removal of all unsuitable existing infrastructure,
- Preparation of the embankment foundations, including stripping of topsoil and upper clays, and re-compaction of the in-situ clays,
- Excavation of the impoundment area to a base elevation of between RL 186.0m and 180.0m. Suitable clays and all excavated rockfill will be stockpiled and conditioned as required for use in embankment and clay liner construction,
- Placement and compaction of a 1.0m thick Zone 1 clay liner and 0.3m thick uncompacted rockfill protection layer (select Zone 3A) over the base of the impoundment excavation,
- Construction of a herringbone underdrainage network over the lined base, discharging into a collection sump at the south-west corner of the facility,
- Construction of a 3.0m wide compacted Zone 1B earthfill zone to act as the BGM liner subgrade up the excavated batter walls to natural surface level,
- Construction of the perimeter embankments, consisting of a downstream Zone 3B rockfill shoulder to a minimum crest width of 4.0m, a 5.0m wide compacted Zone 3A transition fill, and a 3.0m wide Zone 1B earthfill subgrade on the upstream side (following the profile of the Zone 1B earthfill subgrade up the excavated batter walls),
- Construction of the inclined decant structure installed in the south-west corner of the facility,
- Excavation of an Emergency Spillway at the southern end of the facility,
- Installation of the BGM Liner on the upstream face of the embankment and impoundment Zone 1B earthfill subgrade batters,
- Placement of suitable road-base material along the crest of the embankment,





- Construction of access ramps to the crest of the embankment, which will also act as the northern flood diversion bund,
- Construction of flood diversion bunds around the southern and western perimeter of the Brunswick Underground Portal,
- Excavation of clean water diversion drains around the downstream toe of the embankment,
- Installation of tailings delivery pipelines, decant removal pipelines and pumps,
- Construction of the external Return Water Pond (RWP), including
  - Excavation of suitable construction materials,
  - Construction of embankments,
  - Lining with Synthetic Liner.

## 11.4 Early Works

The existing conditions of the Brunswick West TSF site are presented in **Figure 3**, along with the final footprints of the facility. The early works site preparation will generally consist of the following:

- Removal of various existing farm equipment across the site.
- Removal and re-establishment of suitable fences along the new site boundary to prevent livestock from entering the site.
- Removal of the three groundwater monitoring bores (GWMB1 – 3) within the embankment footprint and impoundment (GWMB1 and GWMB3), and grouting of the holes.
- Removal and relocation of the existing overhead powerlines running through the site. MRCO have engaged the asset owners (Powercor) to complete these works, with the powerlines to be buried adjacent to Bradleys Lane.
- Draining of water from the two existing farm dams within the facility footprint area, followed by the removal of the embankments. The areas previously covered by the farm dams should remain free-draining for as long as possible to aid in the dissipation of excess pore pressures.
- Clearing and mulching of large trees and stockpiling of the material for future rehabilitation use.
- Clearing of excess rock from the low-grade ROM pad to re-expose natural foundations.

It is considered that MRCO may commence with the early works preparation prior to the civil contractor mobilising to the site.

Upon completion of the embankments, the low-grade ROM pad may be re-established against the downstream batter slope to provide for storage of ROM rockfill, and provide additional buttressing in this area.

## 11.5 Foundation Excavation and Preparation

Foundation preparation of the site will generally fall within one of the following 4 categories. The approximate areas of the different foundation preparation types are presented in **Figure 4**.

### **Type A1 – Embankment Footprint**

Type A1 Foundation Preparation shall be conducted in all areas where the embankment is in contact with natural ground.

Geotechnical investigations of the site [27] found the depth of topsoil varied from between 0.3m to 0.7m across the site, with an average depth of 0.5m. To ensure all topsoil and remnant vegetation is removed from beneath the embankment footprint, the upper 0.5m (minimum) of topsoil and clays will be classified as topsoil for stripping. Once stripped, the topsoil will be temporarily stockpiled, and will





be loosely placed back on the embankment downstream slopes and re-seeded to begin the establishment of the final closed landform.

Following the stripping of a minimum of 0.5m topsoil, an additional 0.5m of natural clay shall be stripped, or until extremely weathered rock foundations are encountered (whichever occurs first). This will be required to provide a suitable quantity of clayey material to form the impoundment excavation base liner and the earthfill subgrade. This excavated clayey material will be required to be temporarily stockpiled until it can be incorporated into the embankment construction.

The final clay foundations will be tyned and lightly watered, then blade-mixed insitu to ensure equal moisture distribution, and compacted to achieve minimum 98% Standard Maximum Dry Density (SMDD).

## **Type A2 – Impoundment Excavation**

Type A2 works shall be conducted within the impoundment of the facility.

As with Type A1 Foundation Preparation, the upper 0.5m of topsoil shall initially be stripped and temporarily stockpiled. Following topsoil stripping, the natural clays and rock will be excavated down to a base elevation of RL 186.0m at the north, and RL 180.0m at the south, providing an approximate 2% grade running from north to south along the base of the facility. The batter slope of the excavation shall be a minimum of 2:1 (H:V).

All clayey material will be initially excavated and stockpiled separately to provide construction materials for the base liner and the earthfill subgrade.

All rock material will be required to be readily excavatable by civil earthworks equipment. If required, confined, controlled blasting may be utilised to fracture isolated hard rock areas, but not for large scale production of rockfill. Blasting works shall be subject to obtaining approvals for surface blasting prior to implementation

The proposed foundation excavation is similar to what was undertaken for the historical Bombay Cell 2 Starter Embankment construction [24], located less than 500m north of the Brunswick West TSF site. This construction featured a central excavation up to 6.0 m below surface level through weathered rock profiles utilising relatively large (CAT D8 and Komatsu D375A) bulldozers to rip the rock. It was reported that defect spacing within the weathered rock profile provided a varying size of boulders from the impoundment excavation, and that the material was generally of low enough strength that it could be readily broken down into an acceptable size. Larger rock particles that could not be broken down further were stockpiled north of the site.

As discussed in the Geotechnical Investigations [27], it is considered that natural siltstone rock up to a weathering classification of Moderately Weathered can readily be excavated by larger earthmoving equipment (such as CAT D11 dozers and large excavators). At locations with larger defect spacings, additional works may be required to fracture the rock mass, such as the implementation of hydraulic rock breakers. Alternatively, the base excavation depth may be reduced to account for the slightly less weathered rock profile at Brunswick West. This reduction will decrease the overall storage capacity for the TSF and the quantity of rockfill available for embankment construction, necessitating the borrow of material from the nearby Bombay TSF rockfill stockpiles. Ultimately, the depth of rock excavation will be limited by the equipment available to the civil contractor engaged to undertake the works, and a revision of the base excavation depths may be required once construction has commenced and the response of the rock profile to the available earthmoving equipment is known.

## **Type B – Existing ROM Pad**

Type B Foundation Preparation shall be conducted at all areas where the embankment will contact the existing low grade ROM pad.

Following the removal of excess rock from the low-grade ROM pad to expose the previous natural foundations (either undertaken by MRCO prior to mobilisation of the contractor, or by the contractor themselves), all remaining clayey material is to be stripped to expose underlying weathered rock foundations. All clayey material stripped shall be temporarily stockpiled and assessed for potential re-use within the works.

Once exposed, the weathered rock foundations shall be lightly tyned, watered and compacted to a minimum of 98% SMDD.





## Type C – Existing Farm Dams

Type C Foundation Preparation shall be conducted at the existing farm water dams.

Once the water within the existing farm dams has been drained, the embankments and all remnant silts and natural clays are to be excavated to expose underlying weathered rock foundations. The material won from this shall be temporarily stockpiled and assessed for potential re-use within the works.

Once exposed, the weathered rock foundations shall be lightly tined and compacted to a minimum of 98% SMDD.

## **11.6 TSF Construction**

### **11.6.1 Overview**

Details of the TSF construction works are presented in **Figure 5** to **Figure 8**. The various elements are discussed in the following sections.

### **11.6.2 Impoundment Lining**

To meet the requirements of the Victorian ERR [12], a minimum 1.0m thick compacted Zone 1 Clay liner shall be constructed along the excavated base of the facility. An additional 0.3m of uncompacted, select Zone 3A granular fill shall be placed along the top of the clay liner to prevent the clay liner from desiccation cracking and from scour erosion during the initial filling of the facility, as well as providing a drainage path for the underdrainage. A similar lining arrangement was previously adopted for the Bombay Cell 2 impoundment base [24]. During initial deposition into Bombay Cell 2, no excessive seepage was observed at the surrounding groundwater monitoring bores.

Hydraulic performance requirements for the impoundment walls and embankments will be achieved through the use of a BGM Liner (refer **Section 11.6.4**). It is considered that the Zone 1 Clay liner and BGM liner will out-perform the previous Bombay Cell 2 in terms of seepage loss from the facility.

### **11.6.3 Embankment Construction**

The perimeter embankments will be formed by (from upstream to downstream) the following:

- A Zone 1B compacted Earthfill subgrade;
- A Zone 3A Transition Fill; and
- A Zone 3B Rockfill downstream shell.

The 5.0m wide Zone 3A Transition Fill will be constructed with 2:1 (H:V) upstream batter slopes, and will separate the Zone 1B Earthfill liner subgrade from the downstream Zone 3B Rockfill shell. The Zone 3A Transition Fill is positioned such that the upstream toe sits on the crest of the final excavation, as shown in **Figure 6**.

Zone 3B Rockfill will form the bulk of the downstream embankment and will have a minimum 3.0 m width at a surface level 1.0 m below the embankment crest for constructability purposes. Zone 3B will be constructed with 2:1 (H:V) upstream batter slopes, and 4:1 (H:V) downstream batter slopes to allow for formation of the closure profile for the facility.

On the outer edge of Zone 3B, a 1.0 m wide region of clayey material and extremely weathered rock, formed from a blend Zone 1B and Zone 3A material, shall be constructed to aid in the support of topsoil and the promotion of vegetation growth. A nominal 300mm of topsoil material won from clearing of the facility shall be placed on the TSF downstream batter and seeded with local grasses to form the final closure slopes.

The upstream Zone 1B compacted Earthfill Subgrade shall be 3.0m wide (horizontally) and positioned against the excavated batter slopes and Zone 3A Transition Fill to the final crest height of RL 200.0m

The proposed construction sequencing for this is as follows:





1. Construction of the Zone 1B Earthfill subgrade from the base of the excavation up to the natural surface level in multiple horizontal layers;
2. Construction of a layer of Zone 3B Rockfill;
3. Construction of two layers of Zone 1B Earthfill subgrade and Zone 3A Transition fill up to the level of Zone 3B, ensuring Zone 1B and Zone 3A are never higher than the adjacent Zone 3B;
4. Repeat Steps 2 and 3 with Zone 3B and Zone 1B/3A rising uniformly until the final crest height is reached.

Zone 1B will form the subgrade for the placement of the BGM Liner, and shall form a smooth, uniform and unyielding surface with maximum asperities of no more than 30mm. Trimming of the subgrade will be ongoing as the Zone 1B subgrade is constructed.

Following completion of the embankment to the final crest level, a minimum 100mm of road base material will be constructed with a 1-way crossfall of 3% into the TSF.

#### 11.6.4 BGM Liner

The BGM liner shall be an elastomeric modified BGM, nominal minimum thickness 4.0 mm. Products conforming these requirements are as follows:

- Teranap TP431 BGM nominal thickness 4.0 mm, manufactured by Siplast International and supplied by Geofabrics Australia, or
- Coletanche ES3 SBS BGM nominal thickness 4.8 mm, manufactured by Axter Limited.

The BGM manufacturer technical data sheets for these BGM products show a water tightness (i.e., hydraulic conductivity) of  $6 \times 10^{-14}$  m/s, which exceeds the VIC ERR minimum requirements for an equivalent of 1.0 m of  $1 \times 10^{-9}$  compacted clay [12].

The BGM products chosen typically has a unit weight of around 5 kg/m<sup>2</sup>, and is resistant to wind uplift pressures, with the critical time for this to occur being during construction and the early stages of deposition. During construction, temporary ballasting will be required to anchor the BGM panels whilst they are welded and connected. Once placed, the BGM will be anchored at the upstream toe to aid in providing long term ballast, and the deposition of tailings will quickly remove this risk from occurring.

ATCW have previously consulted BGM liner manufacturers regarding the chemical resistance of the product when subject to gold tailings. They recommended that BGM liner will have reactivity issues if the following two conditions are met:

- The tailings will have a pH of more than 10, and
- The temperature of the liquor is more than 70 °C.

Testing on the tailings slurry found the pH to be at 6.7 (refer **Section 10.2.1**). Additionally, the ambient temperature at the Costerfield site rarely exceeds 40 °C, and tailings liquor temperatures approaching 70 °C are considered as impossible to occur. As such, no reactivity issues are expected between the BGM liner and the Brunswick West tailings, and the liner will be suitable for long term use.

A review of the longevity and durability of both exposed and covered BGM liners installed in the 1980's in France was undertaken by Coletanche and published in GeoAmericas 2020 [29]. These BGM liners remained exposed over the service life and are still in use today, and are in a similar arrangement to those proposed for the Brunswick West TSF. The coefficient of permeability of the 4mm thick BGM was found to have decreased by 1 order of magnitude (from  $6 \times 10^{-14}$  m/s to  $4 \times 10^{-13}$  m/s) over a 20-year service life. No significant reduction in the tensile properties of the BGM was found. Additionally, modelling by the French Nuclear Safety Authority (reported in the same paper) indicated that biodegradation of BGM is a very slow process, and it can maintain water tightness for 300 years or more. Given the maximum expected life of the Brunswick West TSF prior to closure is in the order of 10 years, no significant loss of performance of the BGM is expected to occur.

The BGM Liner will provide the primary water-retaining element for the embankments and shall be installed on the upstream Zone 1B subgrade. Once installed the BGM will effectively form a very low permeability seal that will minimise seepage losses from the TSF. The BGM panels will be secured in





an anchor trench at the crest of the embankment, deployed down the Zone 1B subgrade in a continuous run and secured at the toe in another anchor trench.

The BGM will require a specialised lining subcontractor for installation, including panel deployment, heat welding of panel seams, and the completion of both destructive and non-destructive testing on the welds. **If deficiencies in the product or welds are identified during installation, these holes will be patched and re-tested to ensure the watertightness of the BGM liner system. The BGM liner will not be signed off and accepted for use until the lining subcontractor, MRCO and ATCW have reviewed all test results and are satisfied that the requirements of the BGM product have been met.**

## 11.6.5 Decant Structure

The decant structure will consist of three PN20 DN800mm HDPE pipelines slotted with regularly spaced perforations, wrapped in a UV stabilised filter geotextile and secured to a reinforced concrete slab installed on the embankment upstream face. Three pipelines are required to provide suitable opening area to allow sufficient infiltration of decant water without compromising the structural integrity of the pipelines once they are covered with up to 20 metres of tailings. The pipelines will connect to a single buried concrete collection pit at the base.

The geotextile layer will act as a filter and prevent the migration of tailings fines into the decant pipes, while still allowing decant water to seep through for removal. The collected water will be pumped directly to the RWP, where it will be re-circulated to either the Brunswick Processing Plant or the Augusta water storage dams.

The proposed pump for this design is a Flygt BS 2750 corrosion resistant drainage pump, manufactured by Xylem Inc, with a flow capacity of up to 15 L/sec for a head of 25m. The pump is approximately 280 mm in diameter and 780 mm long, which will allow it to comfortably fit within the decant pipelines. The pump will also be fitted with wheels and a steel return cable to allow the pump to be safely retrieved for maintenance and re-lowered down the decant pipelines. The pump is connected to a DN110 mm HDPE pipeline to allow for return water from the system.

This pump will sit at the base of the central decant pipeline within the buried collection pit and will be fitted with a water level sensor. When the decant structure is collecting water, the pump will operate for a fixed amount of time to draw the water down to the minimum pumping depth, before automatically switching off, and repeating the cycle as decant water rises again in the collection pit.

The design of the decant structure is discussed in **Section 13.4**.

## 11.6.6 Underdrainage

The underdrainage system will be constructed at the base of the impoundment on top of the impoundment Zone 1 clay liner. The underdrainage will be arranged in a herringbone pattern, with feeder drains connecting to the central drain via PVC connectors, and the central drain down the centre of the impoundment. The central drain will be connected to the buried concrete decant collection pit at the base of the decant structure, facilitating the removal of underdrainage water via the automated pump installed in the decant structure.

The underdrainage system selected for use is a Drintube Drainage Geocomposite (DDG), supplied by Afitec-Textel Australasia. The DDG is a proprietary geocomposite designed to provide foundation drainage when covered with soils/tailings, with filtration achieved through the use of geotextiles.

The DDG consist of two non-woven geotextiles with a perforated polypropylene pipe placed between the geotextiles at a defined and uniform spacing. The geotextiles are comprised of short synthetic fibres of 100 percent polypropylene or polyester that are needle-punched together to form a geocomposite material. The perforated polypropylene pipe functions as the primary fluid conveyance and are located within the geotextile layers. The pipe is corrugated with two perforations per valley at 180 degrees and rotated 90 degrees per valley.

## 11.6.7 Emergency Spillway

The Emergency Spillway will be constructed at the southern end of the facility. The spillway is located such that a flow through the spillway will discharge into the Clean Water Diversion Drains and around the southern perimeter of the site.





The spillway will be constructed to an invert level of RL 199.5m, with a base width of 6m and batter slopes of 8:1 (i.e., 12.5%) to allow vehicle access around the perimeter of the embankment. Derivation of the spillway geometry is presented in **Section 13.2**.

A reinforced concrete berm shall be constructed at the upstream edge of the embankment to the spillway invert level of RL 199.5 m.

Zone S Erosion Protection rockfill shall be placed on the downstream batter within the spillway outlet channel to prevent scouring of the embankment if a flow through the spillway occurs.

## 11.6.8 Clean Water Diversion Drains

Clean Water Diversion Drains will be constructed around the downstream toe of the embankments on the western/ southern and eastern sides of the facility, as well as surrounding the External Return Water Pond, for the collection of surface water runoff from the external catchments to prevent water flowing against the embankment downstream toe. The drains will be excavated into the natural surface up to a depth of 0.8m and a base width of 1.5m and following the existing grade of the natural surface. The drains will connect to the existing diversion drains running around the western/southern perimeter of the Brunswick site. At the end of the eastern drain, a buried culvert will be installed around the south-eastern toe of the facility connecting to the existing southern perimeter drains to prevent pooling of water in this area.

Derivation of the Clean Water Diversion Drain geometry and sizing is discussed in **Section 13.5**.

To prevent the erosion of natural soils along the base and walls of the drains at expected areas of high flow velocity, a Zone S erosion protection rockfill will be installed within the drains. This material will be placed where the velocities are determined to be at their maximum, generally at the end of the drains, at significant grade changes, and where the drains merge. Localised placement of Zone S erosion protection rockfill will also be implemented at regular intervals along the clean water diversion drain outer batters to aid in the control of flow into the drains.

Along the remainder of the drains, the walls and floor of the drains will be lined with topsoil, then seeded with grasses and hydromulch, effectively forming grassed swale drains to mimic the natural pasture conditions and aid in providing erosion resistance to the underlying dispersive natural clays.

As part of the Clean Water Diversion Drains, Zone 3A rockfill material will be placed and compacted between the inner edge of the drain and the embankment downstream face to allow for a free-draining surface into the drains.

## 11.6.9 Flood Protection Bunds & ROM Infrastructure Re-alignment

As identified in the Dam Break Report **[16]**, a series of flood protection bunds will be required around the site to prevent the inundation of the Brunswick Underground Portal, and limit inundation of the Brunswick Processing Plant in the event of a failure of the embankments. These flood protection bunds are as follows:

- Around the southern perimeter of the Brunswick Underground pit, constructed to a minimum height of 3.0m.
- Along the northern edge of the current haul track towards the ROM, constructed to a height of between 3.0 and 6.0 m. This bund will connect to the northern batter of the primary access ramp up to the crest of the TSF.

These bunds are required to be constructed from compacted Zone 3B rockfill to provide structural integrity when subjected to the potential flood waves. A cascade failure over the flood protection bunds is not expected, given that the flow direction is largely parallel to the bund alignment. Some erosion of the bunds is expected during a dam breach event, however the bunds exist to dampen and absorb the initial flood wave. A criticality of the bund erosion is expected once the peak flood wave has passed, and the flow depths and velocities are less critical.

With the formation of the access ramp to the facility, the existing access to the Brunswick Underground and ROM pads will be required to be re-established. A 6.0m wide haul road will be constructed from the High Grade ROM Pad, around to the current underground haul road, and through existing stockpiles towards the Low Grade ROM Pad, following the alignment of the embankment downstream toe.





The layout and typical sections of the flood protection measures and the facility access re-alignment is presented in **Figure 9**.

It is noted that these works will be required while there exists a risk of a dam breach inundating the Brunswick Underground Portal, and potentially risking the lives of mine personnel. These works will not be required until tailings are stored above ground level, and will only be required whilst the Brunswick Underground Portal is still used to provide access to Youle. MRCO have informed ACTW that underground mining will cease in Q3 2027, hence these measures are expected to be temporary, and can be demolished and returned to stockpile once the risks to personnel associated with the underground are no longer present. **MRCO have indicated that the bunds are to be progressively decommissioned and demolished by excavation to supplement closure activities, such as formation of closure caps. This demolition will not be undertaken until the cessation of underground mining, and if underground mining is extended beyond Q3 2027, these flood protection bunds are required to be maintained.**

## 11.7 External RWP Construction

### 11.7.1 Facility Sizing

The initial sizing requirements for the external RWP are outlined in **Section 10.1**.

As discussed in **Section 13.3.4**, the 1:100 AEP, 72 hr storm event is 172 mm, resulting in approximately 11,000 m<sup>3</sup> of potential rainfall runoff from the Brunswick West TSF. The Bombay TSF and Brunswick TSF are similarly sized, with catchment areas limited by the embankment downstream crest edge (6.3 ha for Bombay, and 6.2 ha for Brunswick). Over these facilities, an additional 21,750 m<sup>3</sup> of potential surface runoff is generated, and a total of 32,750 m<sup>3</sup> of surface runoff is required to be stored in the external RWP.

The tailings bleed rate (at a discharge solids concentration of 35%) is equal to 0.93 m<sup>3</sup>/tonne of tailings deposited. At an average daily deposition rate of 419 tonne/day, this is around 390 m<sup>3</sup>/day of bleed water produced, or approximately 2,750 m<sup>3</sup> of water over a 7-day period. As such, the External RWP initial size is approximately 35,500 m<sup>3</sup>.

To account for normal operating volumes within the RWP, a capacity of approximately 40,000 m<sup>3</sup> has been considered. Validation of this size has been undertaken in the Water Balance Assessment discussed in **Section 12**.

### 11.7.2 Foundation Preparation

Foundation Preparation for the External RWP will consist of either Type A1 Foundation Preparation beneath the embankment footprint, or Type A2 Foundation Preparation within the impoundment.

Type A1 Foundation Preparation will be identical to that undertaken for the TSF Embankment (refer **Section 11.5**). Type A2 will be similar to that undertaken for the TSF, however the excavation will only be required to a base elevation of RL 183.0 m, and graded towards the north-eastern corner of the facility at approximately 0.5% to aid in water removal. The sloped floor will also have the advantage of depressurising beneath the synthetic liner to reduce the risk of wrinkles or wind uplift in the liner.

### 11.7.3 Embankment Construction

The RWP Embankments will be no more than 4.5 m high. As such, the embankments will be formed entirely of a blend of Zone 1B and Zone 3A material won from excavation of the RWP impoundment, and from the TSF works. The embankment will be constructed to a crest height of RL 191.5 m and 4.0m wide at the crest. The embankment will have 2.5 (H:V) downstream batter slopes and 3:1 (H:V) upstream batter slopes.

The embankments will be required to be trimmed to form a smooth subgrade for the placement of the synthetic liner. A similar smooth profile will be required along the RWP impoundment floor to ensure the integrity of the synthetic liner. The upstream batter slopes have been designed at 3:1 (H:V) to allow for a smooth drum roller to safely work on the batter slopes and excavation impoundment floor to achieve a suitably smooth subgrade. If necessary, thin layers of Zone 1 material can be placed in localised spots to ensure a smooth surface.





Following the completion of the embankment, the downstream slope shall be covered with a minimum of 300 mm of topsoil material won from clearing and seeded with local grasses to aid in visual amenity during operation.

#### 11.7.4 Synthetic Liner

The synthetic liner for the pond is required to provide for suitable water storage, and will either be a BGM liner (similar to that utilised on the TSF), or a 1.0mm thick High Density Polyethylene (HDPE) (similar to that previously utilised at Splitters Creek Evaporation Facility). The liner will be required to have a very low hydraulic conductivity (of around  $1 \times 10^{-12}$  m/s, or lower), and will be installed on the embankment upstream face and along the base of the impoundment. The synthetic liner will be secured in anchor trenches at the crest of the embankment.

#### 11.7.5 Emergency Spillway

The RWP Emergency Spillway will be constructed at the eastern side of the facility to allow any potential flows to be directed into the toe drains. The spillway will be 300 mm deep, constructed to an invert level of RL 191.2 m, with a base width of 4.0 m and batter slopes of 8:1 (i.e., 12.5%) to allow vehicle access around the perimeter of the embankment.

Zone S Erosion Protection rockfill shall be placed on the downstream batter within the spillway outlet channel to prevent scouring of the embankment if a flow through the spillway occurs.

### 11.8 Embankment Materials and Construction

#### 11.8.1 Zone 1 Clay

Zone 1 Clay forms the low permeability clay liner at the base of the impoundment excavation. The material shall be won from the foundation preparation and impoundment excavation and shall exclude all topsoil and High Plasticity clays. Zone 1 material shall conform to the following USCS soil classifications:

- CL, CI - CLAY, sandy CLAY, Gravelly CLAY

In addition to the above, Zone 1 shall comply with the following requirements:

- Minimum Fines Content (% passing 75  $\mu$ m) of 50%.
- Maximum particle size of 50 mm.
- Atterberg Liquid Limit within the range of 20% to 50%.
- Atterberg Plasticity Index within the range of 12% to 30%.

Zone 1 shall be placed in 250 mm thick (loose) layers and compacted to a minimum of 98% SMDD with a moisture content variation of between -2% (dry) and + 2% (wet). Compaction shall be achieved by a vibratory pad foot roller, or suitable equivalent.

#### 11.8.2 Zone 1B Earthfill Subgrade

Zone 1B Earthfill forms the BGM Liner subgrade, as well as forming the embankments for the RWP. The material shall be won from the foundation preparation and impoundment excavation and shall exclude all topsoil material. Zone 1B material shall conform to the following USCS soil classifications:

- CL, CI, CH - CLAY, Sandy CLAY, Gravelly CLAY
- GC - Clayey GRAVEL, Clayey Sandy GRAVEL
- SC - Clayey SAND
- RS, EW - Residual & Extremely Weathered Rock

Zone 1B shall have a maximum particle size of 30mm.





Zone 1B shall be placed in horizontal layers of 300mm (loose) thickness and compacted to achieve a minimum of 98% SMDD. Zone 1B will form the subgrade for the placement of the Geosynthetic Liner and HDPE, and should be placed and trimmed such that the maximum asperities are no greater than 30mm for the TSF, and 10mm for the RWP.

### 11.8.3 Zone 3A Transition Fill

Zone 3A Transition Fill forms the upstream transition between Zone 1B and Zone 3B and will comprise of a mixture of Residual Soil, Extremely and Highly Weathered siltstone and sandstone particles in a matrix of clays, silts, sands, and gravels. Zone 3A shall be won from impoundment excavation. Zone 3A rockfill shall conform to the following USCS soil classifications;

- GP, GW                      Poorly and Well Graded GRAVEL
- GC                          Clayey GRAVEL, Clayey Sandy GRAVEL
- SC                          Clayey SAND
- RW, EW, HW              Residual, Extremely and Highly Weathered Rockfill

Zone 3A material shall exclude all material that is primarily clay or silt, wet, or contains high organic content.

In addition to the above, Zone 3A shall have a maximum particle size of 300 mm.

Zone 3A material shall be placed and compacted in horizontal loose layers not exceeding 300mm thickness, and compacted with a vibratory pad foot roller. Field trials shall be conducted at the start of construction to establish the equipment sizing and number of passes required to achieve the desired level of compaction and develop the method specification for compaction of Zone 3A.

### 11.8.4 Zone 3B Rockfill

Zone 3B Rockfill forms the downstream shoulder of the embankment, as well as access ramps and flood protection bunds. Zone 3B will be a general rockfill material, comprising of durable, highly to slightly weathered siltstone and sandstone, and must not degrade under placement. The material is an all-in rockfill mixture but shall exclude material that is primarily clay or silt, wet, or contains high organic content. The material shall be won from impoundment excavation, and nearby waste rock dumps if necessary.

Zone 3B material shall have a maximum particle size of 400 mm, and minimal fines content.

Zone 3B material shall be placed and compacted in loose layers not exceeding 600mm thick, and compacted with. Field trials shall be conducted at the start of construction to establish the equipment sizing and number of passes required to achieve the desired level of compaction and develop the method specification for compaction of Zone 3B.

### 11.8.5 Zone S Erosion Protection Rockfill

Zone S Erosion Protection Rockfill shall be placed within an excavated channel beneath the spillway chutes, and within the Clean Water Diversion drains to minimise surface erosion.

Zone S shall be formed from screened Zone 3B angular rock particles with the particle sizing dependant on the location and use. Particle sizing for Rip-Rap has been undertaken using the eWater Rip-Rap toolkit [30]. Zone S rockfill Zone S Particle Size Requirements are presented in **Table 14**.

**TABLE 14: ZONE S PARTICLE SIZE REQUIREMENTS**

| Location                     | D <sub>15</sub> | D <sub>50</sub> | Max | Installation Thickness |
|------------------------------|-----------------|-----------------|-----|------------------------|
| TSF Spillway                 | 125             | 250             | 500 | 500                    |
| RWP Spillway                 | 100             | 200             | 400 | 400                    |
| Clean Water Diversion Drains | 50              | 100             | 200 | 200                    |





## 11.8.6 Road Base Material

Road base material shall comprise of select medium grained mine waste rock suitable for trafficking by light vehicles. Road base material shall be slightly to fresh rounded to sub-rounded rock particles with a maximum particle size of 75mm.

Suitable alternatives as directed by MRCO may also be utilised as road base material.

## 11.8.7 Decant Structure

### 11.8.7.1 Inclined Structure

The inclined portion of the decant structure shall be formed from three thick walled DN630 HDPE Pipelines with regularly spaced slots cut into the surface and wrapped in UV stabilised filter geotextile. The pipelines will be connected to a reinforced concrete slab cast in-situ directly into the Zone 1B Subgrade.

### 11.8.7.2 Decant Collection Pit

The decant collection pit at the base of the decant structure shall be a custom-made pre-cast reinforced concrete stormwater pit of dimensions 2.2 m x 3.0 m x 2.0 m. The pit shall be rated up to a vertical load of 300 kPa.

## 11.8.8 Geosynthetics

### 11.8.8.1 Geotextiles

The following geotextiles and applications are required for the Brunswick West TSF Construction:

- Texel R range 600R non-woven, marine-grade geotextile – incorporated into the Decant Structure as a filter to prevent the migration of tailings fines.
- Bidim A64 non-woven geotextile – beneath the Zone S Rockfill within the Clean Water Diversion Drains and Spillway to further aid in minimising erosion.

### 11.8.8.2 DRAINTUBE

The DRAINTUBE Drainage Geocomposite (DDG) will be supplied Afitec-Texel Australasia and shall be a DT FT2 D25. The Internal pipe sizing shall be 25mm in diameter, with 4 pipes per roll and an overall roll width of 2m.

The DDG shall be laid stress-free along the top of the impoundment excavation base liner and connect to the underdrainage sump.

### 11.8.8.3 Bituminous Geomembrane Liner

The liner used shall be an elastomeric modified BGM, nominal minimum thickness 4.0 mm. Products conforming these requirements are as follows:

- Teranap Expert 500 BGM nominal thickness 4.0mm, manufactured by Siplast International and supplied by Geofabrics Australia, or
- Coletanche ES3 SBS BGM nominal thickness 4.8 mm, manufactured by Axter Limited.

Standard roll sizes for these products are 4m wide and 85m long.

Within the TSF, The BGM liner shall be placed along the upstream face of the embankment against the Zone 1B subgrade. The BGM Liner shall be installed with the smooth side down for ease of installation and welding. The BGM Liner shall be run from the crest of the embankment to the base of the impoundment in a single run and be anchored at both the top and bottom. To minimise the amount of wasted material, the manufacturer should be contacted to discuss production of custom length rolls. Where this is not achievable or is cost-prohibitive, transverse seams may be considered within the lower 1/3 of the lined slope, with 4-way seaming prohibited.





If BGM material is to be used in the external RWP, the material shall be installed running from embankment crest down to the impoundment base. While the batter slope is flatter than that at the TSF, cross-slope welds should still be avoided. These welds will be permitted on the impoundment base, provided that suitably water-tight connections can be made.

Placement, welding and QA/QC testing of the BGM liner will be undertaken by a specialist lining sub-contractor with suitable previous experience in BGM liner installation.

#### 11.8.8.4 HDPE Liner

If the external RWP is to be lined with HDPE, the material shall be similar to those used at the MRCO site for lining of other water dams. The material shall be a HDPE Geomembrane manufactured from new first quality resin with approximately 2.5% of carbon black added. The HDPE shall be a high quality formulation designed for exposed conditions. The material shall have a minimum thickness of 1.0 mm.

## 12 WATER BALANCE

### 12.1 Objectives

The water balance model has been developed to assess surface water within the TSF and external RWP, and will address the following key objectives:

1. Establishment of the Normal and Maximum Operating Levels for the TSF.
2. Establish the Normal Operating Level for the external RWP.
3. Establish the pumping requirements from the TSF.
4. Assess the likelihood the TSF and external RWP spillways will be engaged.
5. Validate the size of the external RWP.
6. Evaluate the surface water levels on the inactive Bombay and Brunswick TSF.
7. Determine how much of the Brunswick Processing Plant demands can be met by the external RWP

### 12.2 Flow Diagram

A flow diagram of the system assessed in the Water Balance Assessment is presented in **Diagram 1**.

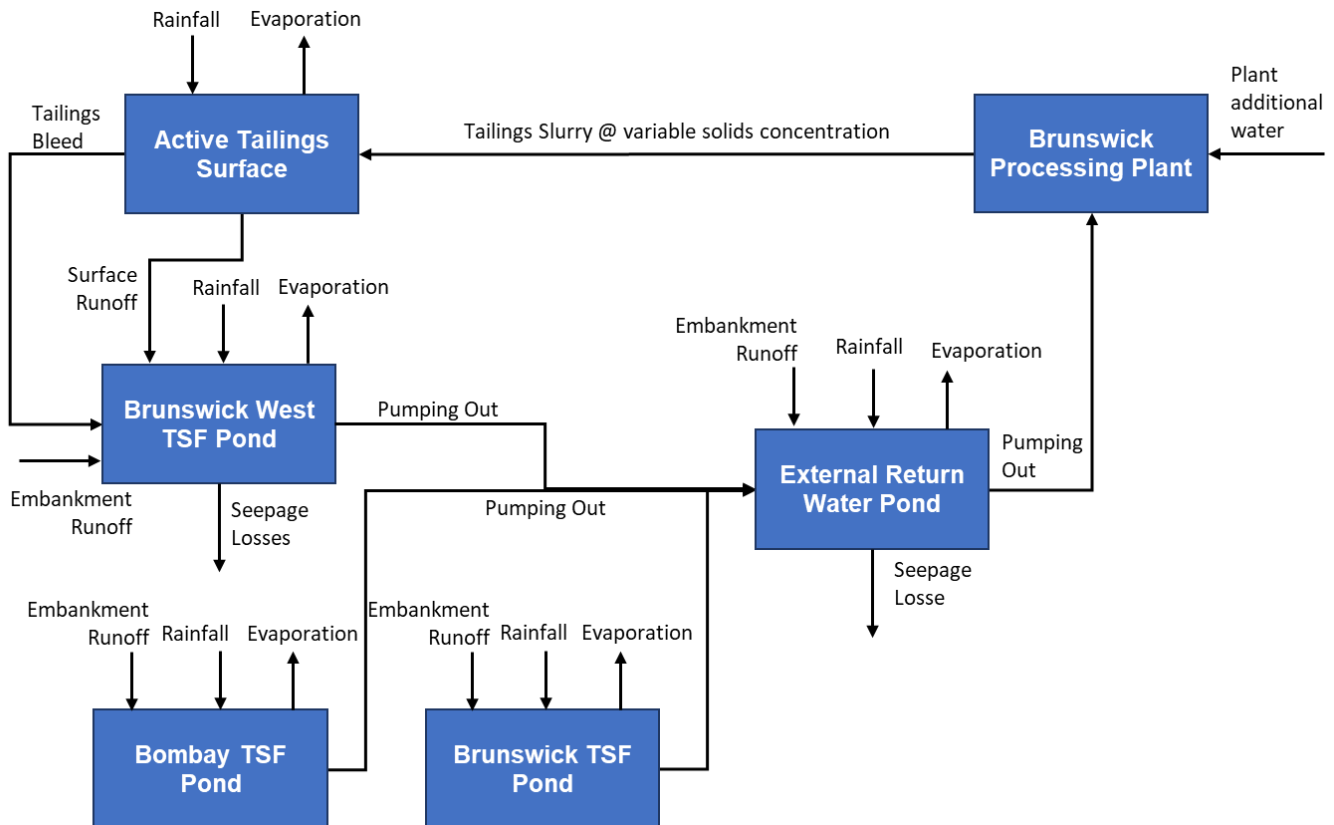
This water balance assessment has been conducted for the “Process Water” system encompassing the Brunswick West TSF, external RWP, inactive Bombay and Brunswick TSFs, and the Brunswick Processing Plant. Assessment of the performance and interaction of this system with the existing surface water infrastructure at MRCO should be undertaken in a site-wide water balance, which is beyond the scope of this design.

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**DIAGRAM 1: WATER BALANCE FLOW DIAGRAM**



## 12.3 Methodology

The water balance model has been developed using Goldsim [31], a probabilistic software used to dynamically model complex systems.

The model was prepared based on the conventional mass balance approach:

$$\Delta \text{Storage Volume} = \text{Inputs} - \text{Outputs}$$

Inputs have included direct rainfall, catchment runoff, and tailings bleed water, and outputs have included evaporation and pumping removal.

The water balance model has been run on a daily basis over the lifetime of the TSF. Deposition into the raise has been assumed to commence at the start of October 2023 and is the start date for the water balance model.

## 12.4 Climate Data

### 12.4.1 Long Term Climate Data Source

In order to construct a representative daily climatic database for the water balance, the Heathcote weather station data was patched using SILO (Scientific Information for Land Owners) to generate approximately 132 years of rainfall records. SILO (Scientific Information for Land Owners) is a database of Australian climate data hosted by the Science Division of the Queensland Government's Department of Environment and Science (DES) [32]. It provides daily datasets for a range of climate variables across Australia with interpolated infills for missing data. The datasets are constructed from observational data obtained from the Australian Bureau of Meteorology.

For this modelling study, the climate data were obtained as a SILO patched dataset for Grid Point data at the TSF site (grid coordinates -36.90, 144.80).





## 12.4.2 Synthetic Data Generation

To account for the uncertainties associated with climate variability, synthetic climate was generated for input into the water balance model.

The long term patched point SILO dataset was used to generate 1,000 realisations of synthetic rainfall and evaporation data using the Stochastic Climate Library [33], a software programme that uses the existing rainfall, evaporation and maximum temperature to generate random data that presents the same long term statistical characteristics as the historical data (mean, variance, skew, long term persistency etc). Each generated realisation of data is a unique set of rainfall and evaporation that is statistically similar to the historical data available.

## 12.5 Rainfall and Evaporation

### 12.5.1 Rainfall Runoff

The three TSFs are all completely encompassed by the embankments, with no natural contributing catchment. Therefore, surface water runoff resulting from rainfall occurs from the embankment crests/upstream face and the dry tailings beach.

The wetted surfaces within the TSF (Decant Pond, and Active and Passive Tailings beaches) are in a saturated state. It has therefore been conservatively assumed that all rainfall on these surfaces will translate directly to runoff reporting to the decant pond.

To relate the rainfall to runoff and estimate the loss due to infiltration for the embankments and dry tailings beach, the Boughton SFB [34] method has been used. The Boughton SFB model was developed by correlating real rainfall records and catchment yields for catchments in Australia. It considers the residual moisture stored in the soil, downward migration of water through the soil strata to base flow, and upward migration of water up the soil strata to evaporation to calculate the total water available for runoff.

The Boughton SFB method is appropriate for small, ungauged catchments based upon a 3-parameter model (S, F and B) where for the model section:

- **S** – The surface storage capacity in mm;
- **F** – The daily infiltration capacity in mm/day controlling percolation from the surface store to the groundwater store; and
- **B** – A baseflow factor in the range of 0 to 1, which determines the portion of the daily depletion of groundwater that appears as baseflow runoff.

Due to the catchment being an isolated system, the values for the parameters adopted in this water balance were estimated based on the suggested values for similar ground conditions, and ATCW previous experience. A summary of the applied Boughton model parameters is shown in **Table 15**.

**TABLE 15: BOUGHTON MODEL PARAMETERS SUMMARY**

| Runoff Area        | Boughton Parameters |            |   |
|--------------------|---------------------|------------|---|
|                    | S (mm)              | F (mm/day) | B |
| Embankments        | 15                  | 5          | 0 |
| Tailings Dry Beach | 10                  | 3          | 0 |

### 12.5.2 Evaporation

Evaporation is expected to occur from the Decant Pond, Active Tailings Beach and Passive Tailings Beach, however evaporative losses to the water balance system are only expected from the Decant Pond and Active Tailings Beach (reducing the total bleed reporting to the Decant Pond). Evaporation from the passive tailings will determine this beach area but will not impact the losses from the water balance system as bleed runoff is no longer being produced from this area.





A pan evaporation factor of 0.8 has been adopted based on ATCW previous experience with storages in similar climatic conditions and at the Costerfield site.

## 12.6 Tailings Properties

### 12.6.1 Throughput Rate

The forecast tailings production rates presented in **Chart 5** indicated a tailings production rate of between 11,000 and 13,500 tonnes/month, with an average daily production rate of 419 tonnes/day. This value has been adopted for the Water Balance Model.

### 12.6.2 Tailings Bleed Rate

As part of the tailings transportation systems assessments [35], ATCW reviewed 1 year of solids concentration values provided by MRCO. It was found that the solids concentration significantly varied over the time period assessed, as low as 35% and as high as 58%. As presented in **Section 10.2.1**, the discharge solids concentration significantly impacts the amount of bleed water produced by the tailings as they settle and sediment. To account for this variability, solids concentration has been input stochastically into the water balance model, resampling every model timestep, with bleed rate and initial settled density dependant on this solids concentration.

The adopted tailings design parameters for input into the water balance model are summarised in **Table 16**.

**TABLE 16: ADOPTED TAILINGS DESIGN PARAMETERS**

| Parameter                         | Units   | Value |      |      |      |      |  |
|-----------------------------------|---------|-------|------|------|------|------|--|
| Discharge Solids Content          | Mean    | %     | 47.5 |      |      |      |  |
|                                   | Std Dev | %     | 4.0  |      |      |      |  |
| Tailings Specific Gravity         | t/m³    | 2.77  |      |      |      |      |  |
| Tailings Shrinkage Limit Density  | t/m³    | 1.65  |      |      |      |      |  |
| Tailings Final Density            | t/m³    | 1.30  |      |      |      |      |  |
| Discharge Solids Content (Lookup) | %       | 35    | 40   | 45   | 50   | 55   |  |
| Tailings Initial Settled Density  | t/m³    | 0.81  | 0.91 | 0.98 | 0.98 | 1.03 |  |
| Tailings Initial Bleed Rate       | m³/t    | 0.98  | 0.77 | 0.53 | 0.34 | 0.22 |  |

## 12.7 Seepage

The results of the seepage assessment (refer **Section 15.5.1**) indicate that, under the design conditions, only a small amount of seepage emanating from the decant pond can be expected through the embankment and foundations. For the water balance, it has been conservatively assumed that seepage losses from the TSFs and RWP are negligible.

## 12.8 Tailings Beach Area

In a sufficiently large TSF, the tailings surface areas would typically comprise of four main areas:

- Active Wet Beach, where fresh tailings slurry has been deposited. This area will generally have a thin film of surface water, and is expected to produce bleed,
- Passive Wet Beach, where deposition of tailings slurry has recently (within the last few days) occurred, but is no longer producing bleed water,
- Dry Tailings Beach, where there has been no recent deposition of tailings, and





- Decant Pond, where the surface water is expected to collect.

The proposed deposition methodology for the Brunswick West TSF is to primarily deposit from a single spigot at the northern end of the facility, with occasional deposition from other locations to help confine the tailings beach. Given the overall shape of the TSF (narrow at the deposition point, and widening out towards the tail end), the tailings will be continually deposited over the same general area, limiting the potential for evaporation to completely dry the tailings beach out. **As such, it is likely that the tailings surface will remain in a moist state (either as active or passive beach) through the operational life, such that rainfall falling over the beach will become runoff and report to the decant pond.**

For this assessment, it has been conservatively assumed that there will be no dry beach forming, with the exposed beach area split as either active wet or passive wet beach.

The potential active wet beach area was calculated based on the average daily volumetric tailings throughput and the expected thickness of tailings that will form over the existing beach slopes. Average daily thickness of tailings will vary based on the throughput rate and slope of the underlying tailings but can be approximated as the average rate of rise of the tailings. This initial settlement is assumed to occur almost instantly, and each daily active beach is dependent on the daily volumetric throughput rate.

The remainder of the exposed beach is then classified as passive wet beach.

**For the Bombay and Brunswick TSFs, the facilities will be inactive once deposition into Brunswick West TSF commences and will not be receiving deposited tailings that can form an active beach. As such, the entire tailings areas of these inactive facilities are classified as a dry beach.**

The total tailings beach and catchment areas for the TSF are summarised in **Table 17**.

**TABLE 17: TSF SURFACE AREA SUMMARY**

| Area  | Brunswick West TSF   | Bombay TSF | Brunswick TSF |
|---|--|------------|---------------|
| Total Catchment area (m <sup>2</sup> )        | 61,500   | 63,300     | 62,300        |
| Tailings Total Surface Area (m <sup>2</sup> ) | Varies:<br>0 at start of filling<br>52,500 at capacity     | 54,500     | 56,900        |
| Embankment Surface Area (m <sup>2</sup> )     | Varies:<br>61,500 at start of filling<br>9,000 at capacity | 8,800      | 5,400         |

## 12.9 TSF Storage Areas

The storage volume within the Brunswick West TSF has been assessed based on the continually filling of the TSF. Maximum storage volumes and surfaces areas are calculated at the start and end of filling, with the capacity at any given point in time calculated by interpolating between the two storage rating curves based on the volume of deposited tailings.

**At the time of writing, the Bombay TSF raise 4 is currently receiving tailings, with deposition expected to continue through the majority of 2023. As such, the exact storm storage capacity on the Bombay TSF tailings surface at the commencement of deposition into Brunswick West TSF is unknown. For this assessment, the design tailings beach as presented in the Bombay TSF design report [26] has been used, providing 29,000 m<sup>3</sup> of storm storage up to the design invert level of RL 200.1m.**

The Brunswick TSF is currently inactive, and ceased receiving tailings in early July 2022. The latest survey of the facility was dated 20<sup>th</sup> May 2022, with approximately 12,000 m<sup>3</sup> of tailings deposited since this survey. Based on how tailings have been deposited into the facility in the final weeks of deposition, it has been estimated there is 21,000 m<sup>3</sup> of storm storage to the spillway invert of RL 194.3m





## 12.10 Pumping Rates

One of the main aims of the water balance assessment has been to determine the required pumping rates for the Brunswick West TSF. This has been determined on an iterative basis to determine a suitable maximum pumping rate that will maintain the Brunswick West TSF in as a dry a state as possible. This has been determined as the capability to maintain an average (mean or 50<sup>th</sup> percentile) decant pond coverage of 10% or less.

Pumping from the existing inactive TSF's has been based on the design maximum pumping rates of 1,000 m<sup>3</sup>/day [15] & [26]. The pumps will draw down the water on the inactive TSFs to a minimum pumpable depth of 0.3 m. Pumping off the inactive TSF's has also been limited where the model predicts high quantities of rainfall runoff that may overtop the external RWP. If this scenario is anticipated, then pumping is halted and water is temporarily held on the Bombay and Brunswick TSFs. As such, one of the aims of the water balance assessment has been to determine if this strategy will result in the Bombay and Brunswick emergency spillways being engaged, and if it does, how much to increase the external RWP sizing by.

The primary withdrawal from the external RWP will be pumping to the Brunswick Processing Plant. MRCO have advised ATCW that the plant requires an average of 720 m<sup>3</sup>/day (30 m<sup>3</sup>/hr), which has been set as the maximum outflow from the external RWP. Where this cannot be achieved (i.e., insufficient water within the RWO), the external RWP will be pumped down to a minimum pumpable depth of 0.2 m, and additional makeup water for the Processing Plant will be sourced from elsewhere (mine water and/or brine). MRCO have advised ATCW that this is ideal, and would aid in the overall water management at the site.

## 12.11 Results

### 12.11.1 General

The water balance model was run for 1,000 realisations of synthetic climate data, with results output stochastically as percentiles. These percentiles do not reflect a specific realisation, but rather show the distribution of daily results and present a snapshot of the probabilistic outputs at any given moment.

The key outputs presented are the 25<sup>th</sup>, 50<sup>th</sup> (median), mean, 75<sup>th</sup>, 95<sup>th</sup> and 99<sup>th</sup> percentiles, and maximum of all cases (where relevant) at any given day. The percentages are representative of "the probability of not exceeding". In other words, the 99<sup>th</sup> percentile means there is a 99% probability that the given value will not be exceeded. When considering 1000 realisations of climate data, this can also be thought of as a 1 in 100 case for the life of the facility.

Key results from the Water Balance Assessment are presented in **Appendix C**.

### 12.11.2 TSF Pond

The initial goal of the Water Balance assessment has been to determine the size of the pond required within the decant structure to maintain the pond in a suitably minimum condition. The results of the TSF pond coverage (measured as the ratio of the pond area to the total beach area) is presented in **Figure C1** for a pump maximum capacity of 15 L/sec, which is roughly in line with the same size pumps currently used at the Bombay and Brunswick TSFs.

On average (mean and median) a pond coverage of around 5% is typically maintained over the life of the facility, with the 10% pond coverage threshold met for up to the 95<sup>th</sup> percentile case. As such, a pump with a 15L/sec capacity within the decant structure will be suitable for use for the Brunswick West TSF.

The TSF pond volume and elevation results (for the 15L/sec pump) are presented in **Figure C2** and **C3**, respectively. Over the life of the facility, the Normal Operating Pond is maintained in a relatively minimum state, typically less than 500m<sup>3</sup>, equating to around a 0.4m depth at the decant structure at the end of operation.

The maximum volume observed within the TSF from the modelling was approximately 13,800 m<sup>3</sup> from all 1,000 realisations. As such, a volume of 14,000 m<sup>3</sup> has been determined as a suitably conservative volume for the Maximum Operating Level (MOL) for the Brunswick West TSF.





The TSF pond elevation results show that the TSF spillway is not expected to be engaged, with a significant amount of freeboard available between the maximum pond levels and the spillway invert. The assessment of the required additional freeboard levels is discussed further in **Section 13.3**.

The stochastic assessment of the net bleed (gross bleed minus evaporation) generated from the tailings is presented in **Figure C4**. The net bleed generated from the tailings can be seen to vary seasonally with evaporation, as well on a day-to-day basis as determined by the discharge solids concentration. At the mean discharge solids concentration of 47.5%, a daily net bleed rate of between 60 m<sup>3</sup>/day and 180 m<sup>3</sup>/day can be expected. In comparison, discharging at a very low solids concentration results in significantly larger fluctuations in bleed quantities to be removed and recycled through the system. For the 99<sup>th</sup> percentile, roughly 3 standard deviations below the mean discharge solids concentration at ~35%, net bleed rates are 2-3 times higher. The higher bleed quantities as a result of long-term deposition of low solids concentration tailings are not expected to detrimentally impact the facility overall, but from an operational perspective will require more frequent operation of the TSF decant and External RWP pumps which in turn require more frequent maintenance and/or replacement of the pumping infrastructure.

### 12.11.3 External RWP

The initial sizing requirements for the external RWP (refer **Section 11.7.1**) found that a capacity of approximately 40,000 m<sup>3</sup> would be suitable to store the 1:100 AEP, 72hr runoff plus 7 days' worth of bleed water from the TSFs (assumed as instantaneously pumped to the RWP).

Validation of this sizing has come from a stochastic assessment of the outflows from the Brunswick West TSF, and the two inactive TSF reporting to the external RWP. The external RWP Volume and Depth plots are presented in **Figure C5** and **C6**, respectively. Additionally, the volume plots for the Bombay and Brunswick TSFs are presented in **Figure C7** and **C8**, respectively.

It can be seen in **Figure C5** that the external RWP size of 40,000 m<sup>3</sup> is sufficient to comfortably store water from all three facilities up to the 99<sup>th</sup> percentile without the spillway engaging or the need to temporarily hold water on the existing TSFs. The normal operating pond within the External RWP is approximately 1.0m deep, with depths below 5.0m up to the 99<sup>th</sup> percentile.

The depths within the external RWP are maintained below the spillway invert level, with the minimum freeboard between the maximum pond level (i.e. maximum value) and the spillway of approximately 0.4m, as presented in **Figure C6**. This is demonstrated by the pond values for the Bombay and Brunswick TSF (refer **Figure C7** and **C8**) remaining relatively low, remaining under 5,000 m<sup>3</sup> for the 99<sup>th</sup> percentile and generally below 10,000 m<sup>3</sup> for the maximum, and indicating that surface water is able to be pumped to the external RWP unrestricted.

The consideration of a higher discharge solids concentration was observed to aid in further providing for the capacity to maintain water on the Bombay and Brunswick TSF's as low as possible. A comparison of **Figure C7** and **C8** with the corresponding figures from Revision 1 of this document shows that up to the 99<sup>th</sup> percentile remains unchanged. However, the maximum values for this document iteration have generally remained lower (generally below 10,000 m<sup>3</sup>), whereas in the previous revision, maximum values were consistently quite high, particularly over the winter periods (up to 20,000 m<sup>3</sup>). It is considered that the decreased net bleed at the TSF as a result of higher discharge solids concentration has allowed for the External RWP pond to be maintained lower during periods of higher rainfall. This provides more surge storm storage from the three facilities pumping water to the External RWP, and helps to further reduce the risk of a potential failure of the existing upstream raised facilities.

The water balance modelling identified that the external RWP has a normal operating pond (as defined by the mean of all results) of around 1,500 m<sup>3</sup>. When considering the initial sizing requirements for the facility of 35,500 m<sup>3</sup> above the normal operating pond (refer **Section 11.7.1**) this results in a volume of 37,000 m<sup>3</sup>, and the sizing for the facility remains valid.

The results of the pumping rates out of the external RWP are presented in **Figure C9**. Mean pumping out rates vary between ~160 m<sup>3</sup>/day (6.5 m<sup>3</sup>/hr) during the summer period to 400 m<sup>3</sup>/day (16.5 m<sup>3</sup>/hr) during the winter period. Based on the Brunswick Processing Plant requiring a consistent 30 m<sup>3</sup>/hr, the external RWP will be able to supply between 22% and 55% of these requirements. It is anticipated that there may be periods of heavy rainfall where the entire Processing Plant requirements are met by the external RWP, indicated by the 75<sup>th</sup> percentile values peaking at 720 m<sup>3</sup>/day around mid-winter.





The modelled water supply shortcomings to the Brunswick Processing Plant will need to be made up with external water from the Augusta mine water dams. MRCO have indicated that this is ideal, as it will aid in dealing with groundwater pumped out as part of underground mining dewatering activities.

## 13 SURFACE WATER MANAGEMENT

### 13.1 Catchment Areas

The Brunswick West TSF will essentially be a paddock-style TSF formed by the creation of the embankments higher than the natural surrounding surface. As a result, the TSF interior has no external catchment, with the catchment area limited by the downstream edge of the embankment. This is equal to a catchment area of approximately 6.3 ha.

Surface water flows towards the Brunswick West TSF embankment toe is directed from farmland further upstream to the west of the facility. The catchment areas of the Brunswick West TSF and surrounding areas are presented in **Figure 10**.

### 13.2 Spillway Design

#### 13.2.1 Overview

In accordance with the ANCOLD Guidelines [9], the emergency spillway for a TSF with a Dam Failure Consequence Category of High B (refer **Section 6.4**) must be sized to pass the greater of the Probable Maximum Flood (PMF), or a 1:100,000 AEP flood plus a 1:10 AEP wind induced wave runup. Given that the facility is a paddock-style TSF with low ponding depths and short fetch distances, the PMF assessment has been determined as the critical case.

The initial condition of the facility is to have the pond taken at its highest point, i.e., the storage is full of water to the invert level of the spillway as per ANCOLD [9] Guidelines.

#### 13.2.2 Design Rainfall

The generation of extreme rainfall depths has been undertaken using the methods recommended in the Australian Rainfall and Runoff (ARR) Guidelines [35]. This method involves the estimation of the Probable Maximum Precipitation (PMP) for short durations (up to 6 hours) and long durations (up to 72 hours) using the Generalised Short Duration Method (GSDM) [37] and Generalised South-East Australian Method (GSAM) [38].

Estimation of the PMP rainfall depths up to 72 hours are presented in **Table 18**.

**TABLE 18: ESTIMATED PMP RAINFALL DEPTHS**

| Duration (Hrs) | Depth (mm) | Duration (Hrs) | Depth (mm) |
|----------------|------------|----------------|------------|
| 0.25           | 140        | 4              | 510        |
| 0.5            | 200        | 6              | 570        |
| 0.75           | 260        | 12             | 640        |
| 1              | 320        | 24             | 710        |
| 1.5            | 360        | 36             | 800        |
| 2              | 400        | 48             | 860        |
| 2.5            | 430        | 72             | 910        |
| 3              | 460        |                |            |

For estimations of other AEP rainfall events, the ARR Guidelines [35] recommend the use of the methods described by Siriwardena & Weinmann [39]. This method recommends using the 1:1,000

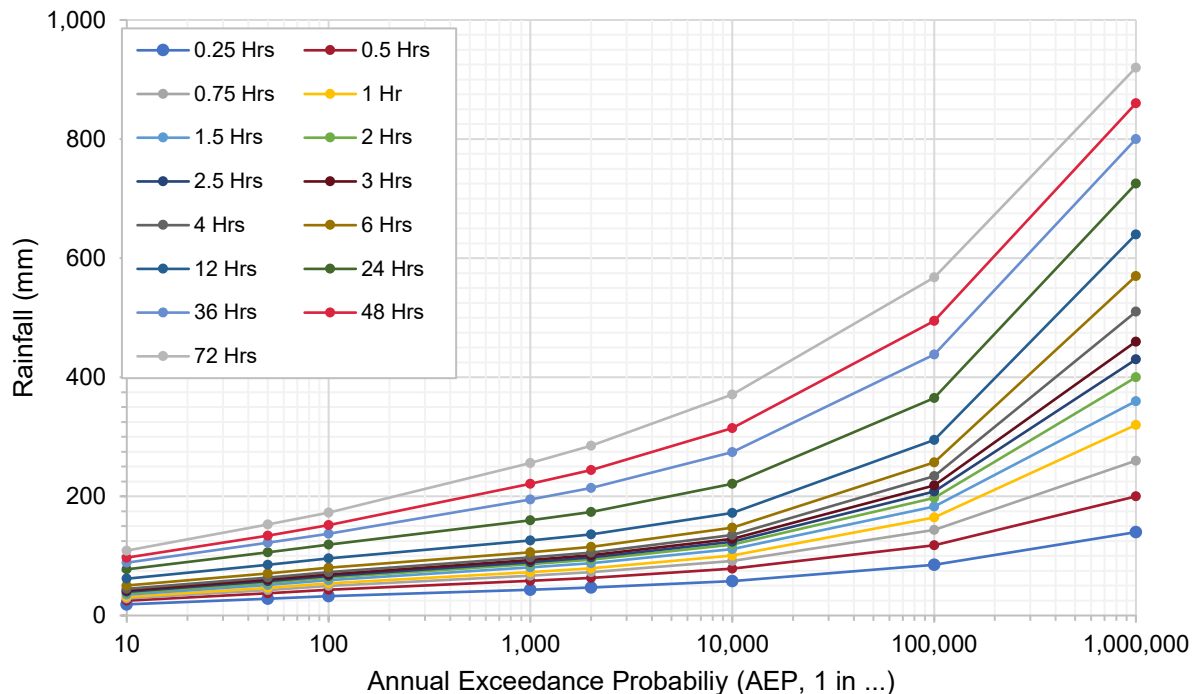




and 1:2,000 AEP events obtained from the Bureau of Meteorology (refer **Section 4.1**) and the generated PMP rainfall depths as reference points for interpolation of storm events of varying AEP.

Estimates of extreme rainfall depths are presented in **Chart 6**.

**CHART 6: ESTIMATIONS OF EXTREME RAINFALL DEPTHS**



### 13.2.3 Design Flood

The inputs in the derivation of the design flood for a given duration are the design rainfall event and the design inflow hydrograph. The design inflow hydrograph for a particular duration storm is the summation of individual component hydrographs from the pond and the surrounding catchment.

In the case of the Brunswick West TSF, the catchment area is limited to the area confined by the embankment crest downstream edge, approximately 6.3 ha.

### 13.2.4 Spillway Flood Routing

#### 13.2.4.1 Methodology

Once the design flood for a particular storm duration had been derived, spillway sizing was undertaken by routing the flood through the storage. This was accomplished using the storage indication method, a direct numerical procedure which is described in the Australian Rainfall and Runoff Guidelines [35].

A flood wave passing through the storage is both delayed and attenuated as it enters and spreads over the pool surface. The surcharge storage is gradually released over the spillway. The outflow depends on the spillway configuration, as well as on the surcharge storage characteristics. To perform satisfactorily, the spillway configuration must be able to pass the critical duration design AEP flood without overtopping of the embankment crest.

Floods from storms of increasing duration were progressively routed through the storage until a peak outflow was obtained. The spillway configuration (i.e., depth and width) was considered satisfactory only if the capacity was greater than the critical peak outflow.

#### 13.2.4.2 Results

Results of the spillway routing calculations are summarised in **Table 19**, with the inflow/outflow hydrograph for the critical duration events (2 hours) presented in **Chart 7**.





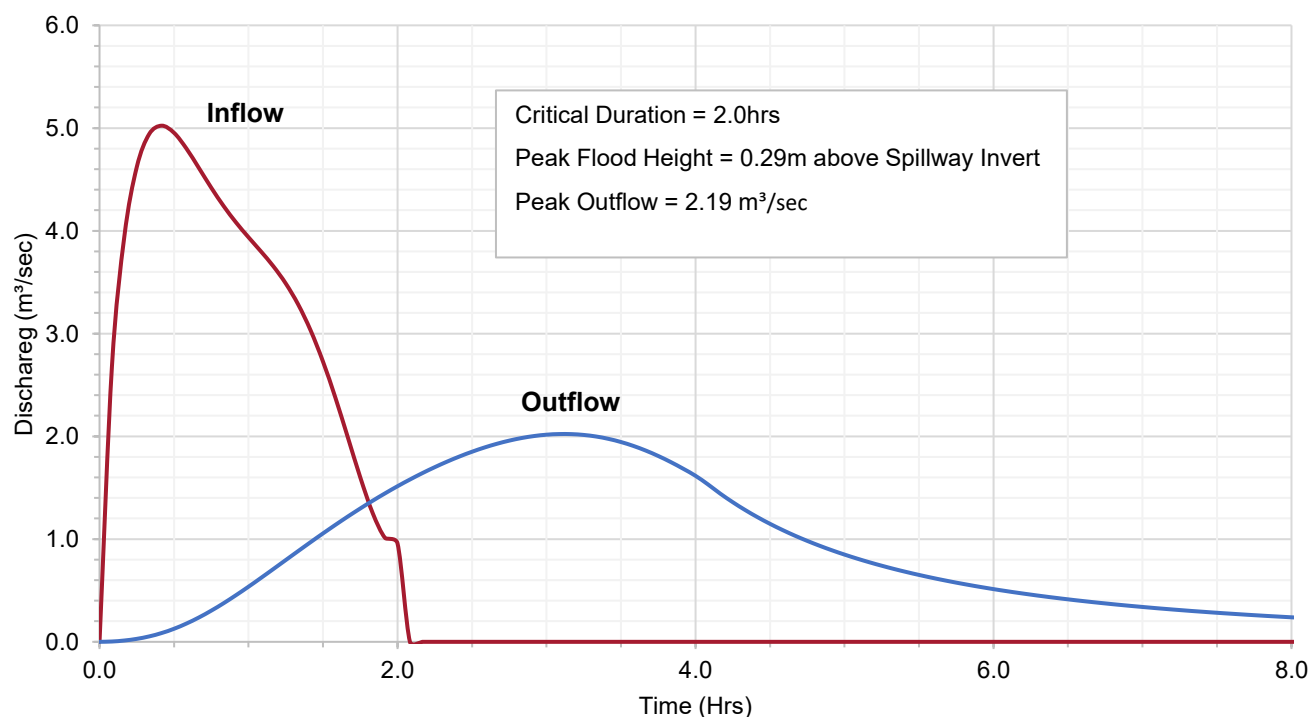
The spillway routing model found a 0.3 m deep and 6.0 m base width spillway, with batter slopes of 12.5% (i.e., 8:1 H:V) can safely pass the PMF flood. However, in light of the potential failure modes identified for the facility and the minimisation of risk, ATCW have opted to increase the depth of the spillway to 0.5m, providing an additional 0.2m of freeboard. This additional freeboard provides the facility with some robustness regarding potential failure modes associated with overtopping failures, such as blockage of the spillway, or loss of freeboard due to crest settlement. It is proposed that the spillway will be located at the southern side of the facility, with flow to be directed towards the Clean Water Diversion Drains running around the southern perimeter of the site.

In the event of a spillway discharge, a significant quantity of water would initially be required to raise the water levels within the TSF from the maximum operating levels to the spillway invert level. As identified in **Section 13.3**, 30,000 m<sup>3</sup> of water would be required before a spillway flow event occurs, significantly dilute the already benign supernatant within the facility.

**TABLE 19: SPILLWAY FLOOD ROUTING**

| Parameter           |                     | Unit                     | Results                |
|---------------------|---------------------|--------------------------|------------------------|
| Spillway Dimensions | Spillway Width      | m                        | 6.0                    |
|                     | Spillway Depth      | m                        | 0.5                    |
|                     | Spillway Capacity   | m <sup>3</sup> /sec      | 6.0                    |
| Peak Outflow        | 1.5 Hour Storm      | m <sup>3</sup> /sec      | 2.15                   |
|                     | <b>2 Hour Storm</b> | <b>m<sup>3</sup>/sec</b> | <b>2.19 (Critical)</b> |
|                     | 3 Hour Storm        | m <sup>3</sup> /sec      | 2.10                   |
| Peak Flood Height   | 1.5 Hour Storm      | m                        | 0.28                   |
|                     | <b>2 Hour Storm</b> | <b>m</b>                 | <b>0.29 (Critical)</b> |
|                     | 3 Hour Storm        | m                        | 0.28                   |

**CHART 7: SPILLWAY INFLOW-OUTFLOW HYDROGRAPH**





## 13.3 Freeboard Requirements

### 13.3.1 Adopted Approach

In accordance with the ANCOLD Guidelines [9] for TSFs with an Environmental Spill Consequence Category of Significant (refer **Section 6.4**), the facility must have the additional storage capacity, over and above the tailings, to contain the following below the invert level of the spillway:

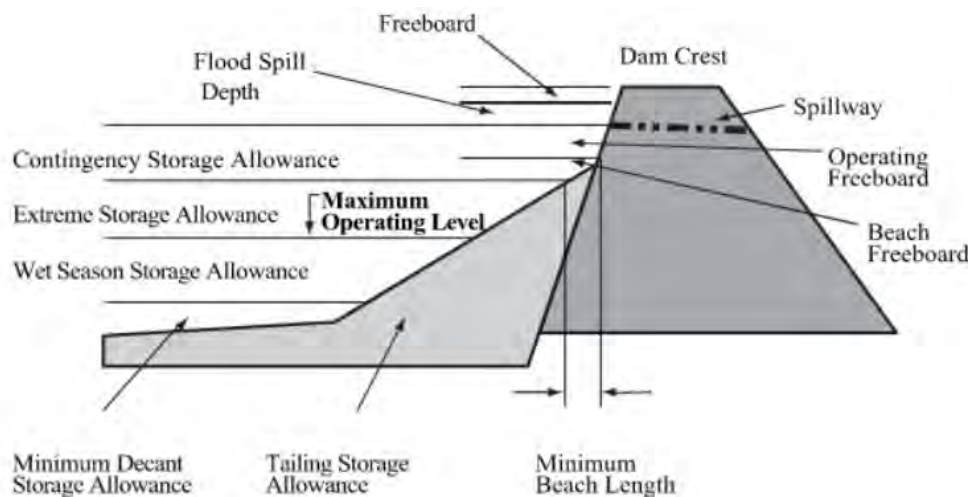
- Maximum Operating Level
- Extreme Storm Storage Allowance
- Contingency Freeboard

The procedure to evaluate the freeboard performance is defined as follows:

$$\text{Maximum Operating Level} + \text{Storm Storage Capacity} + \text{Contingency Allowance}$$

The freeboard design criteria described above are presented in **Diagram 2**.

**DIAGRAM 2: FREEBOARD DEFINITIONS (ANCOLD)**



### 13.3.2 Normal Operating Pond

The Normal Operating Pond has been estimated based on the mean water level in the facility, as informed by the results of the Water Balance Assessment (refer **Section 12.11**), and informs the typical pond levels and extents that can be expected in the facility during operation. For the Brunswick West TSF, this corresponds with a pond depth of 0.4 m, or an RL 198.2 m at the end of filling.

### 13.3.3 Maximum Operating Level

ANCOLD [9] recommend that for a Significant Environmental Spill Consequence Dam, a semi-quantitative risk analysis method should be used for establishment of the Maximum Operating Level (MOL). This has been assessed using the results of the Water Balance Assessment under the expected operating conditions, which is discussed in detail in **Section 12.11**.

The result of the Water Balance modelling indicated that a volume of 14,000 m<sup>3</sup> is suitably conservative for use as the Maximum Operating Pond volume under the expected operating conditions. This corresponds to a depth of 1.1 m and a MOL of RL 198.9m.

### 13.3.4 Extreme Storm Storage Allowances

The Extreme Storm Storage Allowance is the volume allowed for storage of an extreme storm event to prevent a spillway discharge. For a Significant Environmental Spill Consequence Category dam, the required allowance is the volume produced by the runoff from a 1:100 AEP, 72hr duration event.





Based on the IFD data (refer **Section 4.1.1**), this equates to a rainfall depth of 172mm. Applied over the 6.2 Ha catchment of the Brunswick West TSF, this results in approximately 11,000 m<sup>3</sup> of water to be stored. This corresponds to a depth of 0.26 m imposed on the MOL.

### 13.3.5 Contingency Freeboard

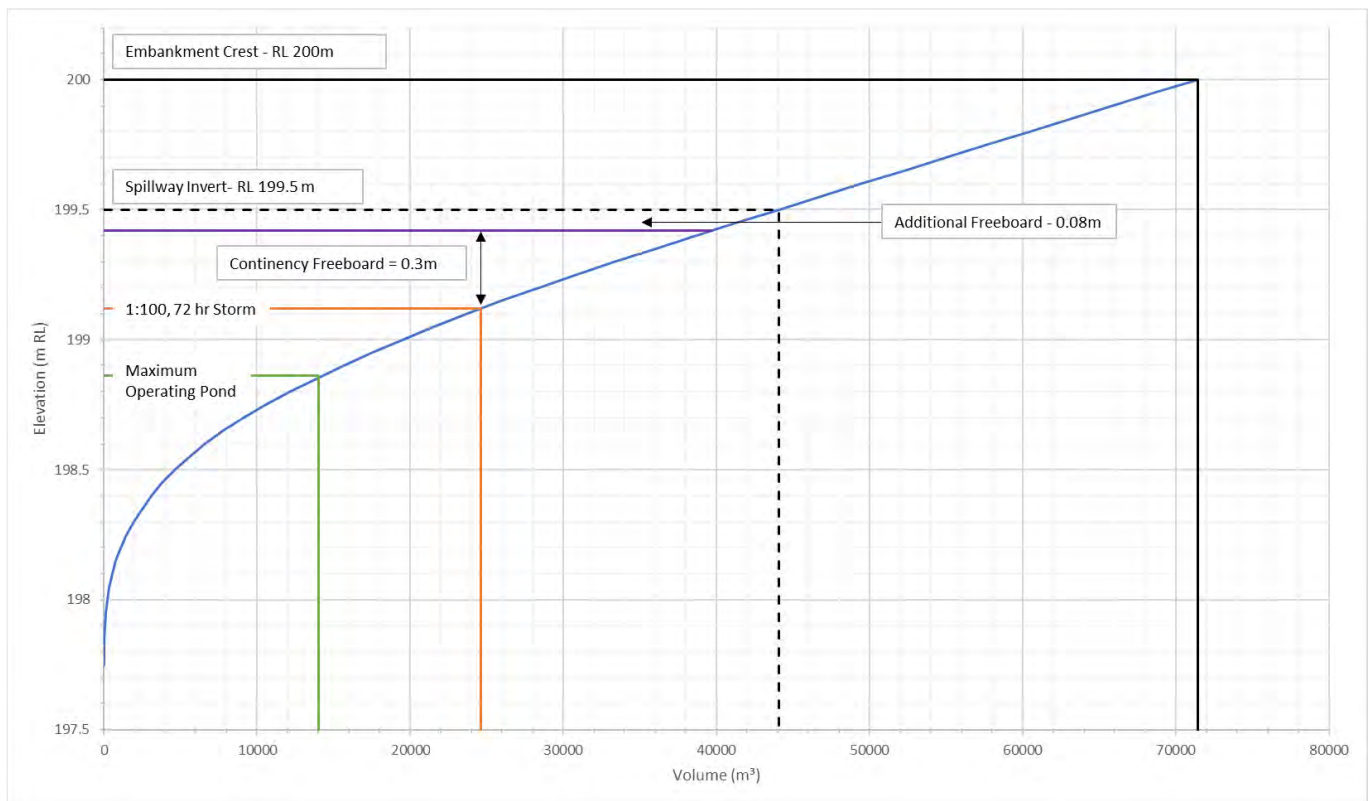
As defined by the ANCOLD Guidelines [9], additional contingency freeboard equal to the wave run-up caused by 1:10 AEP winds, plus 0.3 m is required for a Significant Environmental Spill Consequence Category TSF. Wave run-up from wind is generally only a concern for large dams with relatively deep bodies of water against the embankment and a long fetch distance from the embankments. Given that the Brunswick West TSF is relatively small, with only a shallow decant pond expected to form against the embankment, wave run-up from wind will be negligible.

As such, the contingency freeboard is for the Brunswick West TSF is equal to 0.3 m.

### 13.3.6 Freeboard Levels

The available storm storage and freeboards on the TSF at the end of filling is presented in **Chart 8** and **Table 20**.

**CHART 8: AVAILABLE STORM STORAGE AT END OF FILLING**



**TABLE 20: EMBANKMENT STORAGES AND FREEBOARDS**

| Event                      | Volume (m³) |        | Elevation (m RL) | Remaining Freeboard (m) |
|----------------------------|-------------|--------|------------------|-------------------------|
|                            | Incr.       | Cumul. |                  |                         |
| Maximum Operating Pond     | 14,000      | 14,000 | 198.9            | 0.6                     |
| 1:100, 72 hr Storm Storage | 11,000      | 27,000 | 199.1            | 0.4                     |





| Event                 | Volume (m <sup>3</sup> ) |        | Elevation<br>(m RL) | Remaining<br>Freeboard<br>(m) |
|-----------------------|--------------------------|--------|---------------------|-------------------------------|
|                       | Incr.                    | Cumul. |                     |                               |
| Contingency Freeboard | -                        | -      | 199.4               | 0.1                           |
| Spillway Invert Level | -                        | -      | 199.5               | -                             |
| Embankment Crest      | -                        | -      | 200.0               | -                             |

## 13.4 Decant Structure Design

The decant structure (refer to **Section 11.6.5** for a detailed description) has been designed to allow the free ingress of decant water and rainfall runoff into the structure, where it can be pumped from the facility. From an operational perspective it is desirable to maintain the pond at a depth of less than 400mm, which will require an average withdrawal rate of around 450 m<sup>3</sup>/day (5.2 L/sec).

The design of the decant structure has been based on the following:

- Estimation of the number of slots required to be cut into each of the three pipes to provide the design inflow capacity; and
- Design and selection of a geotextile that will provide suitable filtration of the tailings, whilst being sufficiently robust to prevent rupture due to the tailings overburden.

Fell et al [20] recommend that, for a non-woven geotextile, the minimum opening size for which 95% of the particles are smaller ( $O_{95}$ ) be less than the  $D_{85}$  of the material to be filtered. The tailings particle sizing has been determined from PSD tests undertaken on tailings slurry samples as part of the tailings testing [28], which gave a  $D_{85}$  of approximately 75 micron. The slots will be cut longitudinally into the pipeline with a repeating pattern of 2 or 3 around half the pipeline circumference, such that each repeating pattern will have 5 slots total. Alternatively, cored holes providing a similar opening area per unit length of pipeline would also suffice.

The design of the decant structure is summarised in **Table 21** and typical sections of the decant structure are provided in **Figure 7**.

**TABLE 21: DECANT STRUCTURE DESIGN**

| Item  | Value                      |
|---|----------------------------|
| Required flow rate through geotextile                             | 5.2 L/sec                  |
| Geotextile Product  | Texcel 900R                |
| Geotextile Product Opening Size $O_{95}$                          | <75 $\mu$ m                |
| Geotextile Product Flow Rate @ 100mm Head                         | 45 L/m <sup>2</sup> /sec   |
| Mean Pond Depth (m)   | 0.4 m                      |
| Mean Water head on geotextile                                     | 0.2 m                      |
| Flow Rate Reduction Factor  | 2                          |
| Geotextile Design Flow Rate                                       | 45 L/m <sup>2</sup> /sec   |
| Required Flow Area  | 0.116 m <sup>2</sup>       |
| <u>Required Flow Area per pipeline</u>                            | <u>0.039 m<sup>2</sup></u> |
| Saturated Length up Decant Structure Slope (at 2:1 Batter Slopes) | 0.89 m                     |
| Slot Width  | 30 mm                      |
| Slot Length   | 200 mm                     |





| Item  | Value                      |
|---|----------------------------|
| Minimum spacing between slots (measured along pipeline)                   | 100 mm                     |
| Number of slots per repeating pattern                                     | 5                          |
| Effective length of repeating pattern (inclusive of spacing)              | 600 mm                     |
| Number of repeating patterns per saturated length up slope                | 1.5                        |
| <i>Opening area provided over saturated length up slope, per pipeline</i> | <i>0.045 m<sup>2</sup></i> |

## 13.5 Clean Water Surface Drains

### 13.5.1 Overview

As part of the design of the Brunswick West TSF, a series of clean water diversion drains will be constructed around the toe of the embankment. These drains will divert rainfall runoff from the upstream catchment around the TSF without causing excessive scour and erosion and will be connected to the existing diversion drain network around the site.

The proposed alignment of the Clean Water Surface Drains is presented in **Figure 5**.

The primary external catchment for consideration of the Clean Water Surface Drains is fed from the west and south of the facility, running through grazing farmland and over Bradleys Lane through a natural drainage channel. An additional small catchment has been formed by the construction of the TSF, bound by high ground located in Crown Land to the east. The catchment areas of the Brunswick West TSF and surrounding areas are presented in **Figure 10**.

### 13.5.2 Selection of Storm Event

Selection of the design storm event has been based on consideration of the consequences of uncontrolled flow of surface water against the embankment in a post-closure, i.e., long term environment.

There are no regulatory or standards-based design criteria for mine water diversion systems, however in ATCW experience, for long term closure drainage applications, an AEP of 1:50 to 1:100 is typically adopted. As such, an AEP of 1:100 has been chosen for the design of the surface water drains.

### 13.5.3 Surface Water Drain Design

The Australian Rainfall and Runoff Guidelines [35] recommend the use of a Regional Flood Frequency Estimation (RFFE) approach for the estimation of peak flows for small to medium sized catchments. ARR offer a RFFE online toolkit for the estimation of peak outflow, which is based on relating the location of the catchment area to known gauge flow data. However, this method is not recommended for catchments where construction works have altered the flow paths or where dams have been constructed, and will have lower accuracy for catchments smaller than 0.5 km<sup>2</sup>. As such, the RFFE method is not considered suitable for use for the design of the surface water drains. Alternatively, the Probabilistic Rational Method, as described Pilgrim (1987) [40] (from which the RFFE was developed) had been adopted for the initial surface water drain design.

The design parameters and estimation of the peak outflow are summarised in **Table 22**. An intermediary assessment was conducted through the western/southern catchment to estimate the flow, and hence the drain size of the RWP perimeter drains.

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**TABLE 22: SURFACE WATER PEAK OUTFLOW**

| Parameter                               | Western & Southern Catchment – TSF | Western & Southern Catchment – RWP | Eastern Catchment |
|---|------------------------------------|------------------------------------|-------------------|
| Catchment Area (ha)                     | 45.2                               | 43.0                               | 3.0               |
| Time of Concentration, $t_c$ (mins)     | 34                                 | 33                                 | 12                |
| Runoff Coefficient, $C_y$               | 0.45                               |                                    |                   |
| Design Storm AEP                        | 1:100                              |                                    |                   |
| Rainfall Depth (mm)                     | 44.8                               | 44.5                               | 28.6              |
| Rainfall Intensity (mm/hr)              | 79                                 | 81                                 | 144               |
| <b>Peak Outflow (m<sup>3</sup>/sec)</b> | <b>4.48</b>                        | <b>4.33</b>                        | <b>0.53</b>       |

The surface water drains will follow the downstream toe of the TSF embankment and will generally follow the natural topography of the site. The drains have been sized to pass the outflow at the end of the catchment (i.e., the peak outflow) based on the average grade over the drain length. Intermediate checks were undertaken at the changes in grade to refine the drain depth and base width. Sizing of the surface was undertaken using the Manning's Equations for open channel flow, and have been sized to fit in with the existing drains on site.

The design parameters and estimation of the minimum drain sizing's are summarised in **Table 23**.

**TABLE 23: SURFACE WATER DRAIN SIZING**

| Parameter                                    | Western & Southern Catchment-- TSF | Western & Southern Catchment-- RWP | Eastern Drain |
|--|------------------------------------|------------------------------------|---------------|
| Drain Length (m)                             | 500                                | 190                                | 170           |
| Elevation Change (m)                         | 8.0                                | 3.3                                | 2.5           |
| Average Grade (%)                            | 1.6                                | 1.7                                | 1.5           |
| Manning's Number                             | 0.035                              |                                    |               |
| Base Width (m)                               | 1.3                                | 1.3                                | 0.5           |
| Side Slope Batters (H:V)                     | 2:1                                |                                    |               |
| Depth (m)                                    | 0.8                                | 0.8                                | 0.5           |
| <b>Drain Capacity, Q (m<sup>3</sup>/sec)</b> | <b>5.11</b>                        | <b>6.90</b>                        | <b>1.42</b>   |

#### 13.5.4 Additional Drainage Measures

The construction of the TSF, and formation of the eastern catchment, has resulted in an area off the south-eastern corner of the facility (just north of the access ramp) that will trap surface water runoff. As such, a buried culvert pipeline will be installed at the toe of the embankment, following the alignment of the ROM pad excavation. The pipeline will be required to pass the flow capacity from the eastern drain (0.91 m<sup>3</sup>/sec) without flow becoming turbulent. This has been assessed as water flowing at a depth approximately 65– 70% of the internal diameter.

Over a grade of ~1.5%, a steel reinforced concrete pipe of minimum internal diameter 685mm will be required. The pipeline will also be buried within the ROM pad excavation, and eventually covered with Zone 3B rockfill material up to a depth of 6.0m. A Humes DN675 Class 4 Reinforced Concrete Pipe (RCP) Flush Joint (FJ) is recommended for this application.

The RCP pipes will be connected at either end to a single outlet Reinforced Concrete headwall of suitable pipe opening size.





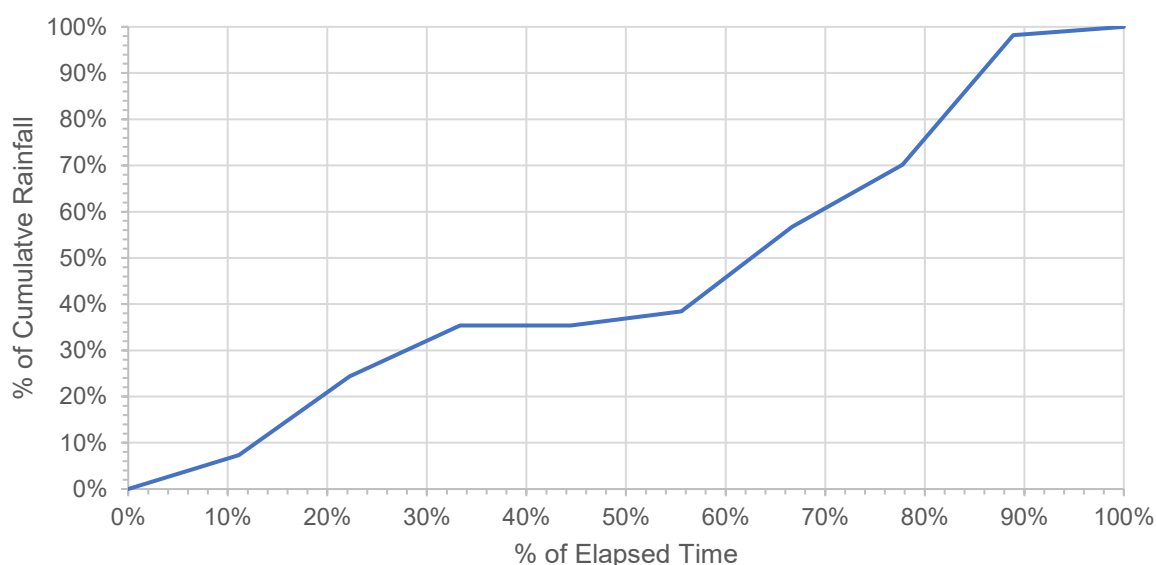
### 13.5.5 Verification of Surface Water Drains

To allow for verification of the Brunswick West TSF clean water surface drains compatibility with the existing diversion drains around the western/southern edge of the site, a rain-on-grid HEC-RAS model has been developed. This model has compared the expected flow conditions of the current conditions of the drain compared with the expected conditions at the completion of construction of the Brunswick West TSF and appurtenant structures.

The drains have been assessed for the 1:100 AEP critical duration storm, based on the total catchment area that would report through the existing southern/western diversion drain, as shown in **Figure 10**. This corresponds to a critical time of concentration of approximately 45 minutes, and based on the IFD data provided in **Chart 2**, this corresponds to a rainfall depth of 50mm.

Temporal patterns for the model were extracted from the ARR datahub, which provides design rainfall patterns for regions in Australia for varying storm intensity levels. The critical temporal pattern was considered as one that had a small amount of rainfall early and peaked late, as the low intensity rainfall would wet up the catchment, followed by high intensity rainfall resulting in surface runoff. The chosen temporal pattern is presented in **Chart 9**.

**CHART 9: RAIN-ON-GRID CRITICAL TEMPORAL PATTERN**



Losses for the system were also extracted from the ARR datahub. For the Costerfield area, an initial storm loss of 26 mm, and a continuing loss of 4.5 mm/hr are recommended. The drain sizing assessment adopted a runoff coefficient of 0.45, and for a 50 mm rainfall event, this would result in total losses of 27.5 mm. To remain consistent with this runoff coefficient, ATCW have adopted an initial storm loss of 25 mm and a continuing loss of 3.33 mm/hr (2.5 mm over 45 minutes).

A summary of the rain-on-grid surface water model parameters, including the adopted Manning's numbers, are presented in **Table 22**.

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**TABLE 24: OVERALL SOUTHERN / WESTERN CATCHMENT SURFACE FLOW PARAMETERS**

| Parameter                           | Overall Southern/<br>Western Catchment |
|-------------------------------------|--|
| Catchment Area (ha)                 | 84                                     |
| Time of Concentration, $t_c$ (mins) | 45                                     |
| Design Storm AEP                    | 1:100                                  |
| Rainfall Depth (mm)                 | 50                                     |
| Initial Storm loss (mm)             | 25                                     |
| Continuing storm loss (mm/hr)       | 3.3                                    |
| <b>Manning's n values</b>           |  |
| General flood plains (pasture)      | 0.03                                   |
| Clean Water Diversion Drains        | 0.035                                  |
| Erosion protection Rip-Rap          | 0.04                                   |
| Concrete Structures                 | 0.013                                  |

The model has been run for two scenarios; existing base conditions and the conditions at end of construction of Brunswick West TSF.

The results of the clean water surface drainage model are presented in **Appendix D**.

The incremental increase as a result of the presence of the Brunswick West TSF is negligible, increasing the flow within the current southern/western drain by approximately 50 - 100 mm. The water flows from the post-construction case are generally contained entirely within the drains, and have similar extents to those found for the base case. This is due to the overall footprint of the Brunswick West TSF being generally contained within the previously existing catchment areas and effectively near the end of the catchment. As such the total flow reporting through the existing drains is largely unchanged. From the flow depth results, it has been determined that existing drains do not need to be expanded.

The primary impact of the Brunswick West TSF come from the concentration of flow from the end of the new clean water diversion drains into the start of the existing drain. The flow velocity in this area is expected to increase from around 0.75 – 1.0 m/s to up to 2.0 m/s for a length of approximately 30m. This area will be lined with erosion protection rip-rap to fit the existing design.

It is noted that further down the channel and away from the influence of the Brunswick West TSF, the velocities are typically in the range of 1.0 – 2.5 m/s for both the base and post construction case. These are largely fed by surface flows from the catchment to the south/west of the existing drain entering into the drain through natural drainage channels (near cross sections 2, 4 and 5), and are beyond the impact of the Brunswick West TSF. To aid in minimising surface erosion within these drains for long-term closure, these areas should also be lined with erosion protection rip-rap. The design of these erosion protection measures for long-term would be part of a detailed closure study, and are beyond the scope of this design.

## 14 FOUNDATION AND EMBANKMENT MATERIAL PROPERTIES

### 14.1 Overview

As discussed in **Section 9.2**, ATCW conducted a geotechnical investigation and laboratory testing [27] to characterise the site and material parameters, which have informed the hydraulic performance and material strength parameters of the foundation and borrow materials used in the design.





Laboratory testing was also previously undertaken by URS as part of the Brunswick First Raise Design [25], which ATCW reviewed during the latest Brunswick raise [15]. Where relevant, these results have been discussed as a point of comparison.

## 14.2 In-Situ Clays

### 14.2.1 Hydraulic Performance

Field permeability testing was not undertaken on the natural clays in the geotechnical investigations. The hydraulic conductivity of the in-situ clays has therefore been inferred from the first consolidation stage of the triaxial tests from Laboratory Testing [27]. Hydraulic conductivities (from the coefficient of consolidation,  $C_v$ ) of  $6 \times 10^{-8}$  m/s and  $3 \times 10^{-9}$  m/s were found. For this design, a hydraulic conductivity of  $5 \times 10^{-8}$  m/s has been adopted. This value presents as a lower bound value for the in-situ clays in the context of low permeability materials.

### 14.2.2 Material Strength

The strengths of the in-situ clays was determined from two undrained triaxial tests undertaken on undisturbed tube samples obtained from the investigations as part of the laboratory testing [27].

A minimum undrained shear strength ratio at failure of  $S_u/\sigma_{vo}'$  of 0.35 was found for both samples. SPTs undertaken on the natural clays in the field found a minimum blow count of  $N = 18$ , implying the clay is very stiff. As such, a minimum shear strength of 20 kPa has also been adopted.

The triaxial stress paths of both the in-situ clay tests are presented in **Chart 10** and **Chart 11**.

The minimum inferred Critical State Line (CSL) (presented in **Chart 10**) has a gradient of  $M=1.20$ . This translates to a drained friction angle of  $30^\circ$  (assuming zero apparent cohesion), which is a similar result to the compacted clay results above. Plotting this failure envelope alongside the Mohr circles at failure (as represented as the solid purple line in **Chart 11**) and inferred Mohr Coulomb Failure Criterion (dashed black line in **Chart 11**) indicates a drained friction angle of  $30^\circ$  is under-representative of the in-situ clays at lower confining stresses, and over-representative at higher stresses, with the cross-over point at approximately 170 kPa. This 170 kPa is equal to approximately 8.5 m of rockfill overburden, which is less than the anticipated maximum height of the embankments. Therefore, the strength profile defined by the Mohr-Coulomb Failure Criterion ( $\phi' = 20^\circ$  and  $c' = 38$  kPa) will be adopted for design.

Field density testing of the undisturbed tubes collected from the investigation found a bulk density of between  $1.83 \text{ t/m}^3$  (near the surface) and  $2.35 \text{ t/m}^3$  (at depth). For the clays that will remain within the foundations, an average dry density of  $2.1 \text{ t/m}^3$  has been adopted, which equals a unit weight of approximately  $20.5 \text{ kN/m}^3$ .

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CHART 10: IN-SITU CLAY TRIAXIAL STRESS (DEVIATOR STRESS)

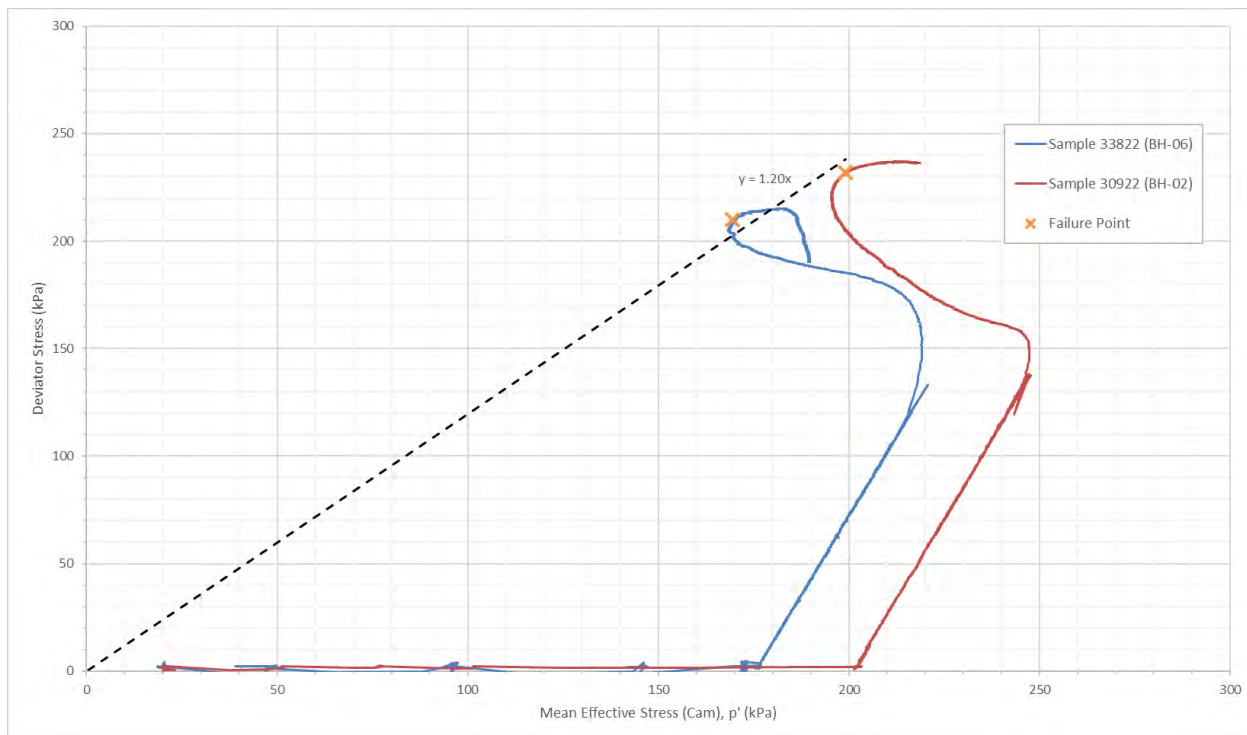
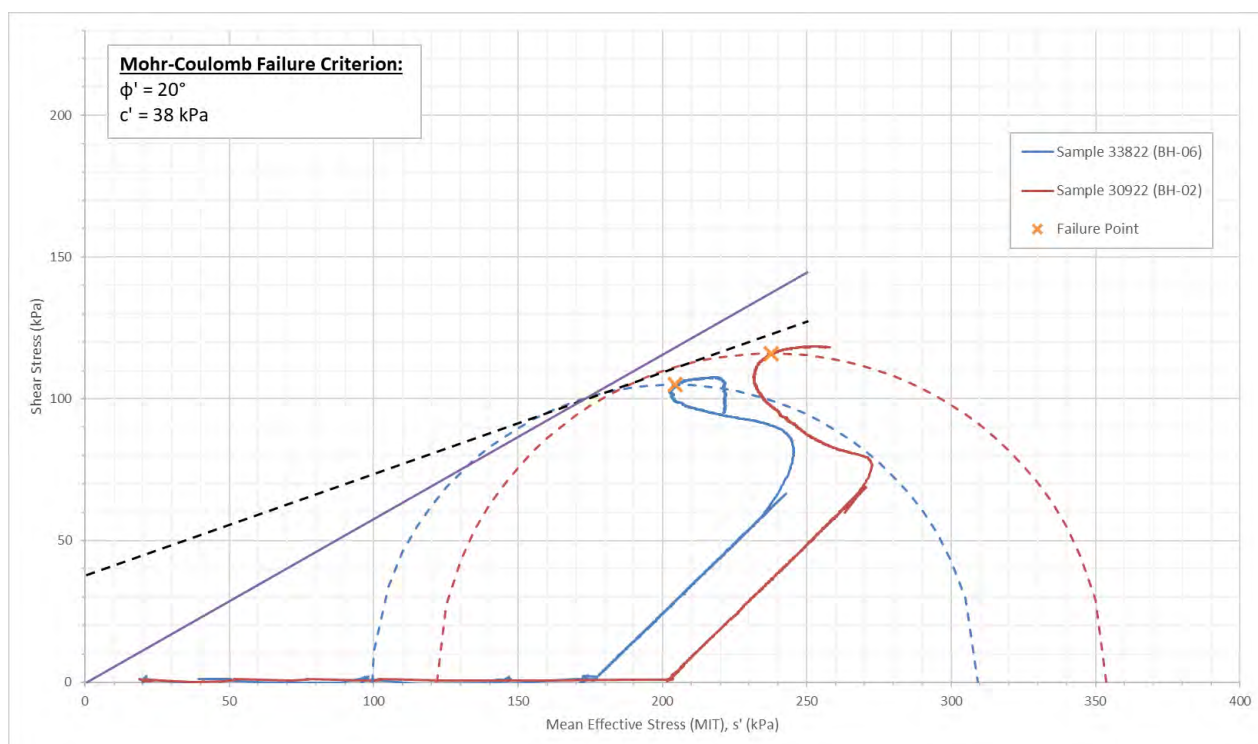


CHART 11: IN-SITU CLAY TRIAXIAL STRESS (SHEAR STRESS)



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## 14.3 Rock Foundations

### 14.3.1 Hydraulic Performance

Falling head permeability testing was undertaken as part of the geotechnical investigations [27]. It was found that the Extremely to Highly Weathered rock is highly permeable, with an estimated hydraulic conductivity of  $2.0 \times 10^{-5}$  m/s. It is likely that when tested, water drained through macro fractures and cracks in the rock mass itself, and likely represents a lower-bound estimate of in-situ permeability. Testing over the less weathered (i.e., Moderately Weathered rock) estimated a permeability of between  $1 \times 10^{-7}$  and  $2 \times 10^{-8}$  m/s.

For design purposes, a hydraulic conductivity of  $1 \times 10^{-5}$  and  $1 \times 10^{-7}$  m/s has been adopted for the EW/HW Rock and MW rock, respectively.

### 14.3.2 Material Strength

Strength of the Extremely Weathered to Residual Soil in-situ rock can be estimated based on the results of the SPTs. The lowest blow count found in the Extremely Weathered rock was  $N = 32$ . Based on the published literature, this correlated with a friction angle of approximately 36 degrees, which will be adopted for the design. The less weathered basement rock has been considered as impenetrable, with embankment stability considered as sliding on these foundations

## 14.4 Zone 1 Clay and Zone 1B Earthfill Subgrade

### 14.4.1 Hydraulic Performance

Constant Head Permeability testing was undertaken on blended samples of clays as part of the Laboratory Testing [27] compacted to 95% SMDD. The High Plasticity blended clay sample had hydraulic conductivity of  $1 \times 10^{-7}$  m/s, whilst the other two combined samples were at a minimum of  $1 \times 10^{-9}$  m/s.

Zone 1 Clay will be specified to exclude the High Plasticity Clays to achieve the VIC ERR Requirements for a clay liner [12] of 1.0m of  $1 \times 10^{-9}$  m/s. The Zone 1B Earthfill Subgrade will not be required to exclude High Plasticity Clays, as its primary function is act as a subgrade for the BGM liner rather than retain water. As such, a hydraulic conductivity of  $5 \times 10^{-8}$  m/s has been adopted.

### 14.4.2 Material Strength

The strengths of the remoulded clay was based on remoulded multi-stage triaxial tests undertaken on the high plasticity blended clay sample described above at 95% SMDD. It is noted that although Zone 1 Clay will exclude high plasticity clays, and Zone 1B will be blended from all clays on site, this high plasticity sample represents a lower bound of the typical strength profile of the clayey materials.

A minimum undrained shear strength ratio at failure of  $S_u/\sigma_{vo}'$  of 0.28 was found, which will be adopted for design. A minimum shear strength of 20 kPa will also be adopted.

The triaxial stress paths of the multi-stage triaxial are presented in **Chart 12** and **Chart 13**.

The inferred Critical State Line (CSL) (as presented in **Chart 12**) has a gradient of  $M=1.22$ , which translates to a drained friction angle of  $30^\circ$ , assuming zero apparent cohesion. Plotting a failure envelope of  $\phi' = 30^\circ$  and  $c' = 0$  kPa alongside the Mohr circles at failure (as presented in **Chart 13**) shows a good match. This failure envelope will therefore be adopted for the drained strength parameters.

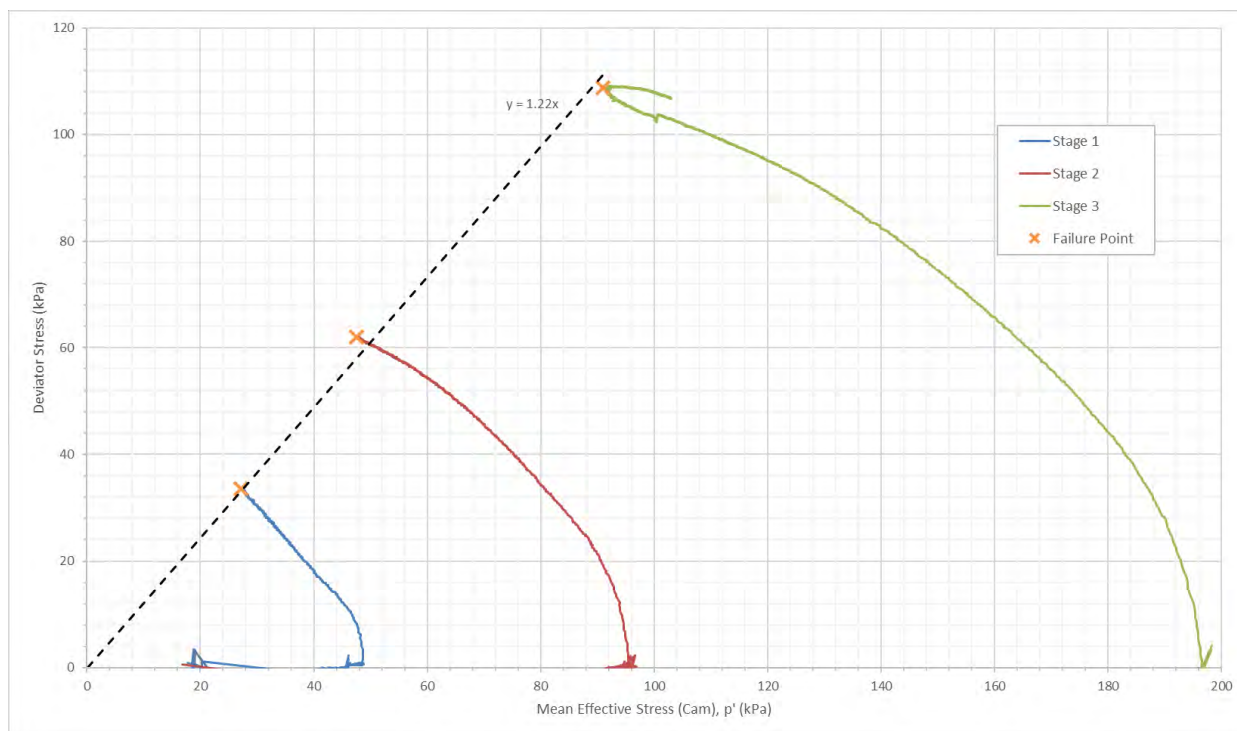
Standard Compaction testing of the clays found a Maximum Dry Density of the high plasticity clay blended sample as  $1.67 \text{ t/m}^3$  with an Optimum Moisture Content of 21%. The remaining two blended samples were found to have a Maximum Dry Density of around  $1.85 \text{ t/m}^3$  and an Optimum Moisture Content of around 15%.

The Zone 1 Clay will be required to be compacted to a minimum of 98% SMDD, while the Zone 1B can be accepted with less compactive effort at 95% SMDD. As such, the adopted unit weights for Zone 1 and Zone 1B are  $20.5 \text{ kN/m}^3$  and  $19.0 \text{ kN/m}^3$ , respectively.

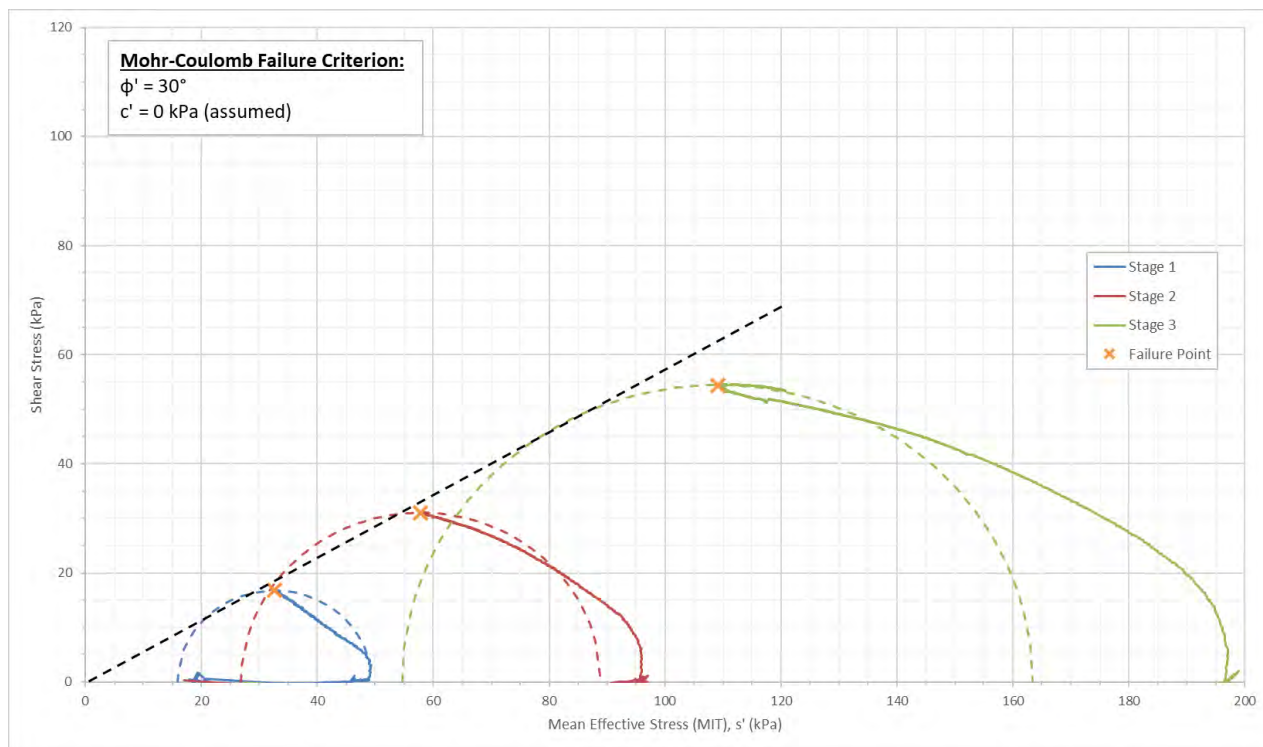




**CHART 12: COMPACTED CLAY TRIAXIAL STRESS PATH (DEVIATOR STRESS)**



**CHART 13: COMPACTED CLAY TRIAXIAL STRESS PATH (SHEAR STRESS)**



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## 14.5 Zone 3A and 3B Rockfill

### 14.5.1 Hydraulic Performance

No hydraulic testing had been undertaken on the compacted Zone 3A and 3B materials. Both materials are classified as rockfill and are generally free draining. Zone 3A comprises of more weathered particles with a higher fines content, and when compacted will be less permeable. Zone 3B generally comprises of more granular particles with a small amount of fine-grained material.

Previous assessments for the Brunswick TSF [15] and Bombay TSF [26] have assumed the rockfill material is relatively free draining. As such, hydraulic conductivities of  $1 \times 10^{-6}$  m/s for compacted Zone 3A and  $1 \times 10^{-5}$  m/s for Zone 3B have been adopted. For the Zone 3A material overlying the Zone 1 Foundation Clay liner, this material will remain uncompacted to aid in providing a free drainage layer for the draitube underdrains. As such, a hydraulic conductivity of  $1 \times 10^{-5}$  m/s has been adopted for this uncompacted region only.

### 14.5.2 Strength Profile

#### 14.5.2.1 Zone 3A

Zone 3A comprises of a well graded mixture of extremely and highly weathered rock particles, sands, silts and clays. As such, the material is typically more of an Earthfill type material than a rockfill.

The material parameters used for the Zone 3A materials have been based on research conducted by Simmons et al [41]. This research was conducted with respect to the shear strength of dumped spoil slopes of sedimentary rockfill for open pit coal mines in the Bowen Basin of Queensland. This approach is considered conservative, as whilst it does take into account weathered materials with matrix-supported structures, it does not necessarily consider the strength gains resulting from compaction.

Simmons [41] described the materials as subdivided into four categories and three possible strength mobilisation modes. The Category relates to physical attributes of the spoil material and the degree of structural control provided by the larger particle framework. For example, Category 3 spoils are predominantly gravel-sized, with the structure supported by the framework. Category 4 indicates a denser, cobble-sized structure with lower proportions of weak particles in the soil matrix.

The “saturated” strength mobilisation mode indicates materials which exhibit a fully softened strength profile due to repeated wetting and drying, regardless of whether true saturation is achieved. “Unsaturated” strength conditions relate to those materials which may compress to a limited extent due to particle crushing and reorientation under load, but do not soften appreciably.

Given the expected high proportion of fine-grained material and sourcing from Extremely and Highly Weathered rock, the Zone 3A material is expected to behave as a Category 2 material, with a matrix-supported structure. As such, Simmons [41] recommends the following strength parameters, which have been adopted for design;

- Unsaturated  $c' = 30 \text{ kPa}$   $\phi' = 28^\circ$
- Saturated  $c' = 15 \text{ kPa}$   $\phi' = 23^\circ$

#### 14.5.2.2 Zone 3B

Zone 3B material will comprise more of a typical rockfill mixture, with a limited amount of fine-grained material. It is well understood that rockfill shear strength is a function of the normal effective stress, dry density, particle roughness, particle crushing strength, grain size angularity and uniformity of grading. To reflect this, a number of rockfill shear strength functions are available which results in a curved strength envelope, which best represents the higher frictional strengths at low confining stresses, and the lower strengths at high overburden pressures due to suppressed dilation and particle crushing.

For this assessment, the Leps (1970) [42] shear stress-normal stress functions were both considered in assigning a strength profile to the rockfill.

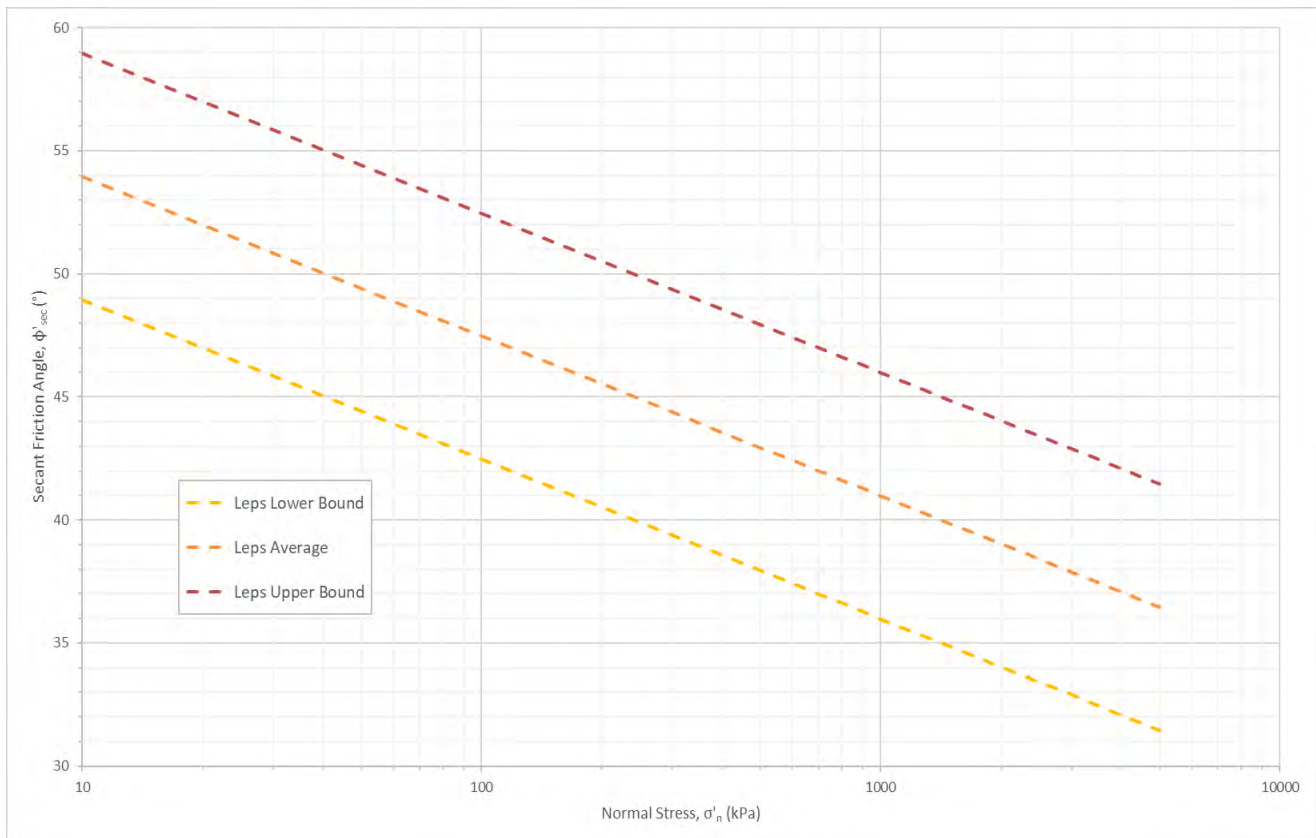
The Leps (1970) method is a database method which adopts upper, average and lower bound shear strength functions based on varying materials of differing grading, density and strength. Alternative





methods, such as Douglass (2003) [43], rely on more properties of the rockfill itself, such as the Angularity rating of the rock particles, Unconfined Compressive Strength, and a more detailed particle grading. Given that these factors are unknown, the Leps [42] Lower Bound function has been conservatively adopted, as shown in **Chart 14**.

**CHART 14: ZONE 3B STRENGTH PROFILE – NORMAL STRESS VS SECANT FRICITION ANGLE**



## 14.6 Tailings

### 14.6.1 Hydraulic Performance

As part of the design for the Bombay Cell 2 Starter embankment [23], Constant Head Permeability testing was undertaken on a flocculated tailings sample consolidated to  $1.56 \text{ t/m}^3$ . A hydraulic conductivity of  $1.4 \times 10^{-8} \text{ m/s}$  was found for this sample. A hydraulic conductivity of  $1 \times 10^{-8} \text{ m/s}$  has therefore been adopted for design.

### 14.6.2 Material Strength

The Brunswick West TSF does not feature any upstream raises, or any reliance on the strength of the stored tailings. As such, ATCW have conservatively assumed a shear strength of 0 kPa for the stored tailings. An overall dry density of  $1.3 \text{ t/m}^3$  has been assumed for the tailings to factor in the potential for evaporative drying, deposition at a relatively high solids concentration, and drainage of water through the underdrainage system. At a typical moisture content of around 25%, this equals a unit weights of approximately  $16 \text{ kN/m}^3$ .

## 14.7 BGM Liner

A hydraulic conductivity of  $1 \times 10^{-12} \text{ m/s}$  has been conservatively adopted for the BGM liner. This is noted to be two orders of magnitude lower values recommended by the manufacturers.





## 14.8 Liquefaction Assessment

### 14.8.1 Liquefaction Definitions and Mechanisms

Whilst there are no universally accepted definitions for liquefaction, it is nevertheless important to define the key terminologies and mechanisms. Those provided below are from ANCOLD [10] and Fell et al. [20] and have fairly wide acceptance:

Flow Liquefaction – Applies only to saturated, strain softening materials (e.g. very loose, granular deposits, sensitive clays and silt deposits), and requires in situ shear stresses greater than the ultimate undrained shear strength of the soil. Flow can be triggered by monotonic or cyclic loading, with deformations occurring after the triggering mechanism.

Cyclic Liquefaction - Can only occur under undrained cyclic loading during which excess pore water pressures surge, causing effective stresses to reach zero, meaning negligible shear strengths. Large deformations can occur when shear stresses are applied. Deformations occur during the cyclic loading and tend to stabilise once the cyclic loading stops.

Cyclic Mobility - Requires undrained cyclic loading, however unlike cyclic liquefaction, shear stresses are always greater than zero. Deformations during cyclic loading will stabilise, unless the material is very loose and flow liquefaction is triggered. Cyclic mobility can occur in any saturated sand where the magnitude and duration of the loading is sufficiently large. Cyclic mobility is possible in cohesive soils, however creep generally controls deformations.

Cyclic Softening – A term used to describe the reduction of shear strength and stiffness of clays and plastic silts under cyclic loading.

### 14.8.2 Methodology

Liquefaction susceptibility been assessed in accordance with current best engineering practise. The adopted procedure to estimate the potential for liquefaction of the tailings is described by the ANCOLD Guidelines for Design of Dams and Appurtenant Structures for Earthquakes [10],

1. Assess whether the materials susceptible to liquefaction, based on material classifications and saturation status. Exclude from further analysis non-liquefiable materials, as well as those above the phreatic surface which cannot become saturated;
2. For potentially liquefiable strata, assess the Factor of Safety (FoS) against liquefaction for the range of seismic Peak Ground Accelerations (PGA) applicable to the facility.

### 14.8.3 Liquefaction Susceptibility

The potential for liquefaction of the borrow materials under cyclic loading was initially assessed in accordance with the criteria described by Seed et al (2003) [44]. This assessment was based on a large database of field data, in conjunction with laboratory testing, to estimate liquefaction potential based on fines content and soil plasticity. Seed et al. indicated that for soils with sufficient fines content that the fines separate the coarser particles and control behaviour, and defined three regions within the plasticity chart;

- Zone A: Potentially susceptible to cyclic liquefaction
- Zone B: May be considered liquefiable
- Zone C: Are generally not considered susceptible to cyclic liquefaction but should be checked for potential sensitivity.

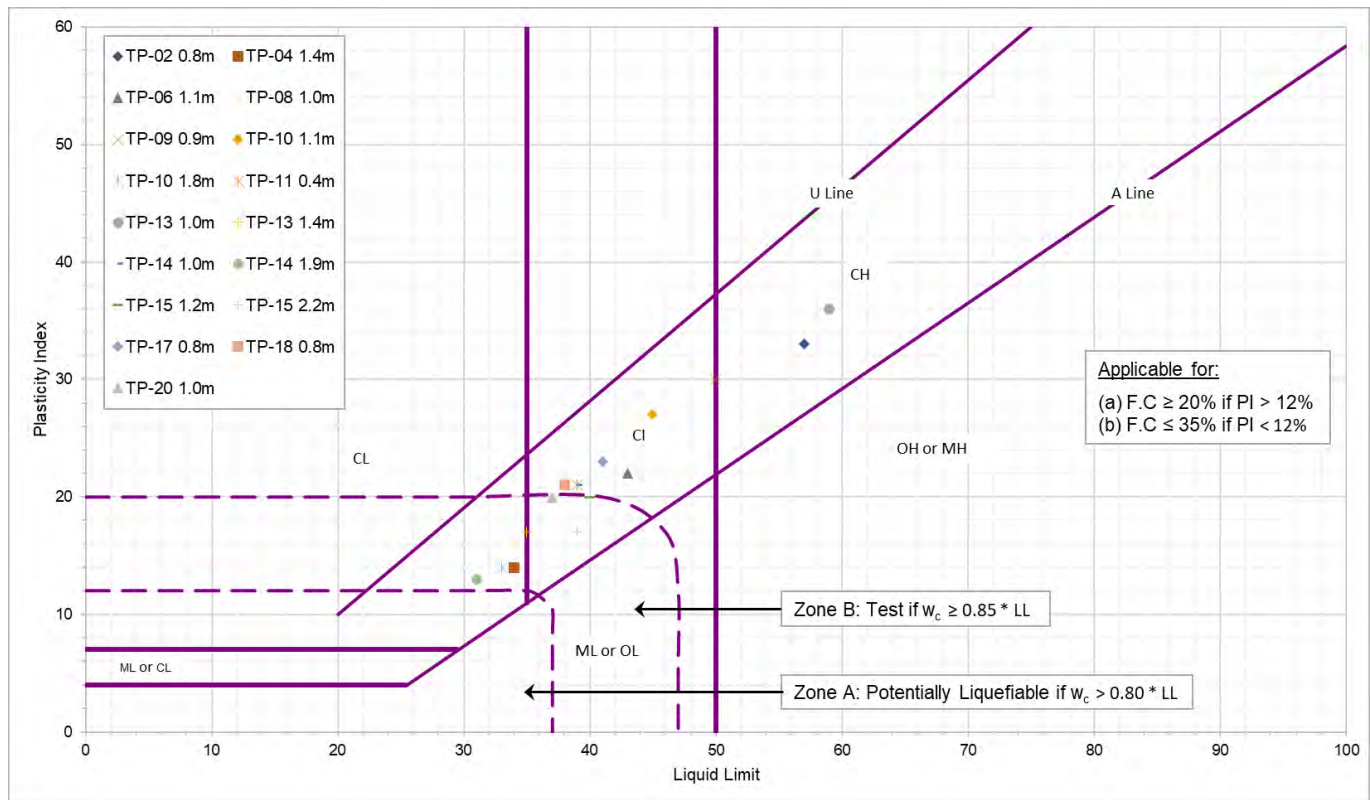
The Atterberg limits of the collected samples, along with the suggested regions susceptible to cyclic liquefaction, are presented in **Chart 15**.

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**CHART 15: POTENTIAL FOR LIQUEFACTION – PLASTICITY INDEX CHART**



It can be seen that 8 of the 22 samples collected from the Geotechnical Investigations fall within Zone B, and may be liquefiable. These materials are a mixture of gravelly clays and Extremely Weathered / Residual Soil Siltstone. The results of the Laboratory Testing for these samples, along with the criteria for Zone B, are presented in **Table 25**.

**TABLE 25: POTENTIAL FOR LIQUEFACTION – MATERIAL CHARACTERISATION**

| Sample Location | Depth (m) | Liquid Limit (%) | Plasticity Index (%) | 85% of Liquid Limit | Moisture Content (%) | $w_c \geq 85\% LL$ ? | Passing 75 $\mu$ m (%) |
|-----------------|-----------|------------------|----------------------|---------------------|----------------------|----------------------|------------------------|
| TP-04           | 1.4       | 34               | 14                   | 29                  | 16.5                 | No                   | 73.8                   |
| TP-08           | 1.0       | 34               | 16                   | 29                  | 12.8                 | No                   | 37.1                   |
| TP-10           | 1.8       | 33               | 14                   | 28                  | 11.8                 | No                   | 41.1                   |
| TP-13           | 1.4       | 35               | 17                   | 30                  | 14.3                 | No                   | 33.3                   |
| TP-14           | 1.9       | 31               | 13                   | 26                  | 11.6                 | No                   | 30.4                   |
| TP-15           | 1.2       | 40               | 20                   | 34                  | 14.8                 | No                   | 51.8                   |
| TP-15           | 2.2       | 39               | 17                   | 33                  | 13.7                 | No                   | 74.8                   |
| TP-20           | 1.0       | 37               | 20                   | 31                  | 14.6                 | No                   | 53.4                   |

None of the samples identified met with the criteria to rule out potential liquefaction, and may be susceptible to cyclic liquefaction. As such, the liquefaction susceptibility is required to be further assessed.





## 14.8.4 Liquefaction Resistance

### 14.8.4.1 Methodology

To assess whether the material will undergo cyclic liquefaction, the next stage of the assessment has been completed in accordance with current best engineering practise, using “simplified methods”.

The simplified methods, as described by ANCOLD [10], require the estimation of two variables for evaluation of liquefaction resistance of soils:

1. Cyclic Stress Ratio (CSR), which is a measure of the cyclic loading applied to the foundation materials by the earthquake loading, and
2. Cyclic Resistance Ratio (CRR), which is the capacity of the material to resist liquefaction. The CRR is estimated from geotechnical investigations such as Standard Penetration Tests (SPT), Cone Penetration Tests (CPT) or, the shear wave velocity.

The FoS against liquefaction can be calculated by CRR divided by the CSR. If the CSR is greater than the CRR, then the FoS < 1.0, and liquefaction is likely to occur.

For this assessment, the results of the SPT testing have been used to determine the Cyclic Resistance Ratio, utilising the methods described by Boulanger and Idriss (2012) [45] and Idriss and Boulanger (2008) [46]. This method normalises the field SPT blow count to a standardised blow count, then correlates these results to an equivalent blow count for a clean sand by adjusting for the fines content. The standardised equivalent clean sands blow count is then compared to similar samples that had undergone liquefaction from a historical database which fit the 15% probability curve for liquefaction.

This method initially gives CRR<sub>7.5</sub>, cyclic resistance ratios for Magnitude (M) 7.5 earthquakes. Smaller magnitude earthquakes giving the same Peak Ground Acceleration (PGA) are less likely to initiate liquefaction, because the earthquake will have fewer cycles of motion. This is allowed for by using a magnitude scaling factor (MSF) in **Equation 2** for factor of safety (FoS) against liquefaction

#### EQUATION 2: FACTOR OF SAFETY AGAINST LIQUEFACTION

$$FoS = \left[ \frac{CRR_{7.5}}{CSR} \right] MSF$$

Where;

*CRR<sub>7.5</sub>* = Cyclic Resistance Ratio for magnitude 7.5 earthquakes; and

*MSF* = Magnitude Scaling Factor

### 14.8.4.2 Seismicity

The ANCOLD Earthquake Guidelines [10] define this approach to design, with two levels of earthquake motion as follows:

- Operating Basis Earthquake: The OBE is used for the purposes of evaluating the serviceability of the dam, rather than its safety. It is an earthquake which could reasonably be expected to occur during the life of the dam, and should only result in minor, easily repairable damage.
- Safety Evaluation Earthquake: The SEE will produce the maximum level of ground motion for which the dam should be designed or analyses. It is a minimum requirement that the impounding capacity of the dam be maintained when subjected to the SEE.

For a High B Dam Failure Consequence Category, the ANCOLD Guidelines [9] recommend Safety Evaluation Earthquake be equal to the 1:5,000 AEP seismic event. However, as discussed in **Section 8** ATCW have adopted the 1:10,000 AEP seismic event for the SEE earthquake for the liquefaction assessment as means of demonstrating the robustness of the embankment design. Based on the site specific Probabilistic Seismic Hazard Assessment (PSHA) [5], a peak ground acceleration of 0.347g was found. A maximum magnitude of M<sub>max</sub> = 7.5 was also adopted.





### 14.8.4.3 Results

The liquefaction potential of the in-situ clays was assessed under the following conditions;

- Rockfill placed up to RL 200.0m, with 1.0m of clay stripped, and assuming a remaining 1.0m of remnant clay (note tests that were performed in the upper 1.0m during the investigations were applied to the remnant clays below);
- The clays are saturated to the top of the layer, with 2.0m of additional phreatic head applied;
- Samples were assessed as if they were present at the most critical section (15m of rockfill overburden applied).

The SPT liquefaction assessment was conducted for all tests in clay that did not refuse. The factors of safety against liquefaction for the tests conducted are presented in **Table 26**, with the full calculations presented in **Appendix E**.

**TABLE 26: LIQUEFACTION ASSESSMENT FACTORS OF SAFETY**

| Borehole | Cyclic Stress Ratio, $CSR_M, \sigma'v$ | Cyclic Resistance Ratio, $CRR_{7.5, \sigma'v}$ | Magnitude Scaling Factor, MSF | Factor of Safety Against Liquefaction <sup>(1)</sup> |
|----------|--|--|-------------------------------|--|
| BH-01    | 0.20                                   | 0.24   | 1.0                           | 1.21   |
| BH-02    |  | 0.36   |                               | 1.81   |
| BH-03    |  | 2.03   |                               | 5.00   |
| BH-04    |  | 20.1   |                               | 5.00   |
| BH-05    |  | 0.27   |                               | 1.35   |
| BH-07    |  | 0.54   |                               | 2.76   |
| BH-08    |  | 7.49   |                               | 5.00   |
| BH-11    |  | 20.1   |                               | 5.00   |
| BH-12    |  | 0.81   |                               | 4.11   |

Note (1) – Factor of Safety against liquefaction capped at 5.0

It can be seen from the results of the liquefaction assessment that the remnant in-situ clays are not expected to liquefy under the adopted 1:10,000 SEE. As such, it will be suitable for the embankment foundations to contain in-situ clay without being at risk of a potential embankment failure. Notwithstanding, the additional compaction of the foundation clays (to approximately 98% SMDD) should still be undertaken to further reduce any liquefaction potential.

### 14.8.5 Considerations for Post Seismic Assessments

The embankment materials used for construction of the TSF are considered as unlikely to liquefy. While it is noted that some of the materials that will be used in construction of Zone 1B (Gravelly Clay) and Zone 3A (Weathered Rockfill) were identified as susceptible to liquefaction (as presented in **Chart 15**), these materials will be compacted to relatively high (in excess of 95% SMDD) density, and will be unlikely to liquefy. The foundation materials have also been considered as non-liquefiable during seismic events based on the results of the SPT tests.

To account for potential strain softening which may be induced by a seismic event, ANCOLD [10] and Fell et al. [20] recommend the reduction in peak strengths. As such, the peak strengths of non-liquefiable embankment and foundation materials have been reduced by 20% to allow for this in post seismic stability analyses.

## 14.9 Summary

A summary of the material parameters for design are presented in **Table 27**.





**TABLE 27: SUMMARY OF MATERIAL PARAMETERS**

| Material                                   | Unit Weight (kN/m <sup>3</sup> ) | Undrained                                | Drained                             | Post-Seismic                          | Hydraulic Conductivity (m/s) |
|--|----------------------------------|--|-------------------------------------|---------------------------------------|------------------------------|
| Zone 1 Clay                                | 20.5                             | $S_u/\sigma'_v = 0.28$<br>Min 20 kPa     | $c' = 0$ kPa<br>$\phi' = 30^\circ$  | $S_u/\sigma'_v = 0.224$<br>Min 16 kPa | $1 \times 10^{-9}$           |
| Zone 1B Earthfill Subgrade                 | 19                               |  |                                     |                                       | $5 \times 10^{-8}$           |
| In-Situ Clay                               | 20.5                             | $S_u/\sigma'_v = 0.35$<br>Min 20 kPa     | $c' = 38$ kPa<br>$\phi' = 20^\circ$ | $S_u/\sigma'_v = 0.28$<br>Min 16 kPa  | $5 \times 10^{-8}$           |
| EW-HW Rock Foundations                     | 22                               | $c' = 0$ kPa<br>$\phi' = 36^\circ$       |                                     | $c' = 0$ kPa<br>$\phi' = 28.8^\circ$  | $1 \times 10^{-5}$           |
| MW Rock Foundations                        | -                                | Impenetrable                             |                                     |                                       | $1 \times 10^{-7}$           |
| Zone 3A Earthfill & Rockfill - Unsaturated | 18                               | $c' = 30$ kPa<br>$\phi' = 28^\circ$      |                                     | $c' = 24$ kPa<br>$\phi' = 22.4^\circ$ | $1 \times 10^{-6}$           |
| Zone 3A Earthfill & Rockfill - Saturated   | 20                               | $c' = 15$ kPa<br>$\phi' = 23^\circ$      |                                     | $c' = 12$ kPa<br>$\phi' = 18.4^\circ$ |                              |
| Zone 3B Rockfill                           | 22                               | Leps Lower Bound Shear Strength Function |                                     |                                       | $1 \times 10^{-5}$           |
| Tailings                                   | 16                               | $S_u = 0$ kPa                            | -                                   | $S_u = 0$ kPa                         | $1 \times 10^{-8}$           |
| BGM Liner                                  | -                                | -  | -                                   | -                                     | $1 \times 10^{-12}$          |

## 15 SEEPAGE ASSESSMENT

### 15.1 Overview

As part of the Brunswick West TSF construction, a series of seepage control measures will be installed, including a Bituminous Geomembrane liner along the embankment upstream face and impoundment excavation batter walls, compacted clay liner along the base of the impoundment excavation, and installation of an underdrainage system.

The purpose of the Seepage Assessment is as follows;

- To determine the seepage fluxes from the TSF at different expected water levels, considering the embankment as designed, and with a flaw in the BGM liner,
- To estimate the impact of the underdrainage system,
- To estimate the seepage losses from the external RWP at different expected water levels, and
- To determine the impacts, if any, the presence of the Brunswick West TSF will have on the regional groundwater, both during filling and post closure.

For the TSF seepage scenarios, the seepage assessment was undertaken at two sections around the facility;

- Typical section along the eastern side of the facility from where deposition will be occurring. This will represent the majority of the facility, as deposited tailings will push surface water towards the centre of the facility away from the embankments. The excavation floor will also grade away from the embankments. Details of this section are presented in **Figure 6**.
- South-western corner, where the decant water will be at its deepest and pooling against the embankments. The underdrainage and excavation floor will also grade towards the embankment. Details of this section are presented in **Figure 7**.





Assessment of the seepage from the external RWP been undertaken on the deepest section at the eastern side of the facility. Details of this section are presented in **Figure 6**.

For the impacts to groundwater, a long section through the centre of the facility has been considered.

The seepage analyses were undertaken with the proprietary software SEEP/W [47]. Steady state seepage was used for the embankment loss and underdrainage assessment, as this presents the worst-case scenario for seepage losses. A transient analysis was used to assess the impact to the groundwater regime, as this assessment is dependent on the impact with time.

## 15.2 Boundary Conditions

The boundary conditions applied to the model are summarised below:

### Embankment Seepage

- A potential seepage face is applied to the embankment downstream face and surface drains to simulate a free drainage boundary condition.
- A zero water rate is applied to the location of the underdrainage (where applicable) to simulate free drainage.
- For the TSF, a constant head boundary applied to the tailings surface corresponding to the expected pond level;
  - Normal Operating Pond – RL 198.2 m.
  - Maximum Operating Level – RL 198.9 m.
  - Spillway Invert Level – RL 199.5 m.
- For the external RWP, a constant head boundary applied to the impoundment corresponding to the expected pond level;
  - Normal Operating Pond – RL 184.0 m.
  - 99<sup>th</sup> Percentile Pond – RL 188.0 m
  - Spillway Invert Level – RL 191.2 m.

### Groundwater Impacts

- A potential seepage face is applied to the embankment downstream face and surface drains to simulate a free drainage boundary condition.
- A zero water rate is applied to the location of the underdrainage to simulate free drainage.
- A total head boundary equal to 0.5m above the tailings level was applied at the lower end of the tailings to simulate the normal operating pond. This is removed once the TSF reaches capacity.
- A pressure head boundary of 0.05m was applied to the of the remainder of the tailings to simulate ongoing deposition. This is removed once the TSF reaches capacity.
- An initial water table of RL 120.0 m was applied to the foundation rock for the transient assessment to simulate the dewatered levels around the Costerfield Site up to the anticipated end of underground mining and dewatering in Q3 2027. Post de-watering, this has been modelled to represent the expected recharge levels each year;
  - Year 0 – RL 120
  - Year 1 – RL 155
  - Year 1.5 – RL 172
  - Year 2.5 – RL 173





- Year 3.5 beyond – Increasing 1m per year until RL 180.0m
- Surface influx from rainfall has not been considered, as evaporation generally exceeds rainfall at the Costerfield site.

## 15.3 Material Parameters

Material properties for the seepage assessments are presented in **Table 27** in **Section 14.9**.

In addition to the hydraulic conductivity values, Matric Suction (Water Content vs Matric Suction) and Hydraulic Conductivity (Hydraulic Conductivity vs Matric Suction) functions have been generated for each of the materials.

Since no detailed laboratory testing was undertaken to determine these parameters, the estimated built-in functions within SEEP/W have been used, using the Fredlund-Xing-Huang method. These have been estimated based on the saturated hydraulic conductivities in **Table 27**, typical particle gradings and estimated saturated volumetric water content.

Based on the hydrogeology assessment (refer **Section 4.4**), the foundation rock consists of a relatively low permeability upper layer, and a more permeable upper layer due to the interconnected fractures along fault lines providing pathways for groundwater movement, as well as an expected rapid recharge once dewatering ceases. Based on the modelled historical groundwater recharge level, this boundary has been inferred at approximately RL 172.0 m. At the peak recharge rate (around 30 m/year), this equals a hydraulic conductivity of  $1 \times 10^{-5}$  m/s. An anisotropic ratio of  $K_y/K_x = 0.1$  has been adopted to simulate the interconnected fractures and rapid recharge rate.

## 15.4 Model Scenarios

### 15.4.1 Embankment Seepage & Underdrainage Performance

The assessment of the TSF embankment seepage and the underdrainage performance has been assessed using a steady state seepage analysis at the end of filling of the facility to full height. The following scenarios have been considered for both embankment sections:

1. As designed, with the BGM Liner fully functional.
2. As designed, with the BGM Liner fully functional and the underdrainage considered.
3. No BGM Liner or underdrainage (assumed worst-case scenario resulting from poor installation of the liner).

These three above scenarios have been considered at three different pond levels;

- Normal operating pond level (RL 198.2 m) to estimate long term seepage losses from the facility under typical operating conditions,
- Maximum operating pond level (RL 198.9 m) to estimate long term seepage losses from the facility under non-ideal operating conditions which may lead to an elevated operating level, and
- Spillway invert level (RL 199.5 m) to provide an indication of short-term seepage losses under temporary flooding conditions.

The performance of a typical underdrainage section has also been assessed at these expected water levels.

Assessment of the RWP embankment seepage has also been undertaken to understand the potential losses from the facility over the operational life.

### 15.4.2 Influence on Groundwater

To model the potential influence the Brunswick West TSF will have on the groundwater regime in the Costerfield Area, a transient seepage assessment was conducted over the life of the facility and post





deposition. The assessment was undertaken on a 6-monthly to yearly filling increment, with a monthly time-step within the seepage model. The following time stages were considered:

- End of Year 1 filling (April 2025). Tailings at RL 188.5m, Groundwater at RL 120.0m.
- End of Year 2 filling (April 2026). Tailings at RL 191. m, Groundwater at RL 120.0m.
- End of Year 3 filling (April 2027). Tailings at RL 194.5m, Groundwater at RL 120.0m
- End of Year 3.5 filling (September 2027). Tailings at RL 190.0m, Groundwater at RL 120.0m.
- End of Year 4.5 filling (September 2028). Tailings at RL 198.2m, Groundwater at RL 155.0m.
- End of Year 5.0 filling (April 2029). Tailings at RL 199.5m, Groundwater at RL 172.0m.
- End of Year 6.0 (April 2030). Tailings at RL199.5m, Groundwater at RL 173.0m.
- End of Year 7 to 10 (April 2031 to April 2034). Tailings at RL199.5m, Groundwater increasing at 1 m/year.

The assessment has considered a single long-section through the deepest part of the TSF along the alignment of the underdrainage. The aims of this assessment have been to determine if the Brunswick West TSF will impact the groundwater levels during filling, and if the recharged groundwater levels post-mining will impact the TSF.

## 15.5 Results

### 15.5.1 Embankment Seepage & Underdrainage Performance

The seepage flux rates from the TSF embankment steady state seepage assessment are summarised in **Table 28**, with the graphical Seep/W outputs presented in **Appendix F**. **Seepage flux rates collected by the underdrainage are estimated as the difference between the total loss and loss at the downstream toe. Seepage loss from the facility (i.e, collected in the downstream toe drains) is then estimated as the difference between the loss at the downstream toe and the loss from the model.**

**TABLE 28: TSF EMBANKMENT SEEPAGE FLUX RATES**

| Scenario                                       | Pond Elevation | Seepage Flux (L/day/unit width) |                |                | Figure |
|--|----------------|---------------------------------|----------------|----------------|--------|
|  |                | Total                           | Downstream Toe | To Environment |        |
| Section 1 – Eastern Embankment Typical Section |                |                                 |                |                |        |
| BGM Liner only                                 | 198.2          | 0.87                            | 0.87           | 0              | F1.1.1 |
| BGM Liner + Underdrainage                      |                | 0.87                            | 0              | 0              | F1.1.2 |
| No BGM Liner or underdrainage                  |                | -                               | 0.87           | 0              | F1.1.3 |
| BGM Liner only                                 | 198.9          | 8.4                             | 8.4            | 0              | F1.1.4 |
| BGM Liner + Underdrainage                      |                | 28.3                            | 0              | 0              | F1.1.5 |
| No BGM Liner or underdrainage                  |                | -                               | 11.4           | 0              | F1.1.6 |
| BGM Liner only                                 | 199.5          | 9.8                             | 9.8            | 0              | F1.1.7 |
| BGM Liner + Underdrainage                      |                | 40.4                            | 0              | 0              | F1.1.8 |
| No BGM Liner or underdrainage                  |                | -                               | 51.2           | 0              | F1.1.9 |
| Section 2 – Decant Area                        |                |                                 |                |                |        |
| BGM Liner only                                 | 198.2          | 12.5                            | 12.5           | 0              | F1.2.1 |
| BGM Liner + Underdrainage                      |                | 28.3                            | 0              | 0              | F1.2.2 |
| No BGM Liner or underdrainage                  |                | -                               | 67.7           | 0              | F1.2.3 |





| Scenario                      | Pond Elevation | Seepage Flux (L/day/unit width) |                |                | Figure |
|-------------------------------|----------------|---------------------------------|----------------|----------------|--------|
|                               |                | Total                           | Downstream Toe | To Environment |        |
| BGM Liner only                | 198.9          | 14.3                            | 14.3           | 0              | F1.2.4 |
| BGM Liner + Underdrainage     |                | 40.6                            | 0              | 0              | F1.2.5 |
| No BGM Liner or underdrainage |                | -                               | 97.9           | 0              | F1.2.6 |
| BGM Liner only                | 199.5          | 15.2                            | 15.2           | 0              | F1.2.7 |
| BGM Liner + Underdrainage     |                | 42.2                            | 0              | 0              | F1.2.8 |
| No BGM Liner or underdrainage |                | -                               | 125            | 0              | F1.2.9 |

The seepage assessment shows that with no significant flaws in the BGM liner, the phreatic surface through the embankment is controlled by the liner. No significant saturation of the embankment section occurs, with the phreatic surface remaining very low, developing at a maximum of 1m above the clay foundations. With the underdrainage considered, the phreatic surface through the tailings is much lower, resulting in a 3-5m thick region of unsaturated tailings at the base of the storage above the underdrainage, as well as further reducing the phreatic surface development in the foundations.

Estimations of total seepage loss from the facility at a given pond elevation will be a combination of both embankment sections, as well as the with and without underdrainage sections. Based on the expected deposition arrangement for the Brunswick West TSF, ~580 m of embankment is represented by Section 1 (perimeter deposition), with the remainder of the embankment (~400 m) represented by Section 2 (water pooling against embankments).

It can be seen that at sections where the underdrainage is present, losses from the facility are zero, independent of the pond level. As is shown in **Figure F1.3.1** (underdrainage typical section), the underdrains form an unsaturated zone approximately 10m wide. **Figure 5** presents the underdrainage layout plan, and shows 12 areas at the embankments where underdrainage will impact the seepage profile, 8 of which are within Section 1, and 4 of which are in Section 2. As such, there will be approximately 120 m of embankment where zero seepage is expected from the facility.

The estimated total seepage losses from the TSF are summarised in **Table 29**

**TABLE 29: ESTIMATED TOTAL SEEPAGE LOSSES**

| Pond Elevation | Embankment Section | Embankment Length (m) | Seepage loss from Embankment Section (L/day) | Total Seepage Loss |                         |
|----------------|--------------------|-----------------------|--|--------------------|-------------------------|
|                |                    |                       |  | L/Day              | L/Ha/day <sup>(1)</sup> |
| 198.2          | Section 1          | 580                   | = 80 x 0 + 500 x 0.87<br>= 435               | 4,935              | 897                     |
|                | Section 2          | 400                   | = 40 x 0 + 360 x 12.5<br>= 4,500             |                    |                         |
| 198.9          | Section 1          | 580                   | = 80 x 0 + 500 x 8.4<br>= 4,200              | 9,348              | 1,700                   |
|                | Section 2          | 400                   | = 40 x 0 + 360 x 14.3<br>= 5,148             |                    |                         |
| 199.5          | Section 1          | 580                   | = 80 x 0 + 500 x 9.8<br>= 4,900              | 10,372             | 1,886                   |
|                | Section 2          | 400                   | = 40 x 0 + 360 x 15.2<br>= 5,472             |                    |                         |

(1) Estimated based on total tailings beach area of ~ 5.5 Ha

It can be seen that for the normal operating conditions, total seepage loss is less than 5,000 L/day. Over the total tailings beach area of approximately 5.5 ha, this is less than 1,000 L/ha/day. Under long





term non-ideal operating conditions in combination with heavy rainfall, where the decant pond may reach the maximum operating level of RL 198.9 m and remain at that level for a significant period of time, the seepage rate is almost doubled to approximately 9,400 L/day. This excessive seepage can easily be mitigated through operational aspects of the TSF such as ensuring deposition at the design solids concentration to reduce the volume of decant water, and implementation of emergency pumping off the TSF to the External RWP following heavy rainfall to maintain the pond as low as possible.

With water at the spillway invert level of RL 199.5 m, the seepage rate is again increased to approximately 10,500 L/day. However, this is expected to be a short term condition resulting from the PMP storm event, and is expected not be significant compared to the amount of water that will be present in the downstream environment due to the excessive rainfall. Additionally, seepage of contaminants from the facility will be significantly diluted, as the majority of the water within the TSF will be as a result of rainfall runoff, compared to tailings decant.

When the facility is considered with no BGM liner or underdrainage in place, which simulates the worst-case scenario of a continuous fault through the BGM liner, the phreatic surface sits much higher, up to 4.0 m above the embankment foundations. The seepage rates from the facility are also increase significantly (as presented in **Table 28**). This scenario can easily be avoided during construction of the TSF through proper installation and quality control measures for placement, welding and leakage testing of the BGM liner.

It should be noted that this assessment has conservatively omitted the impact of tailings consolidation on the overall seepage losses from the facility. As the underdrainage systems provides for two-way consolidation of the tailings, a region of consolidated tailings will form at the base of the storage. In ATCW experience with consolidated gold tailings, they're expected to form a low permeability region at the base of the storage, with a hydraulic conductivity in the order of  $10^{-9}$  m/s. It is estimated the consolidated tailings may be between 3-5m thick as inferred from the unsaturated region presented in the SEEP/W outputs. This relatively thick, low permeability layer will aid in the containment of seepage, and will further reduce the seepage losses from the facility.

Overall, the design of the TSF with BGM liner over a clayey subgrade and foundation lining expected to be effective in minimising seepage emanating from the facility. Furthermore, the underdrainage network at the base of the impoundment will provide significant seepage collection at the primary seepage path. Additional seepage mitigation and collection measures, such as internal drains within the embankment or soil foundation are considered as unnecessary, as seepage through the BGM liner and into the embankment is negligible. Furthermore, seepage that is released from the embankment is expected to be readily evaporated, given the estimated seepage lost compared to the length of the embankment, and as such, downstream seepage collection ponds are not considered necessary.

## 15.5.2 External RWP Seepage

The seepage flux rates from the External RWP steady state seepage assessment are summarised in **Table 30**, with the graphical Seep/W outputs presented in **Appendix F**.

**TABLE 30: EXTERNAL RWP EMBANKMENT SEEPAGE FLUX RATES**

| Scenario                         | Pond Elevation | Seepage Flux (L/day/unit width) | Figure |
|----------------------------------|----------------|---------------------------------|--------|
| Normal Operating Pond            | 184.0          | $2 \times 10^{-9}$              | F1.4.1 |
| 99 <sup>th</sup> Percentile Pond | 188.0          | 0.03                            | F1.4.2 |
| Spillway Invert Level            | 191.2          | 0.4                             | F1.4.3 |

The seepage assessment for the External RWP found that the synthetic liner will sufficiently prevent seepage from the facility. At the normal operating pond, effectively zero seepage is expected from the facility, and even at very high pond levels, the seepage losses are incredibly small (less than 0.4 L/day/unit width). Under the extreme conditions of the pond being maintained at spillway invert level, approximately 120 L/day of seepage is estimated for an embankment crest length of 300 m, significantly outperforming the TSF.

The inclusion of the synthetic liner along the base of the External RWP impoundment in addition to the embankment walls allows for effectively zero seepage losses under typical operating conditions. This





is noted to be to a higher standard than was adopted for the TSF (foundation clay liner plus BGM on impoundment walls). The disparity in lining standards between the two storages is due to the following:

- Storage requirements of the External RWP. The External RWP will be used to store bleed and surface runoff from the Brunswick West TSF, as well as surface water from the inactive Brunswick and Bombay TSF's, and will therefore be subject to higher water level fluctuations due to rainfall runoff than the TSF. The facility also serves as a water supply for the Brunswick Processing Plant, and minimisation of losses due to seepage is essential to ensure continual operation of the Brunswick Processing Plant.
- Overall costing. The size of the External RWP is significantly smaller than the TSF, making it cost efficient to synthetically line the entire facility when compared to the alternative of a lime-treated (for management of the natural dispersive clays) soil liners. The inclusion of an additional synthetic liner on the floor of the TSF would add significant material costing (over 50% material increase) to the project.

It is considered that the disparity in the lining standards between the TSF and external RWP is acceptable, given the seepage management capability of the current arrangement for the TSF (refer **Section 15.5.1**).

### 15.5.3 Influence on Groundwater

The graphical Seep/W outputs from the transient seepage analyses are **Appendix F**.

During initial filling up to Q3 2027, the Brunswick West TSF is not expected to impact the drawn-down groundwater around the site. If the phreatic surface development within the TSF was affecting the groundwater, a localised "mounding" would be expected from the basement groundwater level, increasing slightly in the vicinity of the TSF. However, no such groundwater mounding was observed in the transient seepage model, and it is evident that the TSF underdrainage is providing suitable drainage to prevent the build-up of excess water levels within the TSF tailings.

Beyond Q3 2027, once dewatering ceases around the Brunswick West site, the rising groundwater is still not impacted by the TSF, with no mounding observed. Once deposition ceases in Year 6, the phreatic surface level within the tailings begins to decrease, with only a region against the embankments expected to remain saturated, though it is possible at this time that the underdrainage system will cease working, as the tailings at the base of the deposit will have consolidated, and significantly decreased the hydraulic conductivity. With deposition ceased, the positive hydraulic gradient provided by the decant pond is no longer present, and the driving head that could cause an impact on the groundwater is removed.

The recharged groundwater will eventually reach the base of the excavation at approximately RL 180m. However, by this stage, the facility is expected to have been capped and closed, and downwards migration of tailings water into the groundwater levels will be minimal.

## 16 EMBANKMENT STABILITY ASSESSMENT

### 16.1 Overview

The following section details the static and post seismic stability assessment of the Brunswick West TSF after construction and following filling with tailings. The governing design principle is that the embankment must be designed such that the integrity of the structures with respect to stability under static and seismic loading conditions is preserved.

The stability of the Brunswick West TSF has been undertaken at the critical section at the southernmost end of the facility, where the embankment height will be at its maximum, and the anticipated depth of remaining in-situ clay will be at its thickest (1.0m).

The stability analyses were undertaken with the proprietary software SLOPE/W [48], utilising the General Limit Equilibrium (GLE) method, satisfying both force and moment equilibrium criteria.

#### End of Construction and End of Filling

Static stability was assessed for both the End of Construction and End of Filling scenarios.





The End of Construction (i.e., short term) stability was assessed immediately after the final stage of construction, prior to the deposition of tailings. Given that no perched water table was identified in the foundations and that the construction of the embankments will not occur rapidly, no additional pore pressures have been considered from this assessment. The End of Construction case has considered upstream and downstream failures of the facility, and has considered both undrained and drained conditions.

End of Filling (i.e., Long Term) stability was assessed immediately after filling with tailings, with the decant pond at the spillway invert level, and a significant flaw in the upstream BGM Liner. The End of Filling case has considered downstream failures of the facility that would result in a loss of containment.

#### End of Filling – Post Seismic / Liquefaction

Post seismic / liquefaction stability was undertaken to assess the ultimate safety of the TSF after sustaining the effects of seismic loading (i.e., strain softening or liquefaction). As the concern is the overall safety of the embankment, as opposed to operational issues, the post seismic assessment has been undertaken for the Safety Evaluation Earthquake (SEE), refer to **Section 14.8.4.2**.

Strain softened parameters have been adopted, as none of the foundation or embankment fill materials were considered as liquefiable. The post seismic assessment has considered a downstream failure that would result in a loss of containment.

## **16.2 Stability Criteria**

Embankment Stability has been assessed using the following minimum Factors of Safety (FoS) as recommended in the ANCOLD [9] guidelines;

- Short Term (drained or undrained)      FoS  $\geq 1.5$  (loss of containment)  
FoS  $\geq 1.3$  (no loss of containment)
- Long Term (drained or undrained)      FoS  $\geq 1.5$
- Post-seismic      FoS  $\geq 1.2$

## **16.3 Material Properties**

Material properties for the stability assessments are presented in **Table 27** in **Section 14.9**.

## **16.4 Phreatic Surface Conditions**

At the end of construction, the facility is assumed to be dry, with no significant pooling of water within the base of the TSF.

At the end of filling, the phreatic level has been taken as equal to the spillway invert level to assess the worst-case scenario for the facility. It has been assumed that a fault in the BGM liner has occurred and gone unrepaired, allowing for the development of a phreatic surface through the embankment section.

## **16.5 Results**

A summary of the stability analyses for the Brunswick West TSF are presented in **Table 31**, with the Slope/W output presented in **Appendix G**.

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**TABLE 31: SUMMARY OF STABILITY RESULTS**

| Scenario                        | Failure            | Factor of Safety | Figure |
|---------------------------------|--------------------|------------------|--------|
| End of Construction (Undrained) | Upstream Failure   | 1.7              | G1     |
|                                 | Downstream Failure | 2.8              | G2     |
| End of Construction (Drained)   | Upstream Failure   | 1.9              | G3     |
|                                 | Downstream Failure | 3.4              | G4     |
| End of Filling                  | Downstream Failure | 3.0              | G5     |
| Post Seismic                    | Downstream Failure | 2.1              | G6     |

It can be seen from the stability assessment that the ANCOLD [9] recommended minimum factors of safety against embankment failure are met.

## 16.6 Impact to Brunswick Pit

Pit wall instability can be a concern when high embankments are constructed within close proximity to a pit wall with very weak rock, applying surcharge loads to the rock wall and potentially inducing a slip failure.

The Brunswick West TSF embankment toe is at least 35m away from the northern end Brunswick Pit where the walls are very shallow and unlikely to fail. The current arrangement of the Brunswick Pit has up to 5m of waste rock stockpiled at the north-western wall, and no stability issues have historically been reported. As such, the Brunswick West TSF embankments providing surcharge and contributing to pit wall instability is not considered a risk

## 17 DEFORMATION ASSESSMENT

### 17.1 Overview

The ANCOLD Guidelines for seismic design [10] recommend a staged approach to deformation analyses. The basic approach recommends the estimations using one or more of the available screening /database methods. If the calculated deformations are at or approaching levels, further analyses are required. Further analyses should first utilise one of the simplified methods, and only proceed to detailed numerical analyses if the results of the simplified approaches are unacceptable.

### 17.2 Methodology

In accordance with the ANCOLD Guidelines [10], deformation analyses have been conducted to estimate the potential deformation (crest settlement) of the Brunswick West TSF associated with an SEE earthquake event. The following simplified empirical methods have been utilised for this assessment:

- Swaisgood (2003) [49] and
- Pells and Fell (2003) [50].

For a High B Dam Failure Consequence Category, the ANCOLD Guidelines [9] recommend Safety Evaluation Earthquake be equal to the 1:5,000 AEP seismic event. However, as outlined in **Table 8 (Section 8)** ATCW have adopted the 1:10,000 AEP seismic event for the SEE earthquake for the deformation assessment. Based on the site specific Probabilistic Seismic Hazard Assessment (PSHA) [5], a peak ground acceleration of 0.347g was hence adopted. An earthquake magnitude of  $M_{max} = 7.5$  and distance of 12.0 km have also been adopted from this assessment.





## 17.3 Empirical Database Methods

### 17.3.1 Swaisgood (2003)

The Swaisgood (2003) [49] method utilises a database on embankment dams which have been subject to earthquake and relates the amount of deformation and cracking to the earthquake loading experienced by the dam. The method requires the following inputs:

- Embankment height (including soil foundation thickness), and
- Earthquake Magnitude and Peak Ground Acceleration (PGA).

Crest settlement (as a percentage of the embankment height) is estimated in **Equation 3**.

#### EQUATION 3: ESTIMATED CREST SETTLEMENT – SWAISGOOD (2003)

$$\% \text{ Settlement} = e^{(6.07*PGA+0.57*M-8.0)}$$

The parameters used and results of the Swaisgood assessments are presented in **Table 32**.

**TABLE 32: SWAISGOOD (2003) SEISMIC DEFORMATION PARAMETERS AND RESULTS**

| Parameter                                     | Swaisgood (2003) [49] |
|---|-----------------------|
| Earthquake Magnitude, M                       | 7.5                   |
| Peak Ground Acceleration, PGA (g)             | 0.347                 |
| Maximum Embankment + Alluvial Soil Height (m) | 15                    |
| Crest Settlement (%)                          | 0.2%                  |
| Crest Settlement (mm)                         | 30                    |

The results of Swaisgood (2003) [49] estimate crest settlement in the range of 30 mm. When compared to the Swaisgood database, presented in **Chart 16**, this indicates a relative degree of damage of “Minor” to “None”.

### 17.3.2 Pells and Fell (2003)

The second empirical database method was developed by Pells and Fell (2003) [50], which utilised a larger database than the Swaisgood methods. This method used two correlations; one for earth and rockfill dams, and one for earthfill dams.

For this assessment, the earthfill dam correlation has been conservatively used, given the borrow source for rockfill of Extremely to Highly Weathered siltstone. The Embankment Damage plots at the lower edge of Class 3 (Major Damage), as shown in **Chart 17**. The Damage Classification System for embankment dams under earthquake loading is presented in **Table 33**.

Given the position on the estimated damage class presented in **Chart 17**, the lower range estimate for Class 3 damage has been considered, with an estimated settlement of approximately 75mm to 100mm expected, though this may be as high as 225 mm.

Given the empirical nature of these assessments, this is in general agreement with the Swaisgood (2003) methodology [49], which estimated approximately 30mm of settlement.

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CHART 16: SWAISGOOD (2003) RELATIVE CREST SETTLEMENT VS PGA

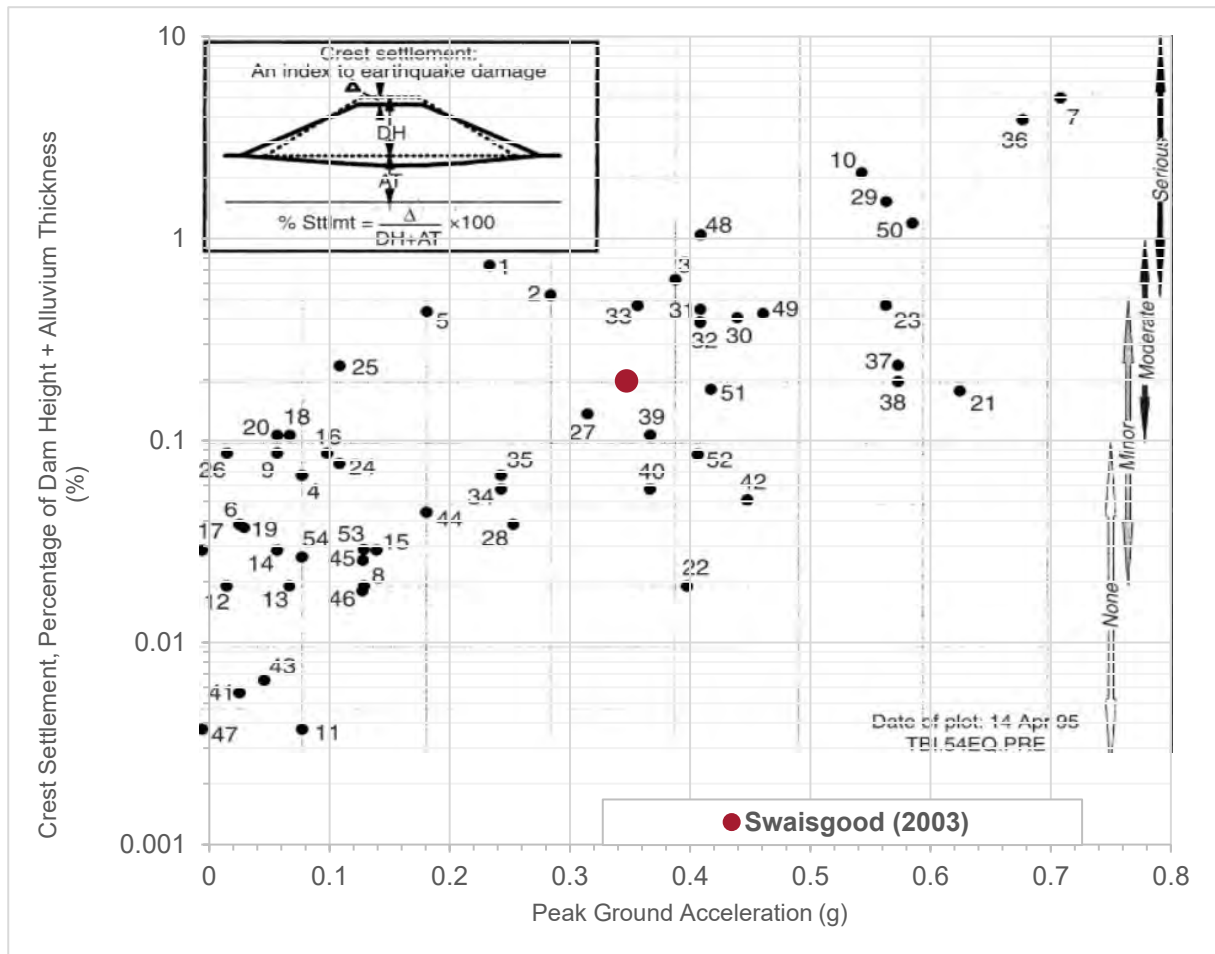
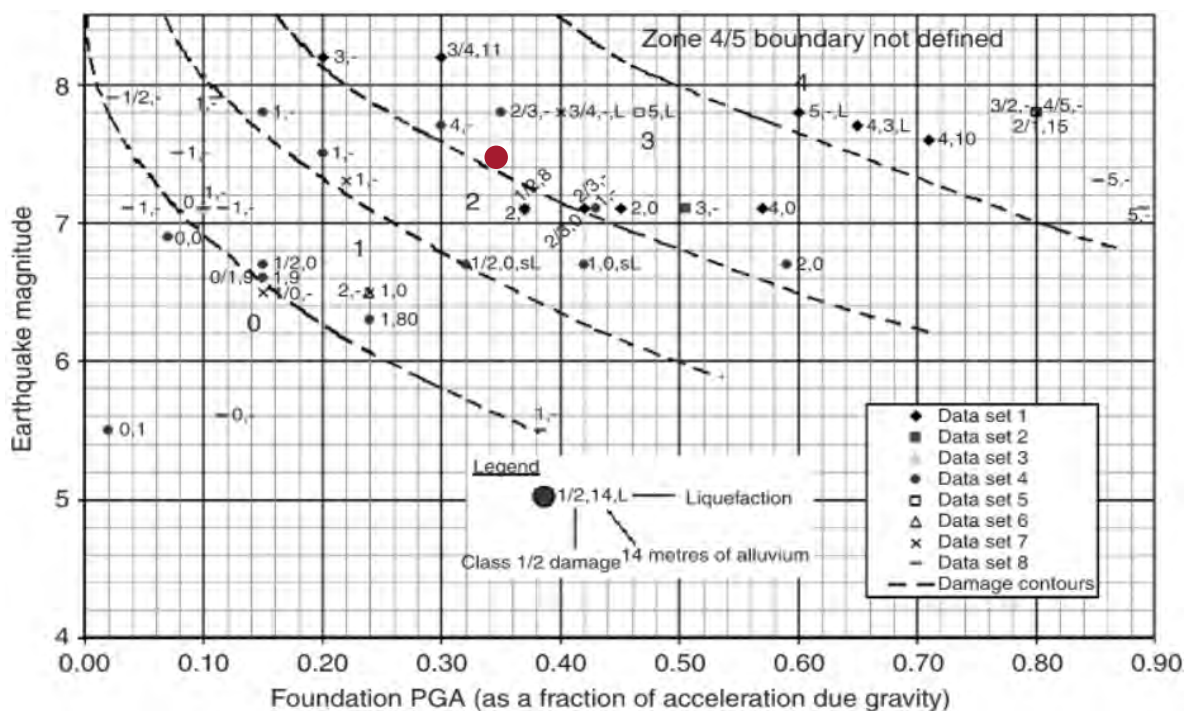


CHART 17: CONTOURS OF DAMAGE CLASS VS EARTHQUAKE MAGNITUDE AND PGA – EARTH AND ROCKFILL DAMS (PELLS AND FELL 2003)







**TABLE 33: DAMAGE CLASSIFICATION SYSTEM (PELLS AND FELL 2003)**

| Damage Class No. | Description  | Maximum Longitudinal Crack Width (mm) | Maximum Relative Crest Settlement (%) | Estimated Settlement (mm) |
|------------------|--------------|---------------------------------------|---------------------------------------|---------------------------|
| 0                | No or Slight | <10                                   | <0.03                                 | <4.5                      |
| 1                | Minor        | 10 – 30                               | 0.03 – 0.2                            | 4.5 – 30                  |
| 2                | Moderate     | 30 – 80                               | 0.2 – 0.5                             | 30 – 75                   |
| 3                | Major        | 80 – 150                              | 0.5 – 1.5                             | 75 – 225                  |
| 4                | Severe       | 150 – 500                             | 1.5 – 5                               | 225 – 750                 |
| 5                | Collapse     | >500                                  | >5                                    | >750                      |

## 17.4 Summary

The empirical database methods have estimated seismic deformation in the range of 30 to 100mm. The Brunswick West TSF will have a specified minimum tailings beach freeboard of 500mm, and a spillway depth of 500mm. It is evident there is a sufficient margin between the amount of seismic deformation predicted by the empirical database methods for the SEE earthquake and the minimum freeboards provided.

In accordance with ANCOLD [10], the use of empirical database methods is at a sufficient level for this study, and it is not considered necessary to undertake a more complex numerical analysis for estimation of deformation during earthquakes.

## 18 EMBANKMENT AND FOUNDATION SETTLEMENT

Post construction settlement of an embankment is, to some degree inevitable. Settlement of the embankment crest may occur as a result of compression of the embankment materials particles, from normal saturation cycles of rainfall and infiltration, as well as compression and compaction foundation soils due to overburden loading.

Based on studies of the behaviour of sedimentary rock masses [51], post construction static settlement of 0.75% to 1% is possible for well compacted rockfill when subject to saturation cycles. For the Brunswick West TSF, the rockfill is expected to remain in largely unsaturated as a result of the BGM liner (refer **Section 15**), and embankment settlement is only possible from the rockfill particles degrading and being crushed, which is expected to be negligible for the Brunswick West TSF. Under the extreme cases of a failed BGM liner, only the lower few metres of rockfill is expected to become saturated due to seepage from the TSF, resulting in less than 50 mm of settlement, which is well within the road base and crest camber of the embankment crest, considered acceptable for this type of embankment.

Settlement within embankment foundations typically occurs where thick layers of soft, compressible soils remain within the foundations, which are then subject to loading from the embankment. The soil profile at the Brunswick West TSF site largely comprises of up to 2.0 m of soils overlying extremely weathered siltstone. As discussed in **Section 11.5**, foundation preparation over natural soil will comprise of the stripping a minimum 0.5m topsoil plus an additional 0.5m of clays to provide borrow material for embankment construction, followed by compaction of the remnant clays to 98% SMDD. Additionally, in-situ density of the foundation clays undertaken as part of the Geotechnical Investigations [27] found the clays to generally be at a naturally high density and close to the maximum dry density. It is considered that the relatively low thickness of remaining clay and high level of compaction specified will minimise the potential for settlement to occur in the embankment foundations, and the expected settlement will be negligible.

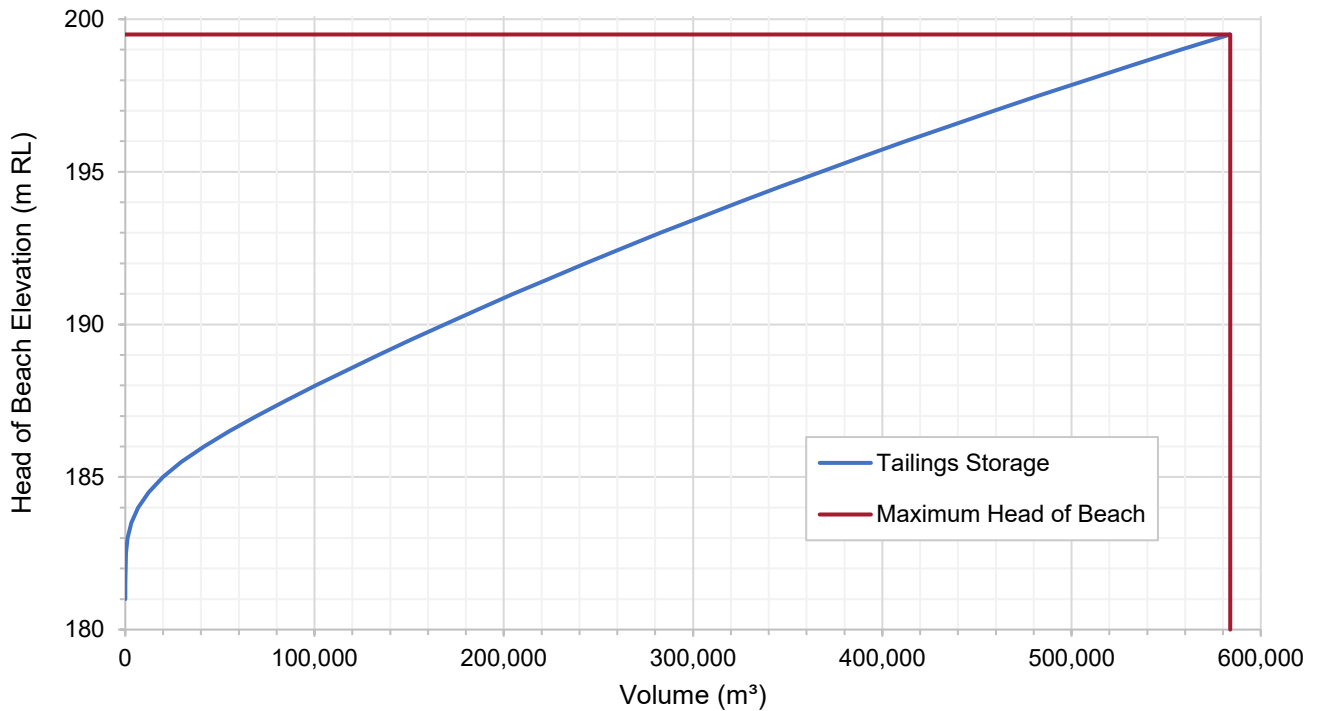




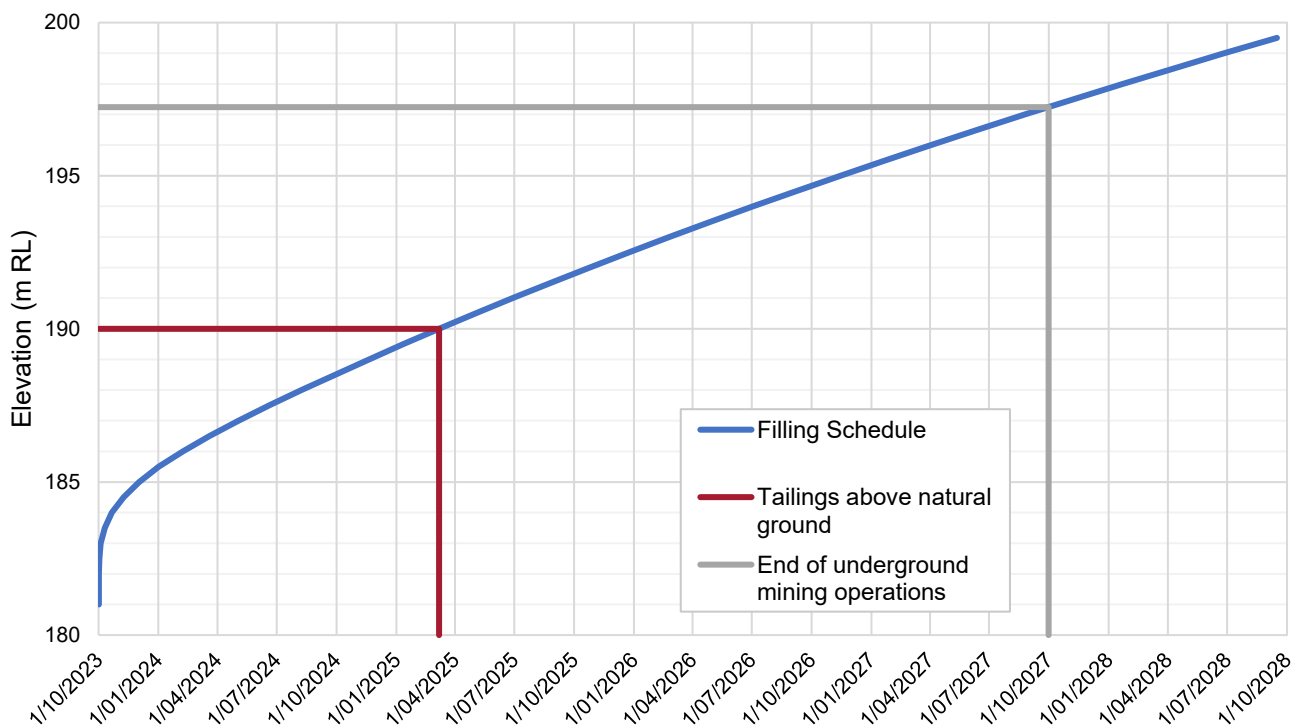
## 19 STORAGE CAPACITY

The tailings volumetric filling curve for the Brunswick West TSF is presented in **Chart 18**, and the estimated filling schedule (elevation vs time) is presented in **Chart 19**. A layout plan of the facility at the end of filling is presented in **Figure 11**.

**CHART 18: TAILINGS VOLUMETRIC FILLING CURVE**



**CHART 19: TAILINGS FILLING SCHEDULE**







At the maximum tailings head of beach of RL 199.5 m, the Brunswick West TSF will have capacity for 584,000 m<sup>3</sup> of tailings, with the tailings rising at between 2.3 and 4.0 m/year, which is generally considered acceptable for this type of facility. The facility will provide storage for the Brunswick Processing Plant for approximately 5 years. Assuming deposition commences in October 2023, storage will be provided until September 2028.

A summary of the tailings storage is presented **Table 34**.

**TABLE 34: TAILINGS STORAGE SUMMARY**

| Parameter                                       | Results |
|---|---------|
| Tailings Maximum Head of Beach (m RL)           | 199.5   |
| Total Volumetric Capacity (m <sup>3</sup> )     | 584,000 |
| Average In-situ Density (tonne/m <sup>3</sup> ) | 1.3     |
| Total Capacity (tonne)                          | 759,000 |
| Average Tailings Production Rate (tonne/day)    | 419     |
| Facility Storage Life (days)                    | 1,811   |
| Facility Storage Life (months)                  | 60      |

## 20 QUANTITIES

The estimated borrow and construction quantities for the Brunswick West TSF are summarised in **Table 35**, and an earthworks materials balance is presented in **Table 36**.

**TABLE 35: ESTIMATED BORROW AND CONSTRUCTION QUANTITIES**

| Item                               |                          | Unit                 | Quantity       |
|------------------------------------|--------------------------|----------------------|----------------|
| <b>Borrow</b>                      |                          |                      |                |
| Topsoil Stripping                  | TSF Embankment Footprint | m <sup>3</sup>       | 27,000         |
|                                    | Impoundment Footprint    | m <sup>3</sup>       | 20,000         |
|                                    | External RWP Footprint   | m <sup>3</sup>       | 7,500          |
|                                    | Toe Drains               | m <sup>3</sup>       | 2,500          |
|                                    | <b>Total</b>             | <b>m<sup>3</sup></b> | <b>57,000</b>  |
| Clay                               | TSF Embankment Footprint | m <sup>3</sup>       | 27,000         |
|                                    | Impoundment Excavation   | m <sup>3</sup>       | 40,000         |
|                                    | External RWP Footprint   | m <sup>3</sup>       | 7,000          |
|                                    | Existing Farm Dams       | m <sup>3</sup>       | 5,000          |
|                                    | Toe Drains               | m <sup>3</sup>       | 2,000          |
|                                    | <b>Total</b>             | <b>m<sup>3</sup></b> | <b>79,000</b>  |
| Extremely to Highly Weathered Rock | Impoundment Excavation   | m <sup>3</sup>       | 80,000         |
|                                    | External RWP Footprint   | m <sup>3</sup>       | 13,000         |
|                                    | <b>Total</b>             | <b>m<sup>3</sup></b> | <b>93,000</b>  |
| Less Weathered Rock                | Impoundment Excavation   | m <sup>3</sup>       | 165,000        |
|                                    | ROM Pad Stripping        | m <sup>3</sup>       | 45,000         |
|                                    | <b>Total</b>             | <b>m<sup>3</sup></b> | <b>210,000</b> |





| Item   |                                | Unit                 | Quantity       |
|--|--------------------------------|----------------------|----------------|
| <b>Required</b>  |                                |                      |                |
| Zone 1 (Clay)  | Impoundment Base Lining        | m <sup>3</sup>       | 27,000         |
| Zone 1B (Clayey Gravel to Gravelly Clay)                 | TSF Embankment Subgrade        | m <sup>3</sup>       | 44,000         |
|  | RWP Embankment                 | m <sup>3</sup>       | 17,000         |
|  | <b>Total</b>                   | <b>m<sup>3</sup></b> | <b>88,000</b>  |
| Zone 3A (Earthfill & Weathered Rockfill)                 | TSF Embankment                 | m <sup>3</sup>       | 55,000         |
|  | Toe Drains                     | m <sup>3</sup>       | 1,000          |
|  | <b>Total</b>                   | <b>m<sup>3</sup></b> | <b>56,000</b>  |
| Zone 3B (Rockfill)                                       | TSF Embankment                 | m <sup>3</sup>       | 310,000        |
|  | TSF Access Ramp                | m <sup>3</sup>       | 3,500          |
|  | ROM Access Realignment         | m <sup>3</sup>       | 3,500          |
|  | Northern Flood Protection Bund | m <sup>3</sup>       | 3,500          |
|  | Southern Flood Protection Bund | m <sup>3</sup>       | 5,000          |
|  | <b>Total</b>                   | <b>m<sup>3</sup></b> | <b>325,500</b> |
| Topsoil Replacement                                      | TSF Embankment Downstream      | m <sup>3</sup>       | 14,500         |
|  | RWP Embankment Downstream      | m <sup>3</sup>       | 1,500          |
|  | <b>Total</b>                   | <b>m<sup>3</sup></b> | <b>16,000</b>  |
| Zone S (Erosion Protection Rockfill)                     |                                | m <sup>3</sup>       | 1,000          |
| Road Base  |                                | m <sup>3</sup>       | 1,700          |
| Decant Structure Pipelines (DN630 HDPE)                  |                                | l.m.                 | 150            |
| Pre-cast concrete pit (2m x 3m x 2m)                     |                                | Item                 | 1              |
| Decant Structure Filter Geotextile (Texcel R Range 600R) |                                | m <sup>2</sup>       | 300            |
| Zone S Geotextile (Bidim A64)                            |                                | m <sup>2</sup>       | 2,000          |
| Draintube (DDG DT FT2 D25)                               |                                | l.m.                 | 900            |
| Bituminous Geomembrane Liner (TSF)                       |                                | m <sup>2</sup>       | 49,000         |
| Geosynthetic Liner (RWP)                                 |                                | m <sup>2</sup>       | 13,000         |

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**TABLE 36: EARTHWORKS MATERIALS BALANCE**

| Material                             | Available           | Required          | Net                 | Outcome  |
|--------------------------------------|---------------------|-------------------|---------------------|--|
| Topsoil                              | 57,000              | 16,000            | 41,000<br>Surplus   | Additional topsoil to be placed on downstream batters (if detailed closure plan permits)<br>Excess topsoil to be stockpiled to the north of the facility for later rehabilitation use around site. |
| Clayey Material (Zone 1 and Zone 1B) | 79,000              | 88,000            | 9,000<br>Shortfall  | RWP embankment material Zone 1B to be blended with weathered rockfill  |
| Weathered Rockfill (Zone 3A)         | 93,000              | 56,000 +<br>9,000 | 28,000<br>Surplus   | Excess to be blended into Zone 3B  |
| Rockfill (Zone 3B)                   | 210,000 +<br>28,000 | 325,500           | 87,500<br>Shortfall | Material to be borrowed from existing stockpiles.  |

The Earthworks materials balance identified that construction of the Brunswick West TSF will result in approximately 87,500 m<sup>3</sup> required to be borrowed from existing stockpiles. However, it is noted that the infrastructure works associated with flood protection of the Brunswick Underground Portal are only required while this entrance remains open. MRCO have informed ATCW that underground mining and access from the Brunswick Portal is forecast to cease in Q3 2027. Beyond this time, the Potential for Loss of Life (PLL) associated with this area will be removed, and the flood protection measures would no longer be required. This would include;

- Removal of ROM Access Re-alignment and restoring current access (regain ~3,500 m<sup>3</sup>),
- Removal of the Northern Flood Protection bund (regain ~3,500 m<sup>3</sup>), and
- Removal of the Southern Flood Protection Bund (regain ~5,000 m<sup>3</sup>).

The net result is that approximately 12,000 m<sup>3</sup> of rockfill material can be returned to stockpiles for future closure use. In the long term, approximately 75,500 m<sup>3</sup> of rockfill will be required to be permanently borrowed from stockpile.

## 21 CONSTRUCTION CONSIDERATIONS

### 21.1 Contractor Requirements

The contractor shall provide all suitable equipment required to allow for completion of the works. This is primarily concerned around the provision of suitably large hydraulic earthmoving equipment capable of readily excavating the foundation rock to the design depths.

The contractor will also be required to engage suitably qualified subcontractors for the installation of the BGM liner, HDPE Liner and the Underdrainage system. The Contractor will be required to submit documentation of the relevant experience of the sub-contractor for approval to ensure they are suitably qualified to undertake the work to a high standard, provide all the relevant construction quality assurance and quality control in both installation and testing, and provide documentation on the installation methodology, including panel placement, weld locations and location of temporary ballasting to prevent wind uplift.

### 21.2 Sediment, Erosion and Water Management

The contractor will be required to develop a sediment and erosion management plan as part of their construction works. This plan will outline all temporary measures required to minimise washout of sediment beyond the construction works, and will be required to meet the Victorian EPA requirements for sediment and erosion control. This should include, but is not limited to, the extents and sizing for , temporary drains and bunds, location of silt fences, and temporary downstream sedimentation ponds.





The contractor will also be required to maintain the construction works in a dry state, free of standing or running water to ensure the integrity of the embankment constructed and minimise water loss from the works site during construction.

## 21.3 Construction Supervision

As part of the construction process, it is envisaged ATCW will provide both office-based support and on-site supervision of the construction works. ATCW will fill the roles of the Design Engineer to provide technical assistance to MRCO and the Contractor, as well as the Site Engineer to provide on-site 3<sup>rd</sup> party quality assurance of the works. ATCW's involvement will consist of, but is not limited to, the following:

### Office based project support:

- General project management, client and contractor liaison.
- Review of the contractors Quality Management Plan and field quality documentation (ITPs and ITRs), and proposed sub-contractors experience.
- Providing engineering responses to RFI's.
- Reviewing and updating specifications and drawings, as required.
- Preparation of the construction report

### On-site construction supervision:

- Undertaking routine inspections and documentation of the works.
- Provision of on-site advice to the contractor to ensure the design intent is met.
- Attend on-site progress meeting between the contractor and MRCO.
- Reviewing the results of compaction trial testing.
- Visual inspections of the material quality and compaction where testing is not required.
- Signing off of QA/QC documentation.
- Provision of additional full-time supervision of the critical elements;
  - Installation of the BGM liner for the TSF;
  - Installation of the HDPE liner for the RWP;
  - Construction of the decant structure, and
  - Installation of the underdrainage.

ATCW will provide part-time supervision (2-3 days per week) during the bulk of the civil works (foundation preparation, excavation and embankment construction), as well as full-time during construction of the critical elements listed above.

## 21.4 Construction Monitoring

Construction monitoring (piezometers and movement monitoring stations) is generally required where there is a risk of the excess pore pressure build-up in soft soils from rapid embankment construction. The worst-case scenario is static liquefaction of the soils, and partial failure of the constructed embankment. This generally occurs from the following three factors:

- High groundwater table within the soil (either natural or from a nearby dam),
- Soft/weak alluvial soils (typically silts) with low shear strength and slow dissipation properties, and
- Rapid earthworks construction applying overburden pressures without allowance for the excess pore pressures to dissipate.





The geotechnical investigation did not identify any natural groundwater at the Brunswick West TSF site. Additionally, groundwater monitoring bores installed from this investigation have not reported any water since the investigation.

The foundations for the Brunswick West TSF will comprise of the remnant natural clays, compacted in-situ to 98% SMDD, providing significant resistance against liquefaction of the clays from excess pore pressures. Furthermore, the seismic liquefaction assessment (refer **Section 14.8**) found the clays to be non-liquefiable under the SEE, and are not expected to be statically liquefiable.

Construction of the embankments, particularly the downstream zones, is expected to be generally quite slow, given the large embankment footprint. Any excess pore pressures generated in the clays from placement of a layer of rockfill are likely to have fully dissipated by the time the next subsequent layer is required.

Based on these above factors, construction monitoring is not considered as necessary as part of the embankment construction. Notwithstanding, the contractor shall assess the safety of the site on a daily basis, and any issues pertaining to embankment stability regarding the embankment foundations should be brought to the attention of ATCW to review and determine if any further measures are required.

## 22 FACILITY OPERATION

### 22.1 Operation Plan

In accordance with ANCOLD Guidelines [9] and Victorian ERR [12] regulatory requirements for a High Consequence Category TSF, an Operations and Maintenance Manual will need to be prepared for the Brunswick West TSF. This will include hydraulic performance criteria, and instructions to cover all necessary monitoring, daily and weekly routing inspections and surveillance activities. Tailings deposition, decant and return water management procedures will also be documented.

In accordance with the ANCOLD Guidelines [9], An Operations, Maintenance and Surveillance (OMS) Manual will be developed for the facility prior to the commencement of tailings deposition.

### 22.2 Tailings Delivery and Return Water

The tailings delivery pipeline will run along the southern edge of the TSF access ramp, crossing over the embankment crest, then along the upstream crest edge in an anti-clockwise direction. The pipelines should not run around the southern side of the facility to prevent potentially blocking the emergency spillway. To allow for vehicle access over the entire crest, the tailings delivery pipelines should be placed within a suitably sized pipeline sleeve across the embankment crest at the design level of RL 200.0 m, then additional road base material built up over the pipeline sleeve.

The return water pipelines from the decant structure will be positioned to run directly down the embankment downstream crest, crossing the clean water diversion drains over the erosion protection material, and into the external RWP. Suitable pipeline supports, such as metal stands, will be required over the crossing of the drains to ensure they remain unimpeded. These pipelines will also be required to cross the TSF embankment crest, and a similar road crossing as adopted for the tailings delivery pipelines should be utilised.

The return water pipelines from the external RWP are expected to tie in with the existing return water pipelines from Bombay TSF. These pipelines will run along the downstream edge of the embankment through the ROM pad and along the northern side of the ROM access road.

To minimise the risk of material flowing off lease in the event of a pipe burst, tailings delivery and return water pipelines should be sleeved within an additional HDPE pipeline in high risk areas, such as up the TSF embankment ramp, and from the RWP to the Brunswick Processing Plant.

The expected alignment of the tailings delivery pipelines and return water pipelines are presented in **Figure 5**, **Figure 9** and **Figure 11**.

As discussed in **Section 10.8**, ATCW are currently engaged with MRCO for the design of the tailings delivery and return water systems for the Brunswick West TSF, with the details of the mechanical infrastructure will be forthcoming upon completion of that study. This will include (but is not limited to)





P&ID diagrams, recommended pipeline diameters, spigot arrangements and recommended minimum pump specifications.

## 22.3 Surveillance and Monitoring

### 22.3.1 Monitoring Overview

This monitoring component of the Operation Plan will be to collect the data necessary to evaluate the performance of the TSF with respect to the original design expectations. The data will form the basis of annual surveillance audits, which will be used to assess, and instigate required maintenance programs, and calibration of the water balance model.

Some of the key monitoring items will include the following (but is not limited to):

- Routine reconciliation of tailings discharge tonnages and solids concentrations,
- Routine monitoring of tailings beach head and beach toe levels,
- Routine monitoring of the performance of the decant structure and decant pump,
- Routine monitoring of water levels and processing plant return water rates,
- Routine monitoring of the groundwater monitoring bores,
- Inspections of the surface drainage measures
- Field evaluation of tailings beach density and shear strength profiles.

Key monitoring items will evolve and be refined as the facility is operated. Records of the monitoring data collected should be kept in an organised and legible format to be reviewed and incorporated into the annual inspection reports.

### 22.3.2 Surveillance

In accordance with ANCOLD Guidelines [9] for a High B Consequence Category TSF, the Brunswick West TSF will be subject to the surveillance inspection regime presented in **Table 37**. This is a non-exhaustive list, and should be reviewed and developed as the Brunswick West TSF is operated.

**TABLE 37: REQUIRED SURVEILLANCE INSPECTION**

| Inspection Type | Frequency | Personnel            | Purpose   |
|-----------------|-----------|----------------------|---|
| Routine         | Daily     | Operations Personnel | <p>Focus on operational performance of the TSF.</p> <p>Will include:</p> <ul style="list-style-type: none"> <li>• Visual inspection of the tailings and return water pipelines for leaks/deficiencies.</li> <li>• Visual inspection of the deposition spigots, and rotating the spigots if necessary.</li> <li>• Visual inspection of the decant pond, noting the approximate size, depth and location.</li> <li>• Visual inspection of the decant structure, noting any deficiencies in the pipelines, filter geotextile or pump</li> <li>• Visual inspection of the return water pond, measuring the depth and condition of the water.</li> </ul> |
| Routine         | Weekly    | Operations Personnel | <p>Focus on the condition of the TSF and RWP embankments, and appurtenant structures, and potential maintenance items required.</p> <p>Will include</p> <ul style="list-style-type: none"> <li>• Visual inspection of the embankments crest and batters, noting for any signs of erosion, cracking, wheel rutting, pooling of water, seepage or excessive vegetation growth.</li> </ul>   |



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| Inspection Type | Frequency                                    | Personnel            | Purpose   |
|-----------------|--|----------------------|---|
|                 |  |                      | <ul style="list-style-type: none"> <li>Visual inspection of the exposed BGM in the TSF and Geosynthetic liner in the RWP noting for tears or holes, or signs of distress.</li> <li>Visual inspection of the clean water diversion drains, noting for signs of excessive erosion, slumping/failures, excessive vegetation growth, or any other blockages which may impede the performance of the drain</li> <li>Visual inspection of the emergency spillways, noting for any blockages or signs of distress</li> <li>Visual inspection of the access roads and tracks, noting for signs of erosion, cracking, wheel rutting, or pooling of water.</li> <li>Visual inspection of the flood protection bunds, noting for signs of erosion or slumping, or any other conditions which may impact the bund structural integrity</li> <li>Visual inspection of the overall development of the tailings beach, and planning for the following weeks deposition strategy.</li> <li>Measurement of the tailings level at the deposition points and the decant structure</li> <li>Inclusive of all items undertaken as part of the routine (daily) inspections</li> </ul>   |
| Routine         | Monthly - Quarterly                          | Operations Personnel | <p>Focus on the collection of monitoring data which will feed into the Annual/Comprehensive inspection.</p> <p>Will include:</p> <ul style="list-style-type: none"> <li>Measurement of the Groundwater Monitoring Bores</li> <li>Review of satellite survey monitoring undertaken.</li> <li>Review of aerial survey undertaken.</li> </ul>  |
| Intermediate    | Annually                                     | Dams Engineer        | <p>Third-party inspection of the TSF and RWP as a whole.</p> <p>Will include:</p> <ul style="list-style-type: none"> <li>Visual inspection of all embankments, drains, spillways, and access roads for signs of deficiencies, such as erosion, cracking, seepage, wheel ruts, pooling of water, excessive vegetation growth, blockages or other signs of distress.</li> <li>Visual inspection of the liner systems to identify potential holes, tears or damages, and recommendations of repairs if necessary.</li> <li>Visual inspection of the decant structure.</li> <li>Visual inspection of the overall development of the tailings beach.</li> <li>Measurement of the tailings level at the deposition points and the decant structure.</li> <li>Measurement of the decant pond and RWP pond levels on the day of the inspection</li> <li>Review of the routine inspection sheets</li> <li>Review of all collected monitoring data</li> <li>Review of tailings storage performance (reconciliation of the stored tailings, densities, storm storage capacity, and remaining capacity)</li> <li>Providing recommendations on the action items to be completed before the next inspection.</li> </ul> |
| Comprehensive   | After first year of operation, then 2 yearly | Dams Engineer        | <p>Third-party inspection of the TSF and RWP as a whole.</p> <p>Will include</p> <ul style="list-style-type: none"> <li>Inclusive of all visual inspection items and measurements undertaken as part of an Intermediate Inspection</li> <li>Testing of the performance of the decant pump and RWP pump.</li> </ul>  |





| Inspection Type | Frequency | Personnel | Purpose   |
|-----------------|-----------|-----------|---|
|                 |           |           | <ul style="list-style-type: none"> <li>Review of the routine inspection sheets</li> <li>Review of all collected monitoring data</li> <li>Review of tailings storage performance (reconciliation of the stored tailings, densities, storm storage capacity, and remaining capacity)</li> <li>Review of all process data (discharge solids concentration, throughput rates) and any tailings laboratory testing undertaken.</li> <li>Providing recommendations on the action items to be completed before the next inspection.</li> </ul> |

## 22.4 Dam Safety Emergency Plan

In accordance with ANCOLD Guidelines [9], a Dam Safety Emergency Plan (DSEP) is required to be developed prior to the commencement of tailings deposition. The DSEP will be informed by the results of the Dam Break assessment [16], and will include inundation maps, methods for identification of a potential dam breach progression, evacuation times and procedures for all downstream populations. The DSEP is required to be reviewed annually and tested at regular intervals.

## 22.5 Instrumentation

The design of the TSF is not sensitive to the development of a phreatic surface through the embankment. As such, no embankment piezometers are required.

To monitor for potential seepage losses from the facility and the impact to groundwater, it is recommended that Groundwater Monitoring Bores be installed at six locations around the toe of the embankment, coinciding with low points in the natural topography. At each location, two bores should be installed; one shallow (typically 2-4m) and one at depth (typically 10-15m) to allow for monitoring of seepage rates through both the upper soil horizon and deeper through the foundation rock.

The locations and typical details of the groundwater monitoring bores is presented in **Figure 11**.

MRCO currently monitor the movement and settlements of the Bombay and Brunswick TSFs via regular drone surveys. **MRCO have committed to extending this survey to include the Brunswick West TSF for embankment movement monitoring, with survey undertaken on a quarterly basis.**

## 22.6 Operation For Storage of Tailings Fines Only

MRCO have indicated to ATCW that they are currently assessing alternative tailings disposal options for the coarse fraction of the tailings produced by the Brunswick Processing Plant. As such, the Brunswick West TSF may be required to store only the fine fraction from the tailings stream.

From an embankment safety perspective, this will not be an issue as the embankments do not rely on the tailings strength. It is also not expected to be an issue from an operations perspective, however MRCO shall commit to completion of the following to validate the design of the Brunswick West TSF for storage of tailings fines only:

- Laboratory testing on the tailings fine fraction to establish the depositional and settling characteristics,
- Validation of the decant structure filter capacity, and
- Re-assessment of the water balance to verify the operation pond and external RWP performance.





## 23 CONCEPTUAL CLOSURE PLAN

### 23.1 Overview

The Conceptual Closure Plan is designed to meet the requirements of the VIC ERR Tailings Guidelines [12], which are in turn derived from the ANCOLD Guidelines [9].

The Conceptual Closure Plan aims to:

1. Securely store the tailings for an indefinite period, and prevent the hazard to public health and safety, or the environment;
2. Make the closed TSF inherently stable and resistant to degradation;
3. Ensure the closed TSF is commensurate with the surrounding landscape and land uses, and
4. Design the closed TSF for the long term, with minimum requirement for long term maintenance and upkeep.

This section presents the conceptual closure plan, and details regarding the staging and construction of closure will be subject to detailed assessment and design.

### 23.2 Closure Concept Plan

#### 23.2.1 Assumptions

In the development of this closure plan, the following assumptions have been made:

1. The conditions at the end of filling will be as modelled (refer **Figure 11**), such that a minimum of 500mm freeboard is maintained between the embankment crest and tailings head of beach, and the tailings surface will develop the beach slopes (1.5% for 50m, 0.6% runout) adopted for design;
2. The tailings will be dewatered with the removal of as much water as is practical using the existing pumping system;
3. The tailings surface will form a desiccated crust capable of supporting tracked construction plant, permitting the relatively straight forward placement of a cover over the tailings using inert mine spoil and overburden materials, generally requiring a minimum of 15 kPa in the upper 3 – 5m of tailings deposit to support light weight earthmoving equipment.

As part of the raise 4 design, in-situ strength testing was undertaken on the Bombay TSF tailings [26] less than 1 year after deposition ceased. Shear vane and CPTu traces found a minimum shear strength of around 8-10 kPa in the upper few metres of the deposit, with the tailings surface readily trafficable by foot. Given no material change is expected in the tailings properties and the similar deposition methodology, it is expected that the Brunswick West TSF tailings will have formed a suitable strength crust within 2-3 years after ceasing deposition;

4. The tailings will continue to remain as inert and Non-Acid Forming (NAF) tailings so that a relatively straight forward self-shedding cover to contain and isolate the tailings is adequate.

#### 23.2.2 Closure Concept

A basic conceptual closure plan was developed for the Brunswick TSF as part of the RL 1196.2 Raise Design [15], which has also been considered for Bombay TSF. It is considered that a similar closure landform will be adopted for the Brunswick West TSF. Ultimately, the closed Brunswick West TSF will have a similar land use as to pre-construction, providing pasture and grazing land for livestock.

It is noted that, as part of the Brunswick West TSF design, the embankment downstream batter slopes will be constructed to 4:1 (H:V) slopes, covered with a minimum of 300mm of topsoil and seeded with local grasses to promote vegetation growth. The primary intention of this has been to address the visual amenity of the site that will come with construction of a ~15 metre high dam and removal of previously planted trees along the Brunswick site perimeter, as well as to reduce the amount of topsoil





required to be stockpiled. Construction of the embankment batters to their closure profile will also minimise the closure works required at the end of life of the facility. These batter slopes are flatter than the proposed 3:1 (H:V) slopes for Brunswick TSF and Bombay TSF.

Formation of the closure landform is generally undertaken to ensure long term stability of the structure (addressing items 1 and 2 in **Section 23.1**), and to minimise surface erosion that can occur without the regular maintenance a facility would experience during operation (addressing item 3).

Since detailed closure erosion modelling is beyond the scope of this design, 4:1 closure batter slopes have been chosen as a typical closure slope for an embankment of this height (up to 15m).

### 23.2.3 Closure Landform

The developed conceptual closure landform will have the following attributes:

1. A domed (convex), self-shedding cover with a 5% grade.
2. The cover layers will comprise a low permeability earthfill material, overlain by inert (i.e., non-acid generating) earthfill and weathered rockfill, and a final layer of topsoil to support revegetation.
3. The low permeability earthfill material will be placed directly over the tailings surface and will be:
  - a. A minimum thickness of 0.5m at the perimeter embankment, and increase in thickness over the tailing surface towards the centre of the TSF to form a minimum 5% grade from the centre of the TSF towards the perimeter embankment,
  - b. The earthfill material will connect to the Zone 1B Subgrade and BGM liner around the entire perimeter of the TSF to fully encapsulate the tailings,
  - c. The increasing thickness of the earthfill material towards the centre of the TSF is designed to support a revegetated surface without vegetation intercepting the tailings below.
4. The earthfill and weathered rockfill will be placed over the low permeability earthfill material to a minimum thickness of 0.5m and matching the underlying 5% grade of the landform.
5. The topsoil material will be placed over the earthfill and weathered rockfill to a nominal thickness of 300mm to match the topsoil thickness on the batter slopes.
6. The decant structure will be decommissioned by removal of the pumping infrastructure, and grouting backfill of the decant pipelines.
7. The emergency spillway will be retained as a drainage structure outlet, with a longitudinal drain to be formed through the centre of the landform to aid in the control of surface runoff.

The estimated quantities required for formation of the closure landform are provided below:

- |             |                        |
|-------------|------------------------|
| • Earthfill | 210,000 m <sup>3</sup> |
| • Rockfill  | 31,000 m <sup>3</sup>  |
| • Topsoil   | 18,500 m <sup>3</sup>  |

If early closure of the facility is expected, the landform can be formed by partial deconstruction of the embankment to the tailings level, and reclamation of embankment materials for backfilling of the impoundment.

Once the Brunswick West TSF, as well as the Bombay TSF and Brunswick TSFs have been capped and closed, the external RWP will no longer be required to provide contingency storage for the TSF, and the RWP can be removed. This would consist of the following activities:

- Removal of the HDPE liner, pipelines and pumps.
- Removal of Zone S material and Geotextile from emergency spillway and clean water diversion drains surrounding external RWP.
- Demolish the external RWP embankments.



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- The excavations of the external RWP impoundment and clean water diversion drains surrounding external RWP will be backfilled to 0.5m below previous natural surface level. Backfilling will utilise Zone 1B material won demolishing the RWP embankments, and remaining Zone 1B material to be used for TSF closure.
- Replacement of 0.5m of topsoil over the previous external RWP and toe drains area to match the previous topography of the area.

The closure concept plan cover system is presented in **Figure 12** and **Figure 13**.

## 23.2.4 Performance of BGM Liner

At the completion of deposition (prior to construction of the landform), the BGM liner will be mostly covered with deposited tailings, with only the remaining upper portion at the embankment crest expected to remain exposed. Once covered with tailings, degradation of the BGM liner can only come from the tailings solids itself, which are not expected to react and chemically degrade the BGM liner (refer **Section 11.6.4**), and the BGM liner is expected to retain its serviceability in the long term.

As discussed in **Section 11.6.4**, the exposed BGM liner above the tailings will not experience significant degradation over the life of the facility. The hydraulic performance of the liner is expected to be maintained for the containment of surface water during the initial closure stage to prevent seepage during this low maintenance phase of the facility.

Post closure (i.e., once the self-shedding landform has constructed), the long-term seepage losses, and potential for embankment internal erosion, from the facility will largely be dependent on the release of water retained in the tailings from long term consolidation. This consolidation will be driven by the self-weight of the tailings themselves plus the additional overburden weight of the closure landform. As the tailings are expected to experience a significant degree of consolidation during operation, the long-term release of water is expected to be relatively slow and not cause seepage issues against the BGM liner. A review of the performance of the BGM against long term seepage should be considered as part of the consolidation modelling.

## 23.2.5 Required Data and Timing

To allow for the formation of the closure landform, the following data and assessments would be required. Estimated time frames are also provided:

- Shear strength profiles of the entire tailings deposit to ensure stability during construction of the initial layers of capping material over tailings, and of the landform itself. As discussed in the assumption, this is expected to be readily achievable within 2 – 3 years of cessation of deposition. Shear strength testing would therefore be expected to be conducted in these 2-3 years after deposition, generally during dry weather to allow for access to the entire facility.
- Measurements of actual returned groundwater levels post de-watering. As de-watering for underground mining is expected to continue until Q3 2027, this is not realistically achievable until then. Based on the high-level estimated groundwater rebound rates, preliminary data on the actual groundwater levels is not expected until around 2029
- Consolidation modelling of the tailings modelling beneath the proposed landform. It is envisaged that 2D consolidation models will initially be developed for the Brunswick and Bombay TSFs prior to their closure, then refined for the Brunswick West TSF. Consolidation modelling for Brunswick West TSF cannot be conducted until operation data on the filling performance has been collected. It is anticipated that this study will be completed at least 6 months prior to the end of deposition.
- Detailed studies of the erodibility of the topsoil material. Topsoil material is expected to be at a surplus from the construction. As such, MRCO will be able to engage an environmental consultant to conduct these works at any point during the operation of the facility. However, this data will feed into the landform design and should be completed prior to commencement of the landform design.





### 23.3 Closure Cover Stability

The stability of the closure system is assessed to verify the long term stability of the system with considerations for long term phreatic surfaces that may generated once pumping ceases, reduced material strength parameters of the outer exposed material due to ongoing weathering, and considerations for the Maximum Credible Earthquake.

The 4:1 batter slopes and single stage construction (i.e., no construction over tailings) of the Brunswick West TSF has presented with significant factors of safety against instability. As presented in **Section 16.5**, the TSF has a long term static FoS of 3.0, and a Post Seismic FoS of 2.1. These assessments considered zero tailings strength and a very high phreatic surface through the embankment as a result of liner failure and pooling of rainfall runoff from extreme storm events.

At closure, the embankment section will have an additional 1-3 m of earthfill and rockfill material providing driving weight. To allow for construction of the landform, the tailings will be required to have sufficient shear to support the overburden weight of the landform (typically a minimum of 10 kPa). The phreatic surface through the tailings and embankment is expected to down to natural levels due to no deposition. Based on the above factors, it is considered that the long-term closure Factor of Safety for the embankments are likely to be in line, if not higher, than those estimated for the worst case operational scenario for the facility, and would meet the minimum factors of safety for long term stability.

## 24 DESIGN CERTIFICATION

This report presents the design of the Brunswick West Tailings Storage Facility (TSF) and appurtenant structures for Mandalay Resources Costerfield Operations Costerfield Gold Mine.

The design and reporting of the Brunswick West TSF has been undertaken in compliance with all relevant ANCOLD and Victorian State Government requirements.

A completed Certificate of Design Compliance is provided in **Appendix H**.

## 25 CLOSURE

Your attention is drawn to the “Conditions of Report” which appear the references in this document.

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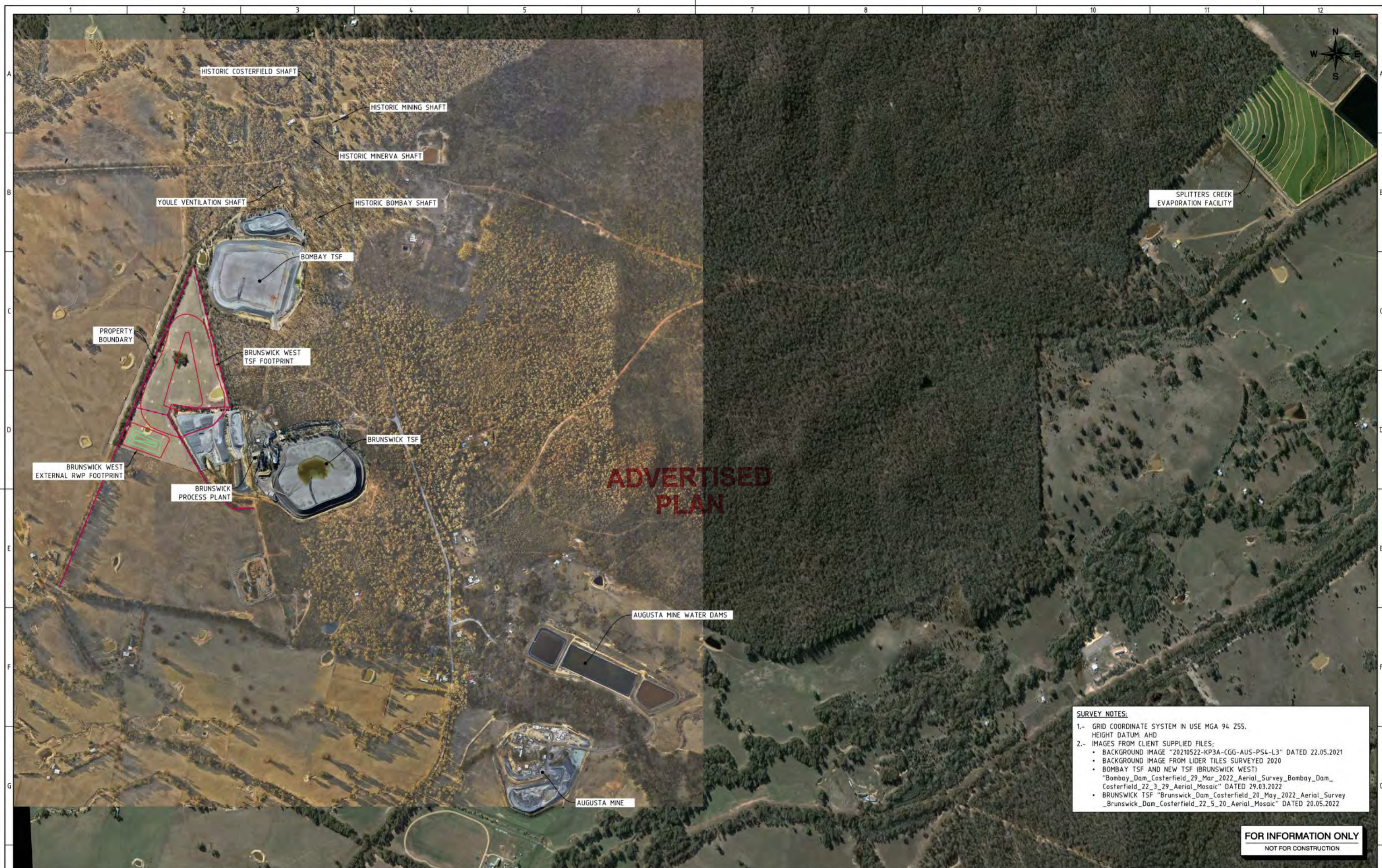


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## FIGURES

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**SURVEY NOTES:**

1.- GRID COORDINATE SYSTEM IN USE MGA 94 Z55.  
HEIGHT DATUM: AHD

2.- IMAGES FROM CLIENT SUPPLIED FILES:

- BACKGROUND IMAGE "20210522-KP3A-CGG-AUS-PS4-L3" DATED 22.05.2021
- BACKGROUND IMAGE FROM LIDER TILES SURVEYED 2020
- BOMBAY TSF AND NEW TSF (BRUNSWICK WEST)  
"Bombay\_Dam\_Costerfield\_29\_Mar\_2022\_Aerial\_Survey\_Bombay\_Dam\_Costerfield\_22\_3\_29\_Aerial\_Mosaic" DATED 29.03.2022
- BRUNSWICK TSF "Brunswick\_Dam\_Costerfield\_20\_May\_2022\_Aerial\_Survey\_Brunswick\_Dam\_Costerfield\_22\_5\_20\_Aerial\_Mosaic" DATED 20.05.2022

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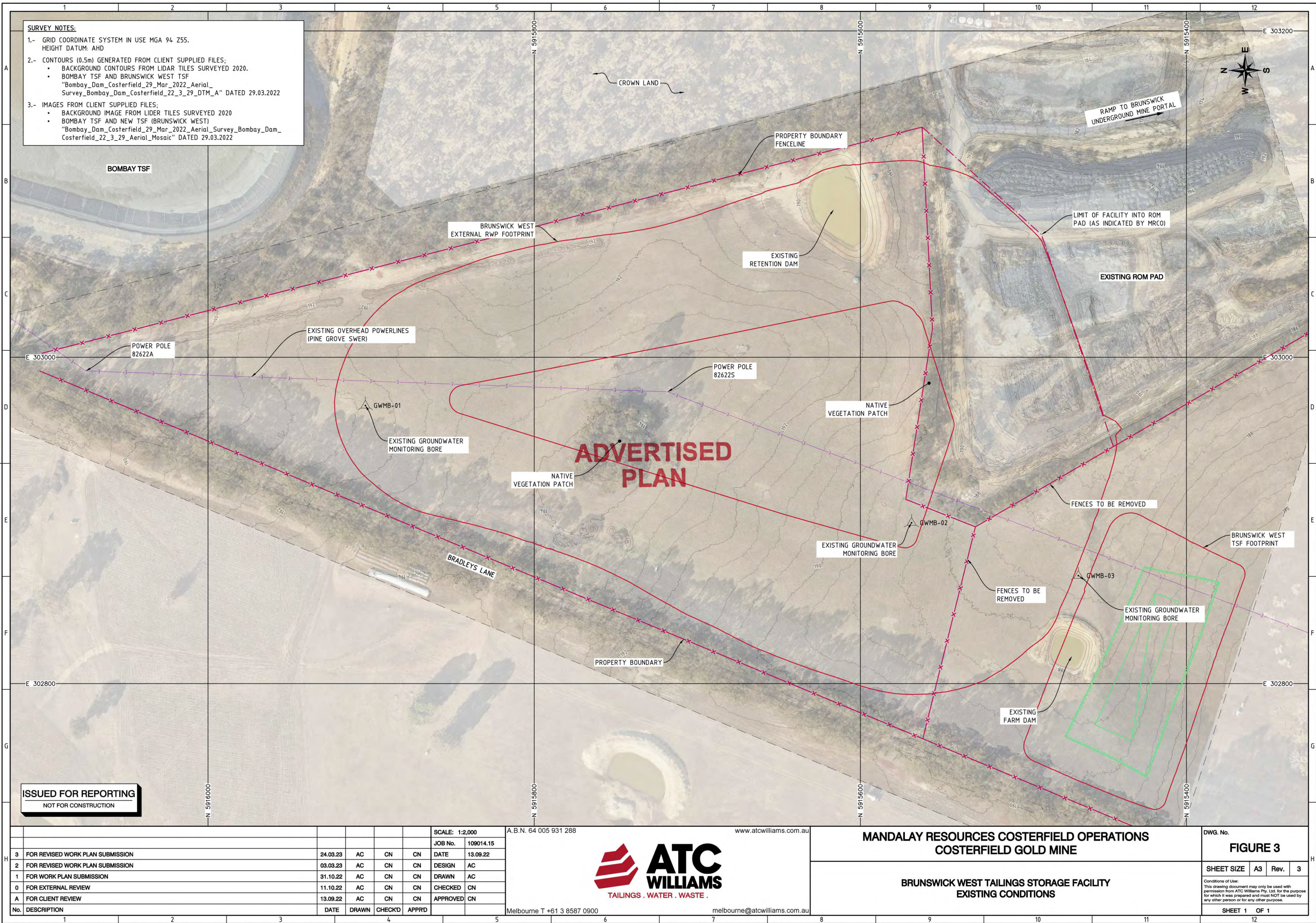
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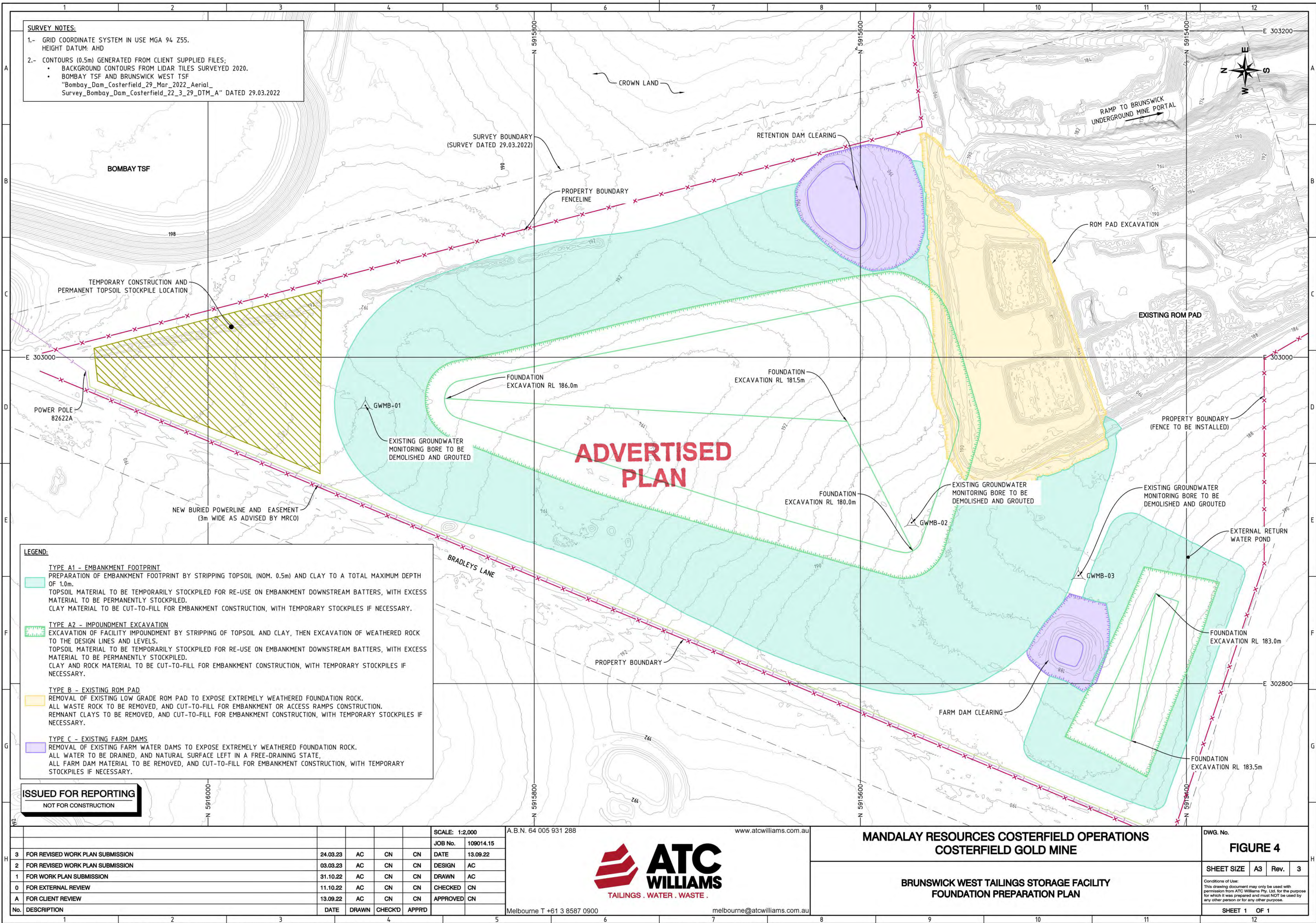
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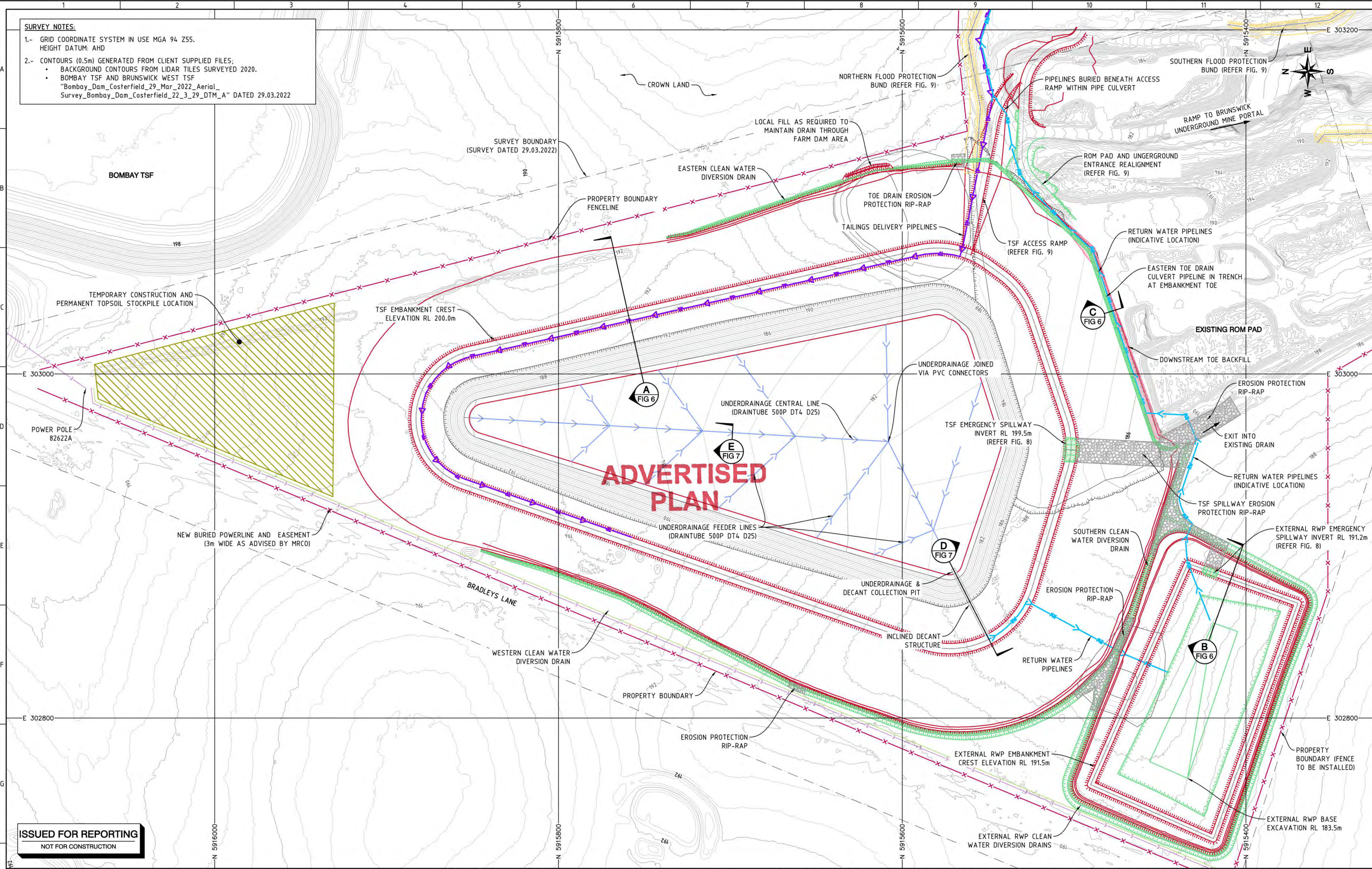












**SURVEY NOTES:**

1.- GRID COORDINATE SYSTEM IN USE MGA 94 Z55.  
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FIGURE 5

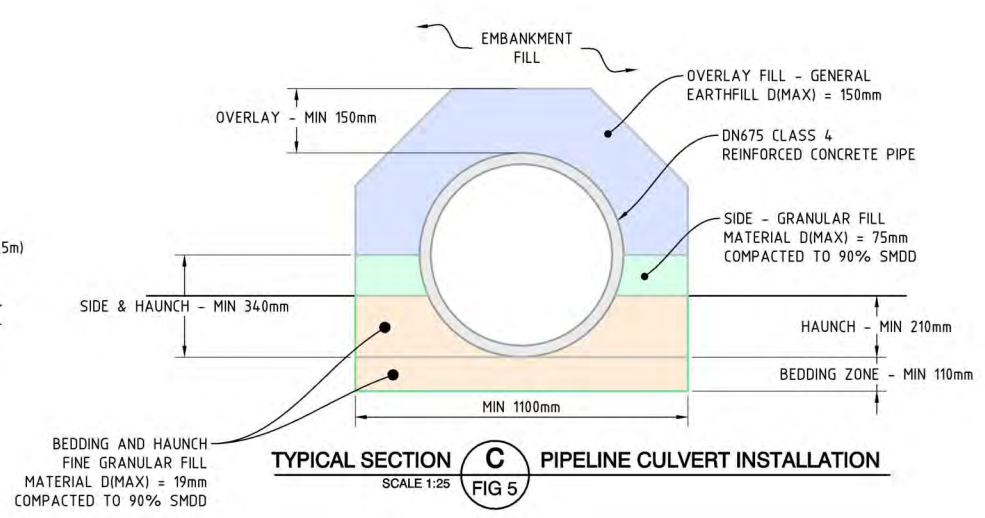
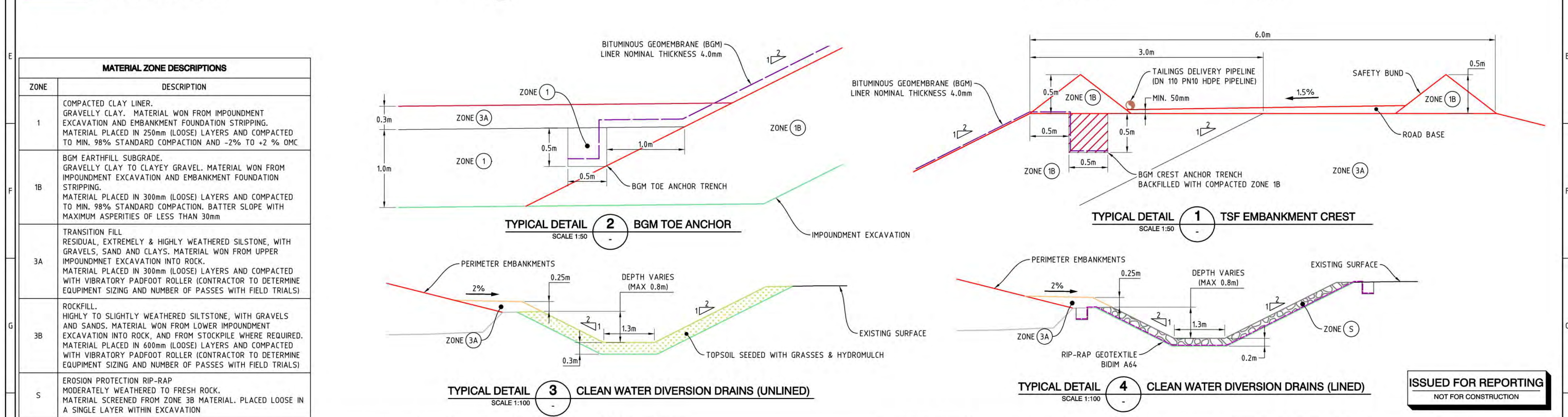
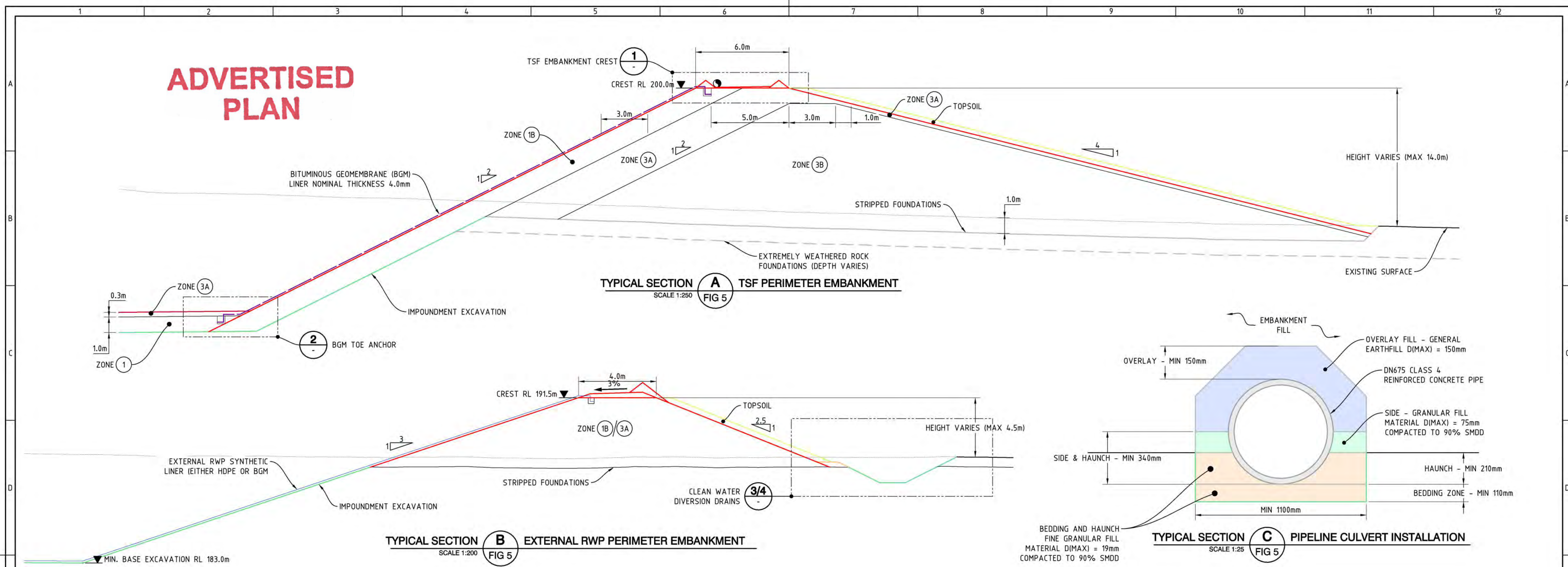
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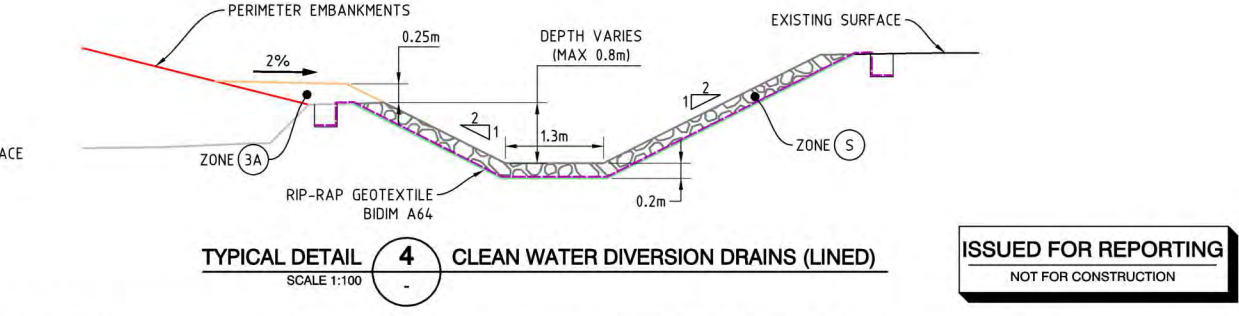
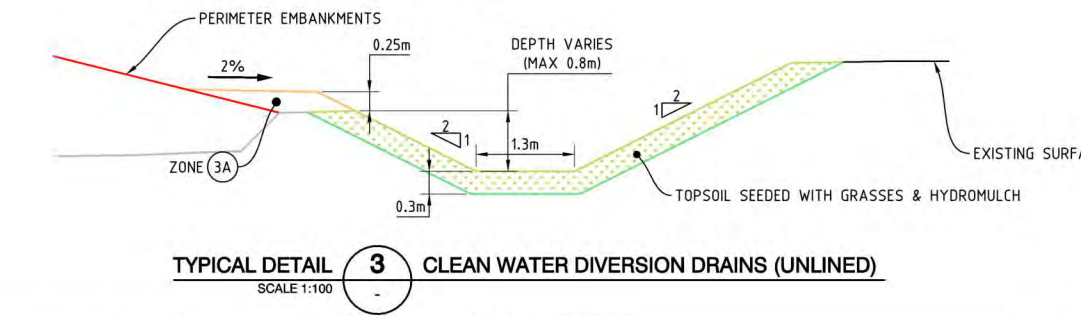
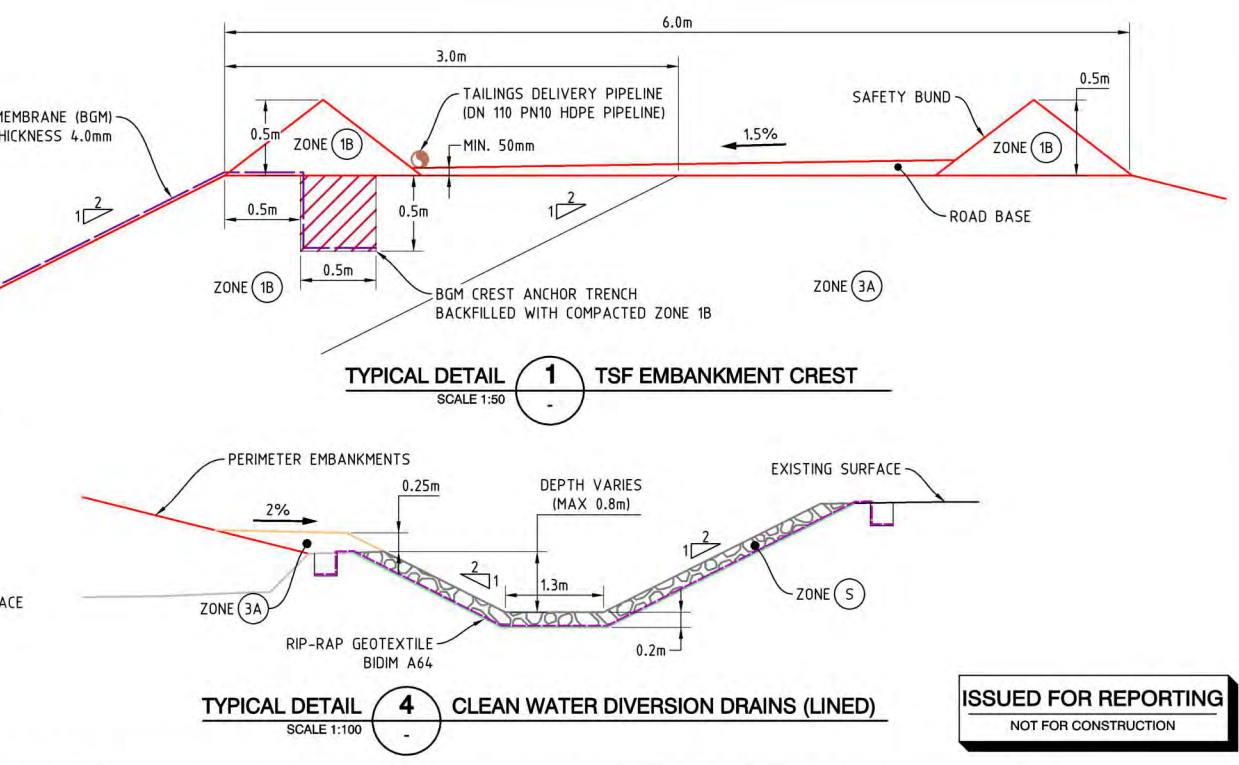
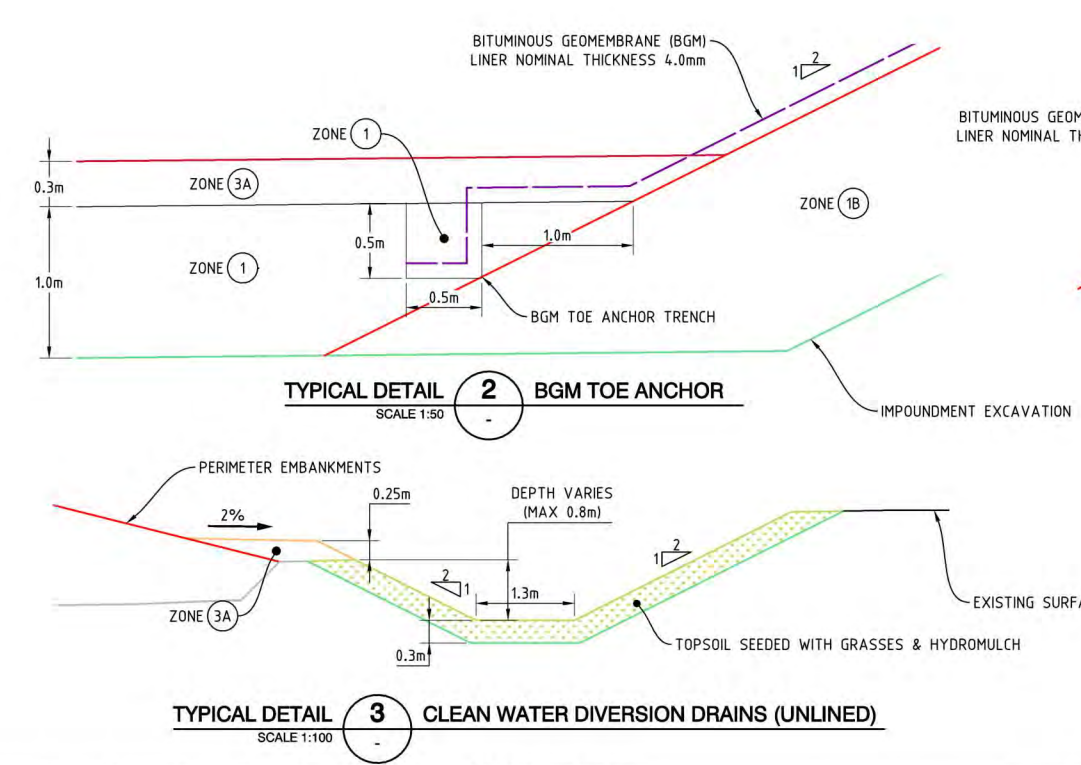
SHEET 1 OF 1



# ADVERTISED PLAN



| MATERIAL ZONE DESCRIPTIONS |  |
|----------------------------|--|
| ZONE                       | DESCRIPTION  |
| 1                          | COMPACTED CLAY LINER. GRAVELLY CLAY. MATERIAL WON FROM IMPOUNDMENT EXCAVATION AND EMBANKMENT FOUNDATION STRIPPING. MATERIAL PLACED IN 250mm (LOOSE) LAYERS AND COMPACTED TO MIN. 98% STANDARD COMPACTION AND -2% TO +2 % OMC   |
| 1B                         | BGM EARTHFILL SUBGRADE. GRAVELLY CLAY TO CLAYEY GRAVEL. MATERIAL WON FROM IMPOUNDMENT EXCAVATION AND EMBANKMENT FOUNDATION STRIPPING. MATERIAL PLACED IN 300mm (LOOSE) LAYERS AND COMPACTED TO MIN. 98% STANDARD COMPACTION. BATTER SLOPE WITH MAXIMUM ASPERITIES OF LESS THAN 30mm  |
| 3A                         | TRANSITION FILL. RESIDUAL, EXTREMELY & HIGHLY WEATHERED SILTSTONE, WITH GRAVELS, SAND AND CLAYS. MATERIAL WON FROM UPPER IMPOUNDMENT EXCAVATION INTO ROCK. MATERIAL PLACED IN 300mm (LOOSE) LAYERS AND COMPACTED WITH VIBRATORY PADFOOT ROLLER (CONTRACTOR TO DETERMINE EQUIPMENT SIZING AND NUMBER OF PASSES WITH FIELD TRIALS)             |
| 3B                         | ROCKFILL. HIGHLY TO SLIGHTLY WEATHERED SILTSTONE, WITH GRAVELS AND SANDS. MATERIAL WON FROM LOWER IMPOUNDMENT EXCAVATION INTO ROCK, AND FROM STOCKPILE WHERE REQUIRED. MATERIAL PLACED IN 600mm (LOOSE) LAYERS AND COMPACTED WITH VIBRATORY PADFOOT ROLLER (CONTRACTOR TO DETERMINE EQUIPMENT SIZING AND NUMBER OF PASSES WITH FIELD TRIALS) |
| S                          | EROSION PROTECTION RIP-RAP. MODERATELY WEATHERED TO FRESH ROCK. MATERIAL SCREENED FROM ZONE 3B MATERIAL. PLACED LOOSE IN A SINGLE LAYER WITHIN EXCAVATION  |



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|                                    |             |          |       |        |       |          |          |
|------------------------------------|-------------|----------|-------|--------|-------|----------|----------|
| 3 FOR REVISED WORK PLAN SUBMISSION |             | 24.03.23 | AC    | CN     | CN    | DATE     | 14.09.22 |
| 2 FOR REVISED WORK PLAN SUBMISSION |             | 03.03.23 | AC    | CN     | CN    | DESIGN   | AC       |
| 1 FOR WORK PLAN SUBMISSION         |             | 31.10.22 | AC    | CN     | CN    | DRAWN    | AC       |
| 0 FOR EXTERNAL REVIEW              |             | 11.10.22 | AC    | CN     | CN    | CHECKED  | CN       |
| A FOR CLIENT REVIEW                |             | 14.09.22 | AC    | CN     | CN    | APPROVED | CN       |
| No.                                | DESCRIPTION | DATE     | DRAWN | CHECKD | APPRD |          |          |
| 1                                  |             |          |       |        |       |          |          |
| 2                                  |             |          |       |        |       |          |          |
| 3                                  |             |          |       |        |       |          |          |
| 4                                  |             |          |       |        |       |          |          |
| 5                                  |             |          |       |        |       |          |          |
| 6                                  |             |          |       |        |       |          |          |
| 7                                  |             |          |       |        |       |          |          |
| 8                                  |             |          |       |        |       |          |          |
| 9                                  |             |          |       |        |       |          |          |
| 10                                 |             |          |       |        |       |          |          |
| 11                                 |             |          |       |        |       |          |          |
| 12                                 |             |          |       |        |       |          |          |

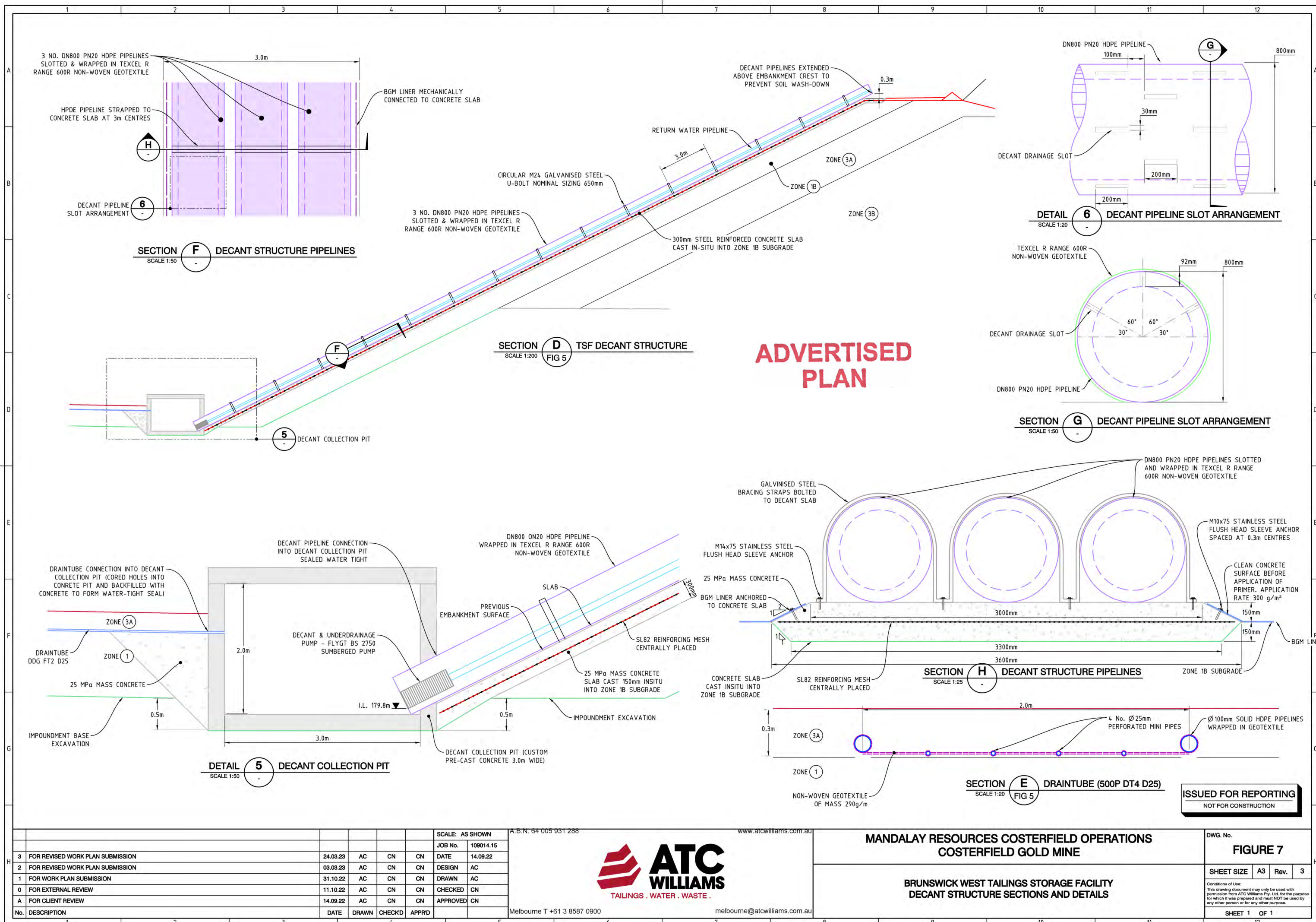


**MANDALAY RESOURCES COSTERFIELD OPERATIONS**  
**COSTERFIELD GOLD MINE**

**BRUNSWICK WEST TAILINGS STORAGE FACILITY**  
**EMBANKMENT SECTIONS AND DETAILS**

|   |    |                 |   |
|---|----|-----------------|---|
| DWG. No.  |    | <b>FIGURE 6</b> |   |
| SHEET SIZE  | A3 | Rev.            | 3 |
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| 3   | FOR REVISED WORK PLAN SUBMISSION | 24.03.23 | AC    | CN     | CN    |
| 2   | FOR REVISED WORK PLAN SUBMISSION | 03.03.23 | AC    | CN     | CN    |
| 1   | FOR WORK PLAN SUBMISSION         | 31.10.22 | AC    | CN     | CN    |
| 0   | FOR EXTERNAL REVIEW              | 11.10.22 | AC    | CN     | CN    |
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JOB No. 109014.15

DATE 14.09.22

DESIGN AC

DRAWN AC

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MANDALAY RESOURCES COSTERFIELD OPERATIONS

COSTERFIELD GOLD MINE

BRUNSWICK WEST TAILINGS STORAGE FACILITY

DECANT STRUCTURE SECTIONS AND DETAILS

DWG. No. FIGURE 7

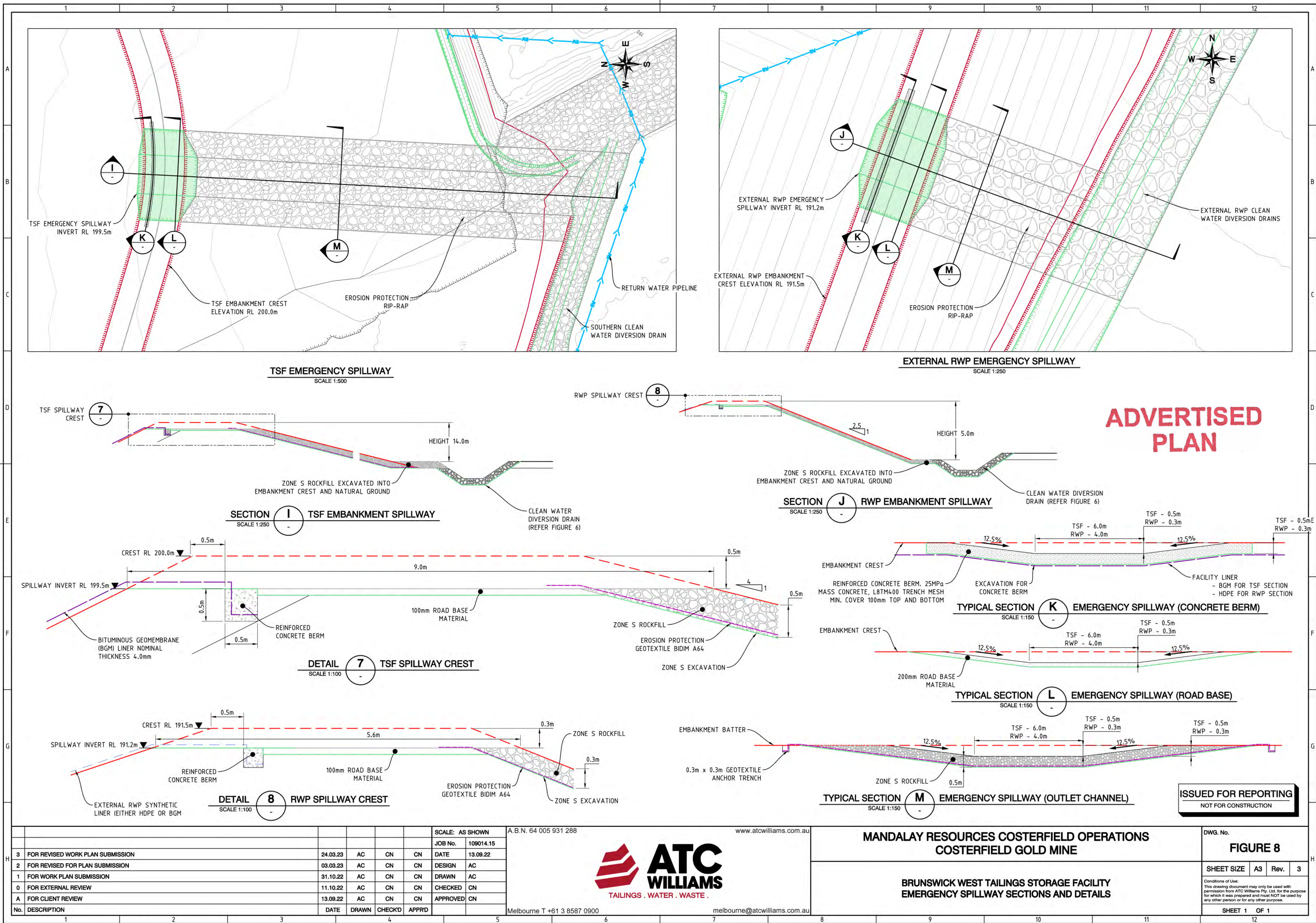
SHEET SIZE A3 Rev. 3

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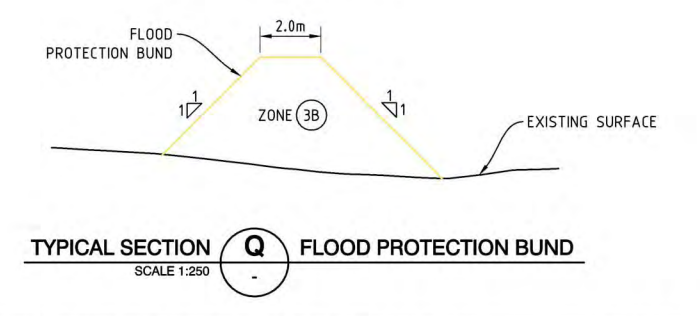
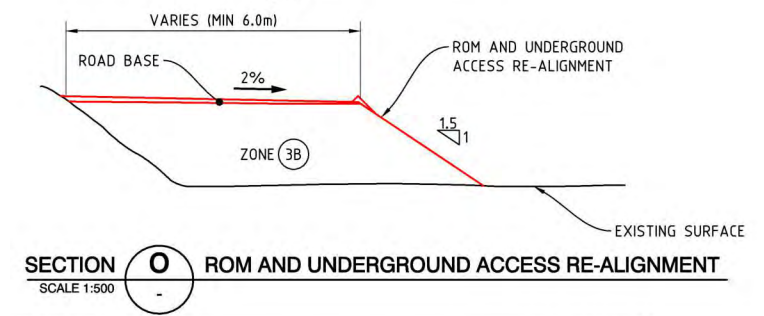
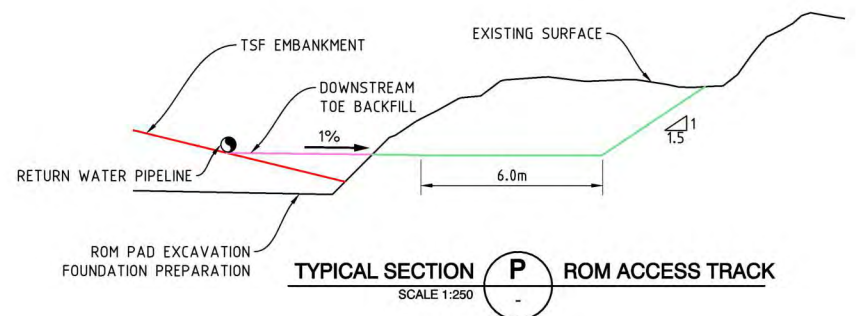
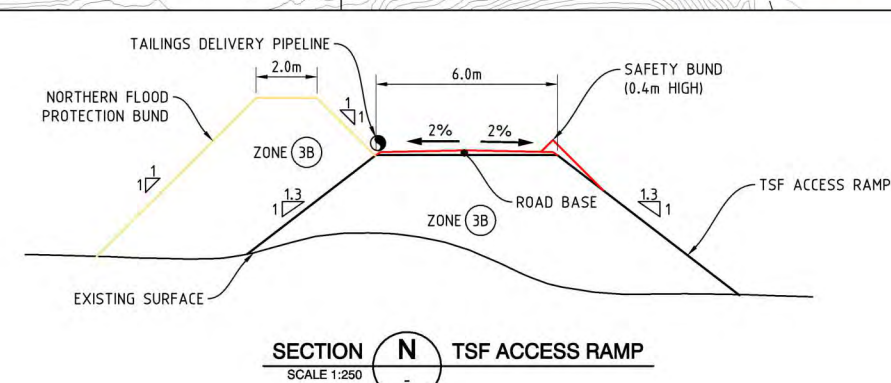
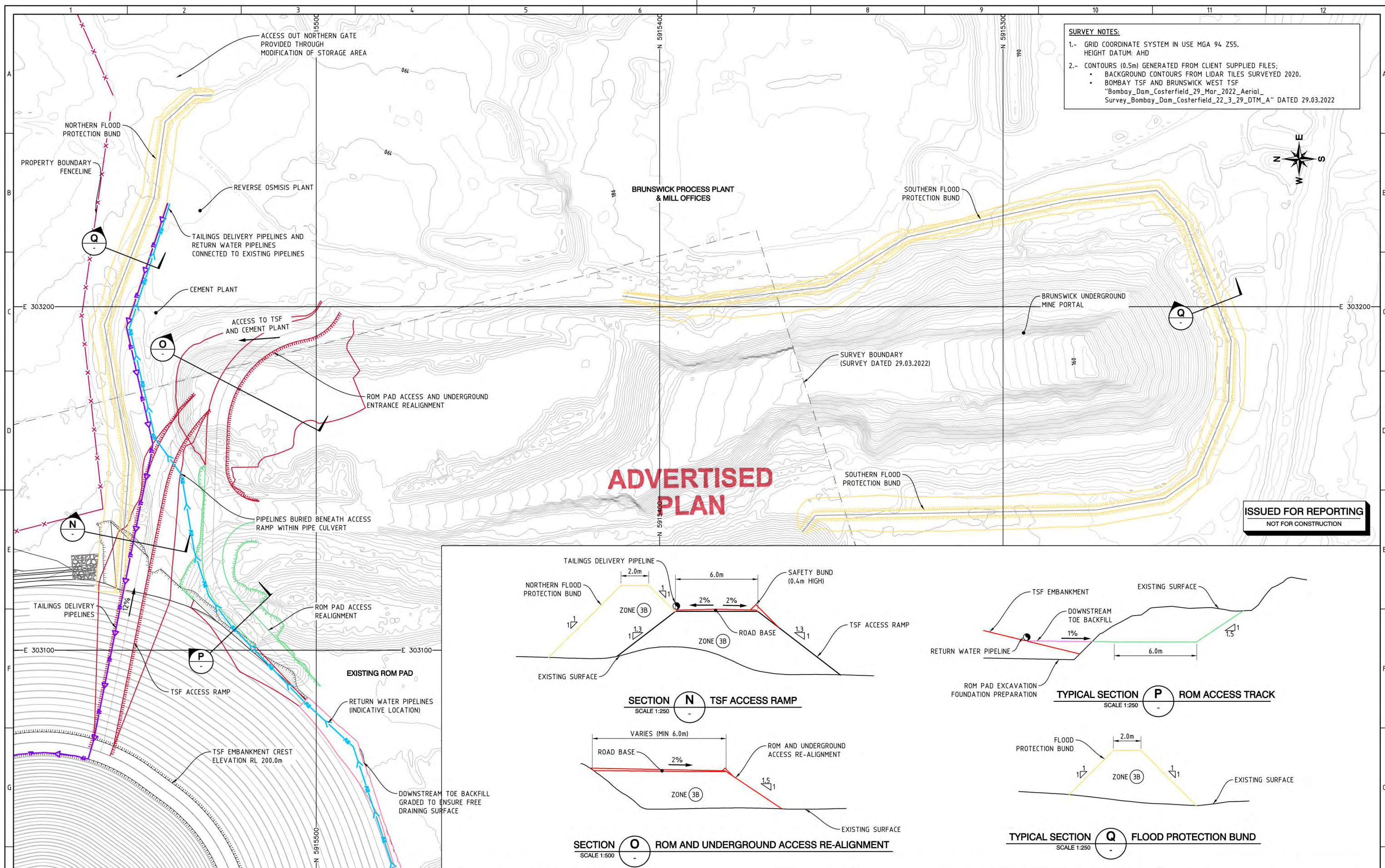
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|     |   |                                  |  |                   |          |       |         |                       |          |                        |                             |  |   |   |              |          |                      |    |  |    |  |    |  |
|-----|---|----------------------------------|--|-------------------|----------|-------|---------|-----------------------|----------|------------------------|-----------------------------|--|---|---|--------------|----------|----------------------|----|--|----|--|----|--|
|     |   |                                  |  | SCALE: 1:1,000    |          |       |         | A.B.N. 64 005 931 288 |          | www.atcwilliams.com.au |                             | MANDALAY RESOURCES COSTERFIELD OPERATIONS<br>COSTERFIELD GOLD MINE |   |   |              | DWG. No. |                      |    |  |    |  |    |  |
|     |   |                                  |  | JOB No. 109014.15 |          |       |         |                       |          |                        |                             |  |   |   |              | FIGURE 9 |                      |    |  |    |  |    |  |
| H   | 3 | FOR REVISED WORK PLAN SUBMISSION |  |                   | 24.03.23 | AC    | CN      | CN                    | DATE     | 13.09.22               |                             |  | BRUNSWICK WEST TAILINGS STORAGE FACILITY<br>FLOOD PROTECTION MEASURES AND FACILITY ACCESS |   |              |          | SHEET SIZE A3 Rev. 3 |    |  |    |  |    |  |
|     | 2 | FOR REVISED WORK PLAN SUBMISSION |  |                   | 03.03.23 | AC    | CN      | CN                    | DESIGN   | AC                     |                             |  |   |   |              |          |                      |    |  |    |  |    |  |
|     | 1 | FOR WORK PLAN SUBMISSION         |  |                   | 31.10.22 | AC    | CN      | CN                    | DRAWN    | AC                     |                             |  |   |   |              |          |                      |    |  |    |  |    |  |
|     | 0 | FOR EXTERNAL REVIEW              |  |                   | 11.10.22 | AC    | CN      | CN                    | CHECKED  | CN                     |                             |  |   |   |              |          |                      |    |  |    |  |    |  |
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| 1   |   | 2                                |  | 3                 |          | 4     |         | 5                     |          | 6                      |                             | 7  |   | 8 |              | 9        |                      | 10 |  | 11 |  | 12 |  |

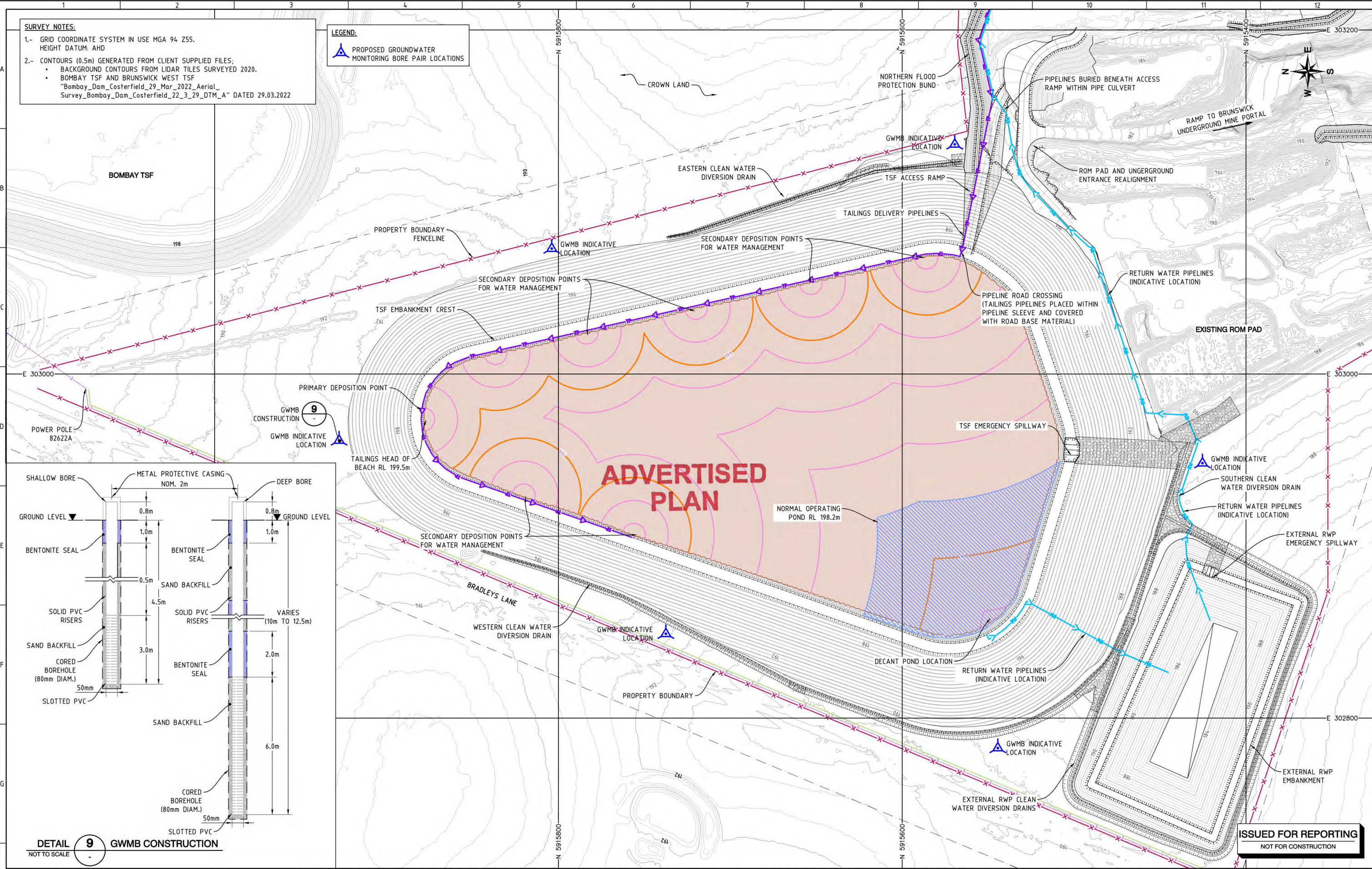
C:\Projects\105\105014\Costerfield\RS New TSP Investigation and Design\CADD\CAD\Design\_Report\Figure 9 - Flood Protection Measures.dwg

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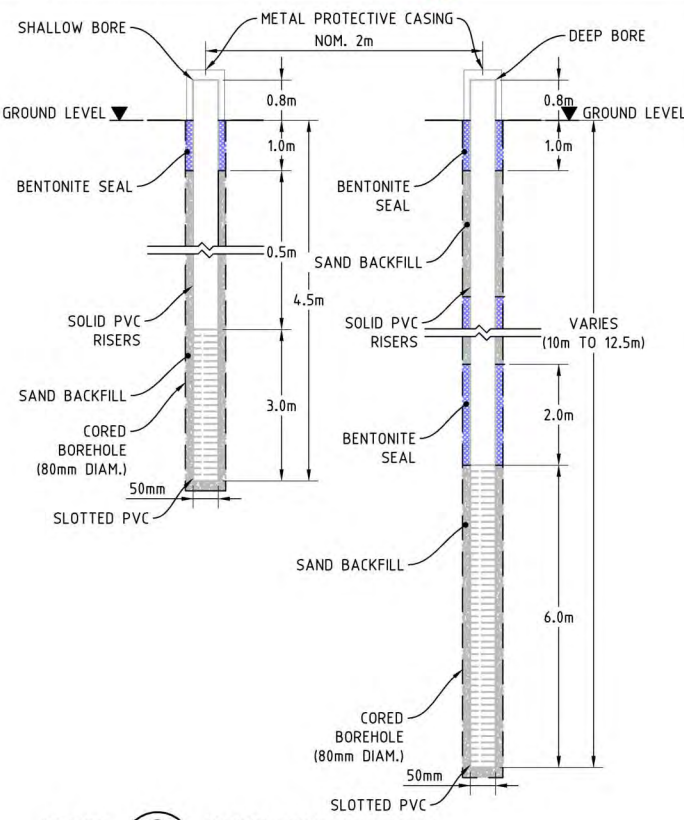
**SURVEY NOTES:**

1.- GRID COORDINATE SYSTEM IN USE MGA 94 Z55.  
HEIGHT DATUM: AHD

2.- CONTOURS (0.5m) GENERATED FROM CLIENT SUPPLIED FILES:  
• BACKGROUND CONTOURS FROM LIDAR TILES SURVEYED 2020.  
• BOMBAY TSF AND BRUNSWICK WEST TSF  
"Bombay\_Dam\_Costerfield\_29\_Mar\_2022\_Aerial\_Survey\_Bombay\_Dam\_Costerfield\_22\_3\_29\_DTM\_A" DATED 29.03.2022

**LEGEND:**

PROPOSED GROUNDWATER MONITORING BORE PAIR LOCATIONS



**DETAIL 9 GWMB CONSTRUCTION**  
NOT TO SCALE

| No. | DESCRIPTION                      | DATE     | DRAWN | CHECKD | APPRD |
|-----|----------------------------------|----------|-------|--------|-------|
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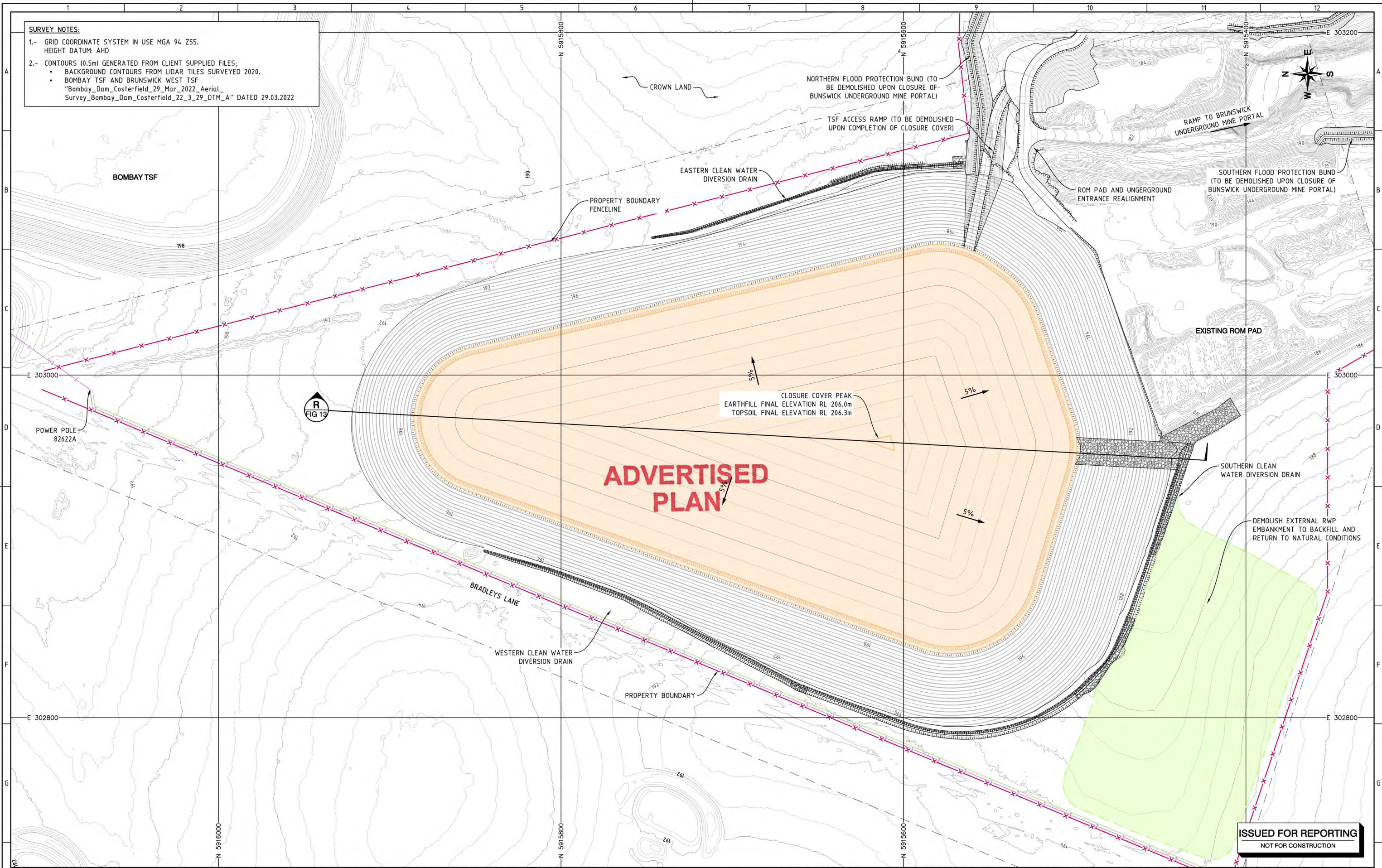


**MANDALAY RESOURCES COSTERFIELD OPERATIONS  
COSTERFIELD GOLD MINE**

**BRUNSWICK WEST TAILINGS STORAGE FACILITY  
CONDITIONS AT END OF FILLING & INSTRUMENTATION PLAN**

|   |           |
|---|-----------|
| DWG. No.  | FIGURE 11 |
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**SURVEY NOTES:**

1.- GRID COORDINATE SYSTEM IN USE MGA 94 Z55.  
HEIGHT DATUM: AHD

2.- CONTOURS (0.5m) GENERATED FROM CLIENT SUPPLIED FILES:  
• BACKGROUND CONTOURS FROM LIDAR TILES SURVEYED 2020.  
• BOMBAY TSF AND BRUNSWICK WEST TSF  
"Bombay\_Dam\_Costerfield\_29\_Mar\_2022\_Aerial\_Survey\_Bombay\_Dam\_Costerfield\_22\_3\_29\_DTM\_A" DATED 29.03.2022

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| JOB No. 109014.15 |
| DATE 13.09.22     |

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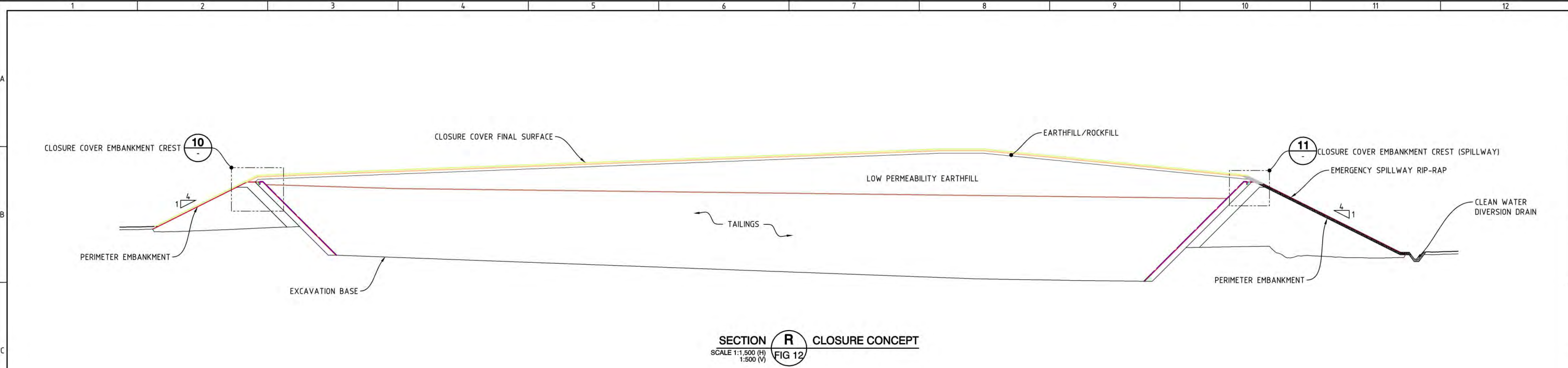
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**MANDALAY RESOURCES COSTERFIELD OPERATIONS  
COSTERFIELD GOLD MINE**

**BRUNSWICK WEST TAILINGS STORAGE FACILITY  
FACILITY CLOSURE LAYOUT PLAN**

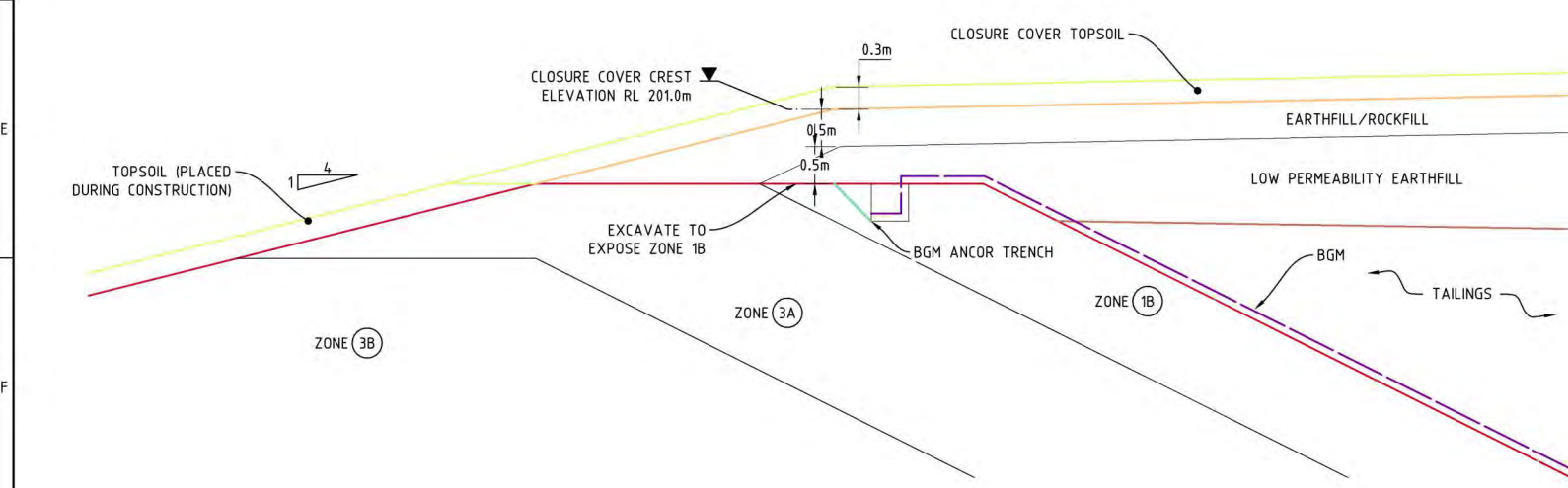
|   |           |
|---|-----------|
| DWG. No.  | FIGURE 12 |
| SHEET SIZE  | A3        |
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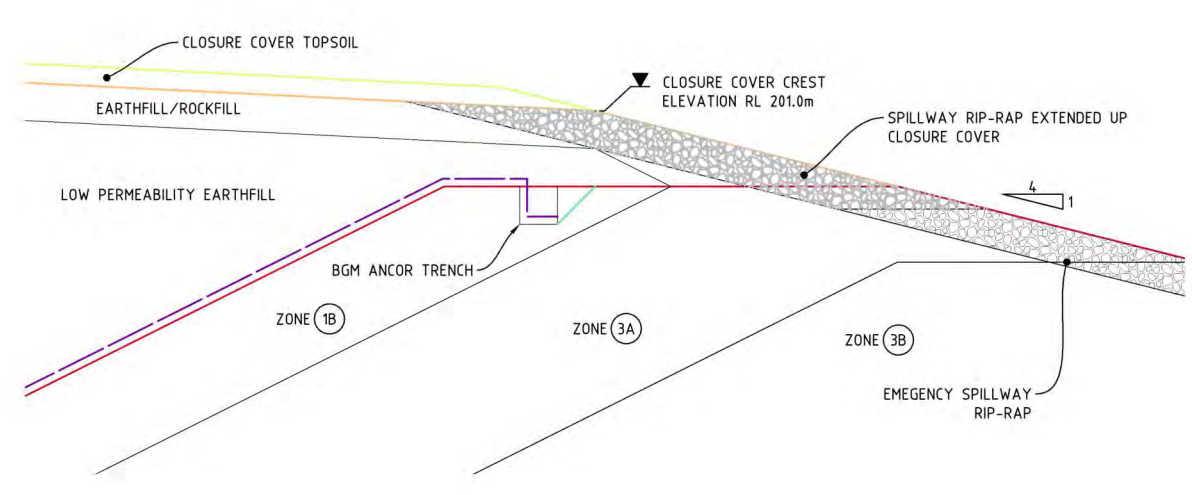


SECTION R CLOSURE CONCEPT  
SCALE 1:1,500 (H)  
1:500 (V)  
FIG 12

ADVERTISED  
PLAN



DETAIL 10 CLOSURE COVER EMBANKMENT CREST  
SCALE 1:100



DETAIL 11 CLOSURE COVER EMBANKMENT CREST (SPILLWAY)  
SCALE 1:100

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| 1   | FOR WORK PLAN SUBMISSION         | 31.10.22 | AC    | CN     | CN    |
| 0   | FOR EXTERNAL REVIEW              | 11.10.22 | AC    | CN     | CN    |
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MANDALAY RESOURCES COSTERFIELD OPERATION  
COSTERFIELD GOLD MINE

BRUNSWICK WEST TAILINGS STORAGE FACILITY  
FACILITY CLOSURE SECTIONS AND DETAILS

| DWG. No.  | FIGURE 13 |
|---|-----------|
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## APPENDICES

# ADVERTISED PLAN





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## APPENDIX A – POTENTIAL FAILURE MODES & RISK REGISTER

**ADVERTISED  
PLAN**



|                    |   |
|--------------------|---|
| <b>Client</b>      | <b>Mandalay Resources Costerfield Operations</b>                        |
| <b>Site</b>        | <b>Costerfield Gold Mine</b>  |
| <b>Project</b>     | <b>Brunswick West Tailings Storage Facility</b>                         |
| <b>Job No.</b>     | <b>109014.15</b>  |
| <b>Title</b>       | <b>Credible Failure Mode Assessment - Initial Qualitative Screening</b> |
| <b>Prepared by</b> | <b>Alex Campbell (ATCW)</b>   |
| <b>Date</b>        | <b>30-Nov-2022</b>  |



#### Assumptions

Unless otherwise stated, the failure mode is assumed to occur at the critical stage, which is the end of filling of the TSF  
These are failure modes that would result in a catastrophic failure of the embankment, resulting in released material

| Reference | Failure Mode   | Failure Progression  | Controls  |   |  | Failure Mode Credibility | Justification   |
|-----------|--|--|---|---|--|--------------------------|---|
|           |  |  | Design  | Construction  | Operation  |                          |   |
| P1        | Geotechnical Piping through embankment - Cracking caused by differential settlement from steep underlying topography | Significant tears/holes/flaws in Upstream Geosynthetic Liner, which are not noticed or repaired.<br>Water levels in the facility rise (either by storm event, or loss of decant removal capacity), begin to seep through flaws in the Geosynthetic Liner, and maximise head against the gravely clay liner subgrade.<br>Concentrated leak erosion against the gravely clay subgrade allows excess seepage through the embankment interior.<br>Excess seepage begins to erode the downstream rockfill, and is not filled in by material washed in from upstream.<br>Intervention methods to stop the breach are unsuccessful.<br>Embankment breaches, releasing tailings and water.   | Design of facility with Geosynthetic Liner to prevent/manage seepage<br>Removal and smoothing of potential steep topography changes (around diversion drains) to prevent localised differential settlement  | Full time QA/QC provided to ensure design specifications for foundation preparation are met<br>Dedicated Installation Crew, Testing regime and QA/QC program to ensure Liner is installed and tested correctly  | Regular removal of excess pooled water to minimise phreatic head differential against the clay<br>Routine inspections to detect flaws in the Geosynthetic liner, and to monitor for signs of erosion progressing (cracking, seepage)   | Not Credible             | No abrupt changes in topography within majority of embankment which would allow for differential settlement. Localised areas (around diversion drains) will be removed and smoothed out   |
| P2        | Geotechnical Piping through embankment - Cracking caused by differential settlement of foundations                   |  | Design of facility with Geosynthetic Liner to prevent/manage seepage<br>Loose material (topsoil and clay) removed from foundations, and remnant clay compacted (in excess of 98% Standard Compaction)   | Full time QA/QC provided to ensure design specifications for foundation preparation are met<br>Dedicated Installation Crew, Testing regime and QA/QC program to ensure Liner is installed and tested correctly  | Regular removal of excess pooled water to minimise phreatic head differential against the clay<br>Routine inspections to detect flaws in the Geosynthetic liner, and to monitor for signs of erosion progressing (cracking, seepage)   | Not Credible             | No deep or non-uniform changes in foundation conditions which may induce significant levels of differential settlement  |
| P3        | Geotechnical Piping through embankment - Cracking caused by loss of support from downstream shoulder                 |  | Design of facility with Geosynthetic Liner to prevent/manage seepage.   | Full time QA/QC provided to ensure design specifications for rockfill placement and compaction are met<br>Downstream rockfill to be compacted to a high density   | Regular removal of excess pooled water to minimise phreatic head differential against the clay<br>Routine inspections to detect flaws in the Geosynthetic liner, and to monitor for signs of erosion progressing (cracking, seepage)   | Potentially Credible     |   |
| P4        | Geotechnical Piping through embankment - Cracking caused by loose/poorly compacted layers in upstream clay zone      |  | Design of facility with Geosynthetic Liner to prevent/manage seepage.   | Full time QA/QC provided to ensure design specifications for rockfill placement and compaction of gravely clay subgrade are met<br>Gravely clay subgrade to be compacted to a high density (in excess of 95% Standard Compaction)                             | Regular removal of excess pooled water to minimise phreatic head differential against the clay<br>Routine inspections to detect flaws in the Geosynthetic liner, and to monitor for signs of erosion progressing (cracking, seepage)   | Potentially Credible     |   |
| P5        | Geotechnical Piping through embankment - Desiccation cracking through upstream clay zone                             | Design of facility with Geosynthetic Liner to prevent/manage seepage.<br>Clay subgrade designed to be completely covered by Geosynthetic liner and rockfill to prevent desiccation cracks forming.   | Design of facility with Geosynthetic Liner to prevent/manage seepage, and prevent animals accessing the embankment upstream face directly.  | Full time QA/QC provided to ensure design geometry is met   | Regular removal of excess pooled water to minimise phreatic head differential against the clay<br>Routine inspections to detect flaws in the Geosynthetic liner, exposed subgrade, and to monitor for signs of erosion progressing (cracking, seepage)   | Not Credible             | Clay Subgrade designed to be completely covered (upstream face and crest) to prevent desiccation cracks forming   |
| P6        | Geotechnical Piping through embankment - Animal burrows and vegetation causing seepage path through embankment       |  |   | Provision of animal-proof fencing around facility to prevent wildlife.  | Regular removal of excess pooled water to minimise phreatic head differential against the clay<br>Routine inspections to monitor for signs of animal burrows (holes in liner), or excessive vegetation<br>Routine inspections to detect flaws in the Geosynthetic liner, and to monitor for signs of erosion progressing (cracking, seepage)<br>Vegetation on embankment to be identified and promptly removed | Not Credible             | Routine inspections of the liner will identify any deficiencies, and be promptly repaired   |
| P7        | Geotechnical Piping caused by transverse seismic cracking  | Seismic Event occurs, causing differential settlement across embankment. Motion also creates tears in the Upstream Geosynthetic Liner.<br>Differential settlement creates a deep crack across the clay subgrade down to water level within the facility (either down to operating pond level, or as deep as possible and rainfall causes the water level to rise).<br>Seepage occurs through the gravely clay subgrade, maximise head differential against the subgrade.<br>Concentrated leak erosion against the gravely clay subgrade allows excess seepage through the embankment interior.<br>Excess seepage begins to erode the downstream rockfill, and is not filled in by material washed in from upstream.<br>Intervention methods to stop the breach are unsuccessful.<br>Embankment breaches, releasing tailings and water. | Design of facility with Geosynthetic Liner to prevent/manage seepage<br>Embankment designed with spillway freeboard such that significant cracking is required to reach maximum pond levels   | Full time QA/QC provided to ensure design specifications for rockfill placement and compaction are met to minimise potential for seismic cracking   | Regular removal of excess pooled water to minimise phreatic head differential against the clay<br>Inspection of facility following seismic events  | Potentially Credible     |   |
| P8        | Geotechnical Piping through foundations  | Significant tears/holes/flaws in Upstream Geosynthetic Liner, which are not noticed or repaired.<br>Water levels in the facility rise (either by storm event, or loss of decant removal capacity), begin to seep through flaws in the Geosynthetic Liner, and maximise head against the clay foundations.<br>Uncompacted/loose foundations allow for high seepage rates beneath the embankment.<br>Excess seepage begins to erode the downstream rockfill, and is not filled in up material washed in from upstream.<br>Intervention methods to stop the breach are unsuccessful.<br>Embankment breaches, releasing tailings and water.  | Design of facility with Geosynthetic Liner extending to the base of foundation excavation.<br>Loose material (topsoil and clay) removed from foundations, and remnant clay compacted (in excess of 98% Standard Compaction)<br>Floor foundation is located below natural topography | Full time QA/QC provided to ensure design specifications for foundation preparation are met<br>Dedicated Installation Crew, Testing regime and QA/QC program to ensure Liner is installed and tested correctly  | Routine inspections to detect for signs of erosion progressing (cracking, seepage)   | Not Credible             | Tailings will form a low permeability seal against the upstream face and foundations, limiting the depth of standing water against the foundations to prevent the initiation of piping<br>Only conceivable scenario for this to occur is partway through deposition with tailings just below foundation soil level and high pond levels. Failure in this case would only release a small amount of material (i.e. not a catastrophic failure) |
| P9        | Geotechnical Piping into foundations   | Significant tears/holes/flaws in Upstream Geosynthetic Liner, which are not noticed or repaired.<br>Water levels in the facility rise (either by storm event, or loss of decant removal capacity), begin to seep through flaws in the Geosynthetic Liner, and maximise head against the gravely clay subgrade<br>Seepage works downwards through the embankment, directly into the foundations.<br>Uncompacted/loose foundations allow for high seepage rates beneath the embankment.<br>Excess seepage begins to erode the downstream rockfill, and is not filled in up material washed in from upstream.<br>Intervention methods to stop the breach are unsuccessful.<br>Embankment breaches, releasing tailings and water.  | Design of facility with Geosynthetic Liner extending to the base of foundation excavation.<br>Loose material (topsoil and clay) removed from foundations, and remnant clay compacted (in excess of 98% Standard Compaction).  | Full time QA/QC provided to ensure design specifications for foundation preparation, and placement/compaction of the clay subgrade are met<br>Dedicated Installation Crew, Testing regime and QA/QC program to ensure Liner is installed and tested correctly | Routine inspections to detect for signs of erosion progressing (cracking, seepage)   | Potentially Credible     |   |

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| Client      | Mandalay Resources Costerfield Operations                        |
| Site        | Costerfield Gold Mine  |
| Project     | Brunswick West Tailings Storage Facility                         |
| Job No.     | 109014.15  |
| Title       | Credible Failure Mode Assessment - Initial Qualitative Screening |
| Prepared by | Alex Campbell (ATCW)   |
| Date        | 30-Nov-2022  |

#### Assumptions

Unless otherwise stated, the failure mode is assumed to occur at the critical stage, which is the end of filling of the TSF  
These are failure modes that would result in a catastrophic failure of the embankment, resulting in released material

| Reference | Failure Mode  | Failure Progression  | Design   | Controls   |  | Failure Mode Credibility | Justification  |
|-----------|---|--|--|--|--|--------------------------|--|
|           |   |  |  | Construction   | Operation  |                          |  |
| O1        | Embankment Overtopping due to loss of spillway capacity   | Spillway capacity reduced or completely removed by blockage (such as debris, pipelines or storage of materials)<br>Storm event exceeds reduced spillway capacity/remaining freeboard<br>Flow of stormwater and mobilised tailings over the embankment crest causes deep scouring, which progressing an embankment failure.   | Spillway designed to safely pass the Probable Maximum Flood (PMF) with the pond starting at Spillway Invert Level, with additional freeboard provided in the spillway<br>Tailings pipeline and decant pipeline aligned to not cross spillway   | Ensure construction debris is cleared from spillway once embankment is complete.                                   | Routine inspections of the TSF to check for and remove potential blockages   | Potentially Credible     |  |
| O2        | Embankment Overtopping due to crest scour from concentrated rainfall runoff                                     | Extended rainfall causes concentrated rainfall runoff and scours the embankment crest to below spillway level, reducing available freeboard.<br>Storm event occurs in excess of this reduced freeboard<br>Flow of stormwater and mobilised tailings through the initial scour exacerbate scouring of the embankment crest, which progressing an embankment failure   | Embankments designed with a uniform cross fall to allow rainfall to freely drain into the TSF without concentration<br>Flow of stormwater and mobilised tailings through the initial scour exacerbate scouring of the embankment crest, which progressing an embankment failure                      | Full time QA/QC provided to ensure design specifications are met, particularly around compaction of the road base. | Routine inspections of TSF required to identify any potential scouring/concentrated runoff, and to be readily repaired   | Not Credible             | Significant concentrated rainfall scour is highly unlikely given uniform crest shape and drainage. Potential scour would be noticed early and repaired   |
| O3        | Embankment Overtopping due to crest scour from pipeline burst   | Pipeline (either tailings or return water) bursts, causing material to flow uncontrollably on embankment crest at high velocity. Pipeline burst is not noticed by operations.<br>Flow of material scours embankment crest to below spillway level, reducing available freeboard.<br>Storm event occurs in excess of this reduced freeboard<br>Flow of stormwater and mobilised tailings through the initial scour exacerbate scouring of the embankment crest, which progressing an embankment failure | Embankments designed with additional road base material to prolong potential erosion.<br>Pipelines placed on upstream side of embankment crest to direct potential burst flows towards the interior of the facility.   | Full time QA/QC provided to ensure design specifications are met, particularly around compaction of the road base. | Continual (i.e. automated) monitoring of pipeline flow pressures to monitor for deficiencies<br>Routine inspections of TSF and Pipelines for signs of degradation  | Potentially Credible     |  |
| O4        | Embankment Overtopping due to poor deposition management - Spillway Blockage                                    | Poor deposition management causes tailings to build-up in spillway, reducing or completely removing spillway capacity<br>Storm event exceed reduced spillway capacity/remaining freeboard<br>Flow of stormwater and mobilised tailings over the embankment crest causes deep scouring, which progressing an embankment failure.  | TSF designed with a maximum storage level which will be below the Spillway Invert Level which shall not be exceeded<br>Spillway designed to safely pass the Probable Maximum Flood (PMF) with the pond starting at Spillway Invert Level, with additional freeboard provided in the spillway         |  | Routine inspections of the TSF to check for tailings near the spillway invert, and move deposition away from the spillway if needed<br>Tailings to be primarily spigotted at opposite end of facility from spillway  | Potentially Credible     |  |
| O5        | Embankment Overtopping due to poor deposition management - Decant Blockage                                      | Poor deposition management causes tailings to push water away from decant shaft AND/OR tailings inundate inclined decant shaft and remove capacity for removal of water<br>Water cannot be removed from the facility, and builds up to spillway level under normal conditions<br>Storm event exceeds spillway capacity/remaining freeboard<br>Flow of stormwater and mobilised tailings over the embankment crest causes deep scouring, which progressing an embankment failure.                       | TSF Designed with limited number of deposition points at opposite end of the decant structure to enable pond to be maintained around decant structure<br>Decant pipeline wrapped in geofab to reduce risk of decant blockage due to tailings ingress   |  | Routine inspections of the TSF to monitor deposition, pond extents, decant blockages, and implement remediate actions if needed  | Potentially Credible     |  |
| O6        | Embankment Overtopping due to poor deposition management - Over deposition                                      | Poor deposition management results in tailings being deposited above the maximum storage level, reducing available freeboard<br>Storm event consumes reduced freeboard and exceeds spillway capacity<br>Flow of stormwater and mobilised tailings over the embankment crest causes deep scouring, which progressing an embankment failure.   | TSF designed with a maximum storage level which will be at or below the Spillway Invert Level which shall not be exceeded<br>Spillway designed to safely pass the Probable Maximum Flood (PMF) with the pond starting at Spillway Invert Level, with additional freeboard provided in the spillway   |  | Routine surveillance to ensure maximum storage level is not exceeded<br>Tailings to be spigotted in select locations making over deposition difficult to achieve   | Potentially Credible     |  |
| O7        | Embankment Overtopping due to build-up of excess tailings bleed water   | Increased significant amounts of bleed water occur due to a combination of change in slurry composition and loss of decant removal capability<br>Increased pooling if not noticed, and stand-by pumps are not mobilised<br>Storm event consumes reduced freeboard and exceeds spillway capacity<br>Flow of stormwater and mobilised tailings over the embankment crest causes deep scouring, which progressing an embankment failure.  | Stochastic water balance to include variations on tailings composition, and potential impacts on pond levels<br>Spillway designed to safely pass the Probable Maximum Flood (PMF) with the pond starting at Spillway Invert Level, with additional freeboard provided in the spillway                |  | Procurement of an additional stand-by pump for emergency removal of water from the TSF<br>Upgrade to tailings delivery system to allow for full utilisation of High Rate Thickener<br>Routine Inspections and monitoring of pond level/extents<br>Routine monitoring of tailings slurry composition to ensure bleed rate is within design limits | Potentially Credible     |  |
| O8        | Embankment Overtopping due to higher than expected operating pond levels  | Water balance assessment not suitable for facility, resulting in insufficient surface water removal (i.e., insufficient pumping capacity) and rising operating pond<br>Increased pooling if not noticed, and stand-by pumps are not mobilised<br>Storm event consumes reduced freeboard and exceeds spillway capacity<br>Flow of stormwater and mobilised tailings over the embankment crest causes deep scouring, which progressing an embankment failure.  | Stochastic water balance of 1000 scenarios of climate data to allow for detailed modelling of predicted maximum pond levels<br>Spillway designed to safely pass the Probable Maximum Flood (PMF) with the pond starting at Spillway Invert Level, with additional freeboard provided in the spillway |  | Pumping capacity via decant system (and stand-by pumps) provided to aid in removal of stormwater<br>Routine Inspections and monitoring of pond level/extents   | Potentially Credible     |  |
| O9        | Embankment Overtopping due to single/multiple large storms that exhaust freeboard and exceeds spillway capacity | Single or multiple storm events larger than design events consume freeboard and exceed spillway capacity<br>Flow of stormwater and mobilised tailings over the embankment crest causes deep scouring, which progressing an embankment failure.   | Freeboard above Maximum Operating Pond to Spillway Invert Level provided<br>Spillway designed to safely pass the Probable Maximum Flood (PMF) with the pond starting at Spillway Invert Level, with additional freeboard provided in the spillway  |  | Pumping capacity via decant system (and stand-by pumps) provided to aid in removal of stormwater   | Potentially Credible     |  |
| O10       | Embankment Overtopping due to loss of spillway capacity from seismic induced crest settlement                   | Seismic event causes crest deformation in excess of spillway depth, creating a low spot below spillway level, effectively removing spillway capacity<br>Storm event occurs consuming remaining freeboard, and flows through deformation low spot<br>Flow of stormwater and mobilised tailings causes scouring of the embankment crest, which progressing an embankment failure.  | Site-specific Seismic Hazard Assessment undertaken to understand maximum seismic level<br>Embankment constructed by downstream method with primarily compacted rockfill, and are expected to experience only minimum deformation under SEE loading   | Full time QA/QC provided to ensure design specifications are met to minimise potential for crest settlement        | Inspections following seismic event to be undertaken to assess for potential crest settlement.   | Not Credible             | Deformation for 1:10,000 AEP Seismic Event indicate maximum 1.5% of total height to bedrock as deformation. At 15m, this is 225mm, which is less than the depth of the spillway and beach freeboard. |
| O11       | Embankment Overtopping due to reduced spillway capacity from seismic induced crest settlement                   | Seismic event causes crest deformation, creating a low spot above spillway invert level, reducing spillway capacity<br>Storm event occurs consuming remaining freeboard, and flows through the reduced spillway. Water eventually flows through the deformation low spot<br>Flow of stormwater and mobilised tailings causes scouring of the embankment crest, which progressing an embankment failure.  | As above, plus<br>Spillway designed to safely pass the Probable Maximum Flood (PMF) with the pond starting at Spillway Invert Level, with additional freeboard provided in the spillway  | Full time QA/QC provided to ensure design specifications are met to minimise potential for crest settlement        | Inspections following seismic event to be undertaken to assess for potential crest settlement.   | Potentially Credible     |  |
| O12       | Embankment Overtopping due to scour from failure of Spillway Erosion Protection Rip-Rap                         | Large storm event occurs, causing rapid flow down the spillway.<br>Erosion protection rip-rap is not suitable, and is quickly washed away/displaced.<br>Flow of water over the now exposed embankment causes scouring down to tailings level. Stormwater and mobilised tailings then accelerate the scouring, which progressing an embankment failure.   | Erosion Protection Rip-Rap designed to meet the maximum expected velocities down slope, and installed into the embankment<br>Geotextile underlay provided for additional erosion protection  | Full time QA/QC provided to ensure design specifications for rip-rap rockfill material selection and placement.    | Routine inspections of Spillway area for signs of degradation of Rip-Rap   | Potentially Credible     |  |

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| Site        | Costerfield Gold Mine  |
| Project     | Brunswick West Tailings Storage Facility                         |
| Job No.     | 109014.15  |
| Title       | Credible Failure Mode Assessment - Initial Qualitative Screening |
| Prepared by | Alex Campbell (ATCW)   |
| Date        | 30-Nov-2022  |

#### Assumptions

Unless otherwise stated, the failure mode is assumed to occur at the critical stage, which is the end of filling of the TSF  
These are failure modes that would result in a catastrophic failure of the embankment, resulting in released material

| Reference | Failure Mode  | Failure Progression  | Controls  |   |  | Failure Mode Credibility | Justification  |
|-----------|---|--|---|---|--|--------------------------|--|
|           |   |  | Design  | Construction  | Operation  |                          |  |
| S1        | Embankment Instability due to incorrect material characterisation - Embankment fill materials | Adopted embankment material strength parameters too high, and unsuitable embankment geometry is designed.<br>Under static loading embankment, experiences a slip failure and deformation equal to the remaining freeboard, resulting in tailings and water flow over the embankment crest, progressing an embankment failure.  | Conservative embankment material strength parameters based on laboratory testing adopted.<br>Embankments designed with suitable batter slope to provide sufficient FoS against static failure of embankment materials only.   | Full time QA/QC provided to ensure embankment design specifications are met   | Routine inspections to monitor for signs of movement   | Potentially Credible     |  |
| S2        | Embankment Instability due to incorrect material characterisation - Foundation materials      | Adopted foundation material strength parameters too high, and unsuitable foundation conditions are adopted<br>Under static loading embankment, experiences a slip failure and deformation equal to the remaining freeboard, resulting in tailings and water flow over the embankment crest, progressing an embankment failure.   | Conservative foundation material strength parameters based on laboratory testing adopted.<br>Embankments designed to provide sufficient FoS against static failure through foundations  | Full time QA/QC provided to ensure foundation preparation design specifications are met   | Routine inspections to monitor for signs of movement   | Potentially Credible     |  |
| S3        | Embankment Instability due to high phreatic surface   | Storm event raises water level to spillway invert level.<br>Significantly large hole in Geosynthetic Liner present<br>Water is not removed, and creates a high phreatic surface through the embankment section<br>Under static loading embankment with a high phreatic surface, experiences a slip failure and deformation equal to the remaining freeboard, resulting in tailings and water flow over the embankment crest, progressing an embankment failure.  | Embankment stability assessed at maximum phreatic surface level<br>Design of facility with Geosynthetic Liner to stop phreatic surface development<br>Majority of embankment designed as rockfill to freely drain water and prevent build-up of excess pore pressure  | Full time QA/QC provided to ensure embankment design specifications are met to prevent unexpected low permeability zones in downstream rockfill   | Pumping capacity via decant system (and stand-by pumps) provided to aid in removal of stormwater | Potentially Credible     |  |
| S4        | Embankment Instability due to inadequately constructed embankments                            | Unsuitable material used in construction of the embankments over a continuous region of the embankment section.<br>This unsuitable material is considerably weaker than the design materials<br>Under static loading embankment, experiences a slip failure and deformation equal to the remaining freeboard, resulting in tailings and water flow over the embankment crest, progressing an embankment failure.   |   | Full time QA/QC provided to ensure suitable embankment materials are used in construction, and placed/compacted in accordance with the specifications to meet the design intent.                                | Routine inspections to monitor for signs of movement   | Potentially Credible     |  |
| S5        | Embankment Instability due to inadequately prepared foundations                               | Inadequate foundation preparation undertaken during construction, resulting in a continuous weak region across the embankment section.<br>Under static loading embankment, experiences a slip failure and deformation equal to the remaining freeboard, resulting in tailings and water flow over the embankment crest, progressing an embankment failure.   |   | Full time QA/QC provided to ensure suitable foundation preparation is undertaken (stripping of unsuitable material, compaction of foundations) in accordance with the specifications to meet the design intent. | Routine inspections to monitor for signs of movement   | Potentially Credible     |  |
| S6        | Embankment Instability due to seismic deformation   | Significantly large seismic event occurs, causing deformation in excess of the freeboard to operational pond level<br>Tailings and operational water flow over the embankment crest, progressing an embankment failure.  | Site-specific Seismic Hazard Assessment undertaken to understand maximum seismic levels<br>Embankment constructed by downstream method with primarily compacted rockfill, and are expected to experience only minimum deformation under SEE loading.  |   | Inspections following seismic event to be undertaken to assess for signs of movement             | Not Credible             | Deformation for this scenario is greater than the deformation required for Case O10, so is determined non-credible |
| C1        | Embankment erosion failure due to cumulative static settlement and seismic deformation        | Poor construction controls implemented, resulting in loose uncompacted downstream rockfill.<br>Static settlement of the embankment crest occurs over the life of the facility, which is un-noticed and not remedied by mine personnel.<br>Seismic event causes significant crest deformation and liquefies tailings deposit.<br>Cumulative static settlement and crest deformation is in excess of the beach freeboard.<br>Tailings and operational water flow through low spot in the embankment, causing further scouring of the embankment crest, which progresses an embankment failure. | TSF designed with significant beach freeboard<br>Downstream rockfill specified to be compacted to minimise settlement<br>Site-specific Seismic Hazard Assessment undertaken to understand maximum seismic levels<br>Embankment constructed by downstream method with primarily compacted rockfill, and are expected to experience only minimum deformation under SEE loading. | Full time QA/QC provided to ensure embankment design specifications are met   | Routine inspections and aerial survey to identify crest movement, with works to be remedied.     | Potentially Credible     |  |

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| Site        | Costerfield Gold Mine                            |
| Project     | Brunswick West Tailings Storage Facility         |
| Job No.     | 109014.15  |
| Title       | Design, Construction and Operation Risk Register |
| Prepared by | Alex Campbell (ATCW), Shannon Green (MRCO)       |
| Date        | 31-Oct-2022                                      |



| Reference | Phase  | Identified Hazard or Risk               | Hazard/Risk Event   | Causes  | Potential Impacts       | Will this lead to catastrophic failure of the TSF? | Risk       |             |                | Control Measures   | Residual Risk |             |                | Comments   |
|-----------|--------|---|---|---|-------------------------|--|------------|-------------|----------------|--|---------------|-------------|----------------|--|
|           |        |   |   |   |                         |  | Likelihood | Consequence | Classification |  | Likelihood    | Consequence | Classification |  |
| Des1      | Design | Geotechnical Piping through Embankments | Piping through flaw in embankment core, which progresses and eventually leads to failure of TSF | Consistently high water levels within the facility.<br>Flaws in embankment upstream clay zone (cracking, poorly compacted layers etc) allowing for continued excess seepage through the embankment.<br>Lack of downstream filtering capability through the embankment section.<br>Progression of erosion not noticed. | Loss of 6 or more lives | Yes  | D          | 5           | 19             | Geosynthetic Liner provided to control/mitigate seepage through embankments<br>Ensure water within TSF is routinely pumped off<br>Full time Construction QA/QC to ensure design intent of materials and compaction is met<br>Routine inspections to detect for early signs of erosion progressing<br>Diversion bunding to be constructed around perimeter of Brunswick Pit to reduce PAR   | E             | 4           | 10             | Likelihood reduced to E, given numerical failure mode analysis<br>Consequences reduced to 4, given assessment of PLL = 1.0 |
| Des2      |        | Overtopping of Embankments              | Embankment overtopped by overwhelming reduced/lost of spillway capacity                         | Spillway partially or fully blocked.<br>Build up of excessive supernatant.<br>Extreme storm events.   | Loss of 6 or more lives | Yes  | C          | 5           | 22             | Ensure spillway mouth remains clear of blockages<br>Adhere to maximum storage levels for tailings<br>Ensure water within TSF is routinely pumped off<br>Diversion bunding to be constructed around perimeter of Brunswick Pit to reduce PAR  | E             | 4           | 10             |  |
| Des3      |        |   | Embankment overtopped due to spillway being overwhelmed   | Extreme storm events<br>Insufficient Spillway capacity  | Loss of 6 or more lives | Yes  | D          | 5           | 19             | Spillway designed to pass PMF, with additional spillway freeboard allowed for in design<br>Freeboard above Maximum Operating Pond to Spillway Invert Level provided<br>Diversion bunding to be constructed around perimeter of Brunswick Pit to reduce PAR   | E             | 4           | 10             |  |
| Des4      |        |   | Embankment overtopped by flow through low point below spillway invert                           | Excessive erosion of crest<br>Seismic or static crest deformation   | Loss of 6 or more lives | Yes  | D          | 5           | 19             | Routine inspections of embankment crest for assessment of crest low spots<br>Embankment materials sufficiently compacted to minimise static settlement<br>Site-specific Seismic Hazard Assessment undertaken to understand maximum seismic levels & design takes these levels into account<br>Ensure water within TSF is routinely pumped off<br>Diversion bunding to be constructed around perimeter of Brunswick Pit to reduce PAR | E             | 4           | 10             |  |
| Des5      |        |   | Failure of Spillway Erosion Protection Rip-Rap  | Erosion protection rip-rap is not suitable<br>Extreme storm events  | Loss of 6 or more lives | Yes  | D          | 5           | 19             | Erosion Protection Rip-Rap designed to meet the maximum expected velocities down slope, and installed into the embankment<br>Geotextile underlay provided for additional erosion protection<br>Diversion bunding to be constructed around perimeter of Brunswick Pit to reduce PAR   | E             | 4           | 10             |  |
| Des6      |        | Embankment Instability                  | Embankment instability  | Unsuitable materials in embankment or foundations<br>Unsuitable design<br>High phreatic surface caused by failure of liner  | Loss of 6 or more lives | Yes  | D          | 5           | 19             | Full time Construction QA/QC to ensure design intent of materials and compaction is met<br>Embankment designed with suitably high FoS against failure<br>Design incorporates a Geosynthetic Liner<br>Diversion bunding to be constructed around perimeter of Brunswick Pit to reduce PAR   | E             | 4           | 10             |  |



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| Reference | Phase        | Identified Hazard or Risk  | Hazard/Risk Event  | Causes   | Potential Impacts                          | Will this lead to catastrophic failure of the TSF? | Risk       |             |                | Control Measures   | Residual Risk |             |                | Comments |
|-----------|--------------|--|--|--|--|--|------------|-------------|----------------|--|---------------|-------------|----------------|----------|
|           |              |  |  |  |  |  | Likelihood | Consequence | Classification |  | Likelihood    | Consequence | Classification |          |
| Con1      | Construction | Extreme Weather Events   | Struck by lightning  | Human Error/Lack of awareness<br>Poor planning/monitoring of incoming weather<br>Unauthorised operations   | Loss of 1 life                             | No   | C          | 4           | 18             | Ensure extreme weather response plans are in place, and adhered to<br>Equipment and site to be locked and inaccessible in event of extreme weather   | E             | 4           | 10             |          |
| Con2      |              | Fall down embankment slope   | Fall/trip down embankment slope while walking  | Human Error/Lack of awareness<br>Uneven surfaces   | Broken limb                                | No   | A          | 2           | 16             | Provisions of safety bunds against all edges during construction<br>Ensure surfaces are even, with no abrupt changes which may cause a tripping hazard<br>Ensure personnel on foot are alert, aware and fit for work.<br>Only conduct operations in daylight hours<br>Downstream batters 4:1   | C             | 2           | 8              |          |
| Con3      |              | Fall down embankment slope during Liner installation                 | Fall down embankment slope during Liner installation   | Human Error/Lack of awareness<br>Uneven surfaces<br>Unsuitable Safety Equipment  | Long term disabling injury                 | No   | A          | 3           | 20             | Contractor and lining sub-contractor to develop specific Safe Work Method Statement and assess whether use of suitable safety harnesses and rappelling equipment for walking down slopes is required<br>Qualified liner installers to be used<br>Ensure liner personnel are alert, aware and fit for work.<br>Additional PPE identified and worn<br>Machinery installation to be utilised where possible   | B             | 2           | 12             |          |
| Con4      |              | Fall down embankment slope while driving vehicle (LV or Haul Trucks) | Fall down embankment slope while driving vehicle (LV or Haul Trucks)                             | Human Error/Lack of awareness<br>Unsuitable driving surface<br>Lack of skilled operator<br>Equipment used outside of specifications<br>Non-compliant/damaged equipment<br>Inadequate Traffic Management Plans<br>Lack of protective measures | Loss of 1 life                             | No   | B          | 4           | 21             | Provisions of safety bunds against all edges during construction<br>Safety bunds to be at least half the largest vehicle tyre using that work area<br>Speed limits to be set and enforced<br>Equipnebt with ROPS<br>Ensure equipment is maintained in a safe and functional manner<br>All mobile equipment to be inspected prior to commencement of operation on site<br>Sufficient room provided on ramps and embankment crests to allow vehicles to turn around and reverse if needed<br>Detailed Traffic Management Plans provided for all stages of construction for approval<br>All operators on site to be inducted, and access approved by MRCO | C             | 3           | 13             |          |
| Con5      |              | Vehicle accident   | Collision with public vehicle on public roads  | Fatigue<br>Uneven/dangerous roads<br>Non-compliant/damaged equipment<br>Inadequate Traffic Management Plans  | Loss of 1-5 lives                          | No   | C          | 4           | 18             | Detailed Traffic Management Plans provided for haulage of material on public roads, with plans to be approved by local council (as required), and communicated to locals<br>Identify and manage number of truck movements<br>Transport and stockpile material early to avoid heavy traffic loads during construction<br>Suitable signage provided to public in areas of concern<br>Speed limits to be set and enforced<br>Working within private land as much as possible  | E             | 4           | 10             |          |
| Con6      |              | Collision with mine vehicles on haul roads                           | Collision with mine vehicles on haul roads   | Fatigue<br>Human Error/Lack of awareness<br>Uneven/dangerous roads<br>Non-compliant/damaged equipment<br>Inadequate Traffic Management Plans   | Loss of 1-2 lives                          | No   | C          | 4           | 18             | Detailed Traffic Management Plans provided for all stages of construction<br>Ensure sufficiently wide haul roads provided for 2 way traffic, or establish and demarcate a 1-way circuit<br>Ensure equipment is maintained in a safe and functional manner<br>Regularly clean and maintain haul roads<br>Speed limits to be set and enforced<br>Dedicated two-way communication channel for construction  | E             | 3           | 6              |          |
| Con7      |              | Collision with mine vehicles on narrow access ramps/crests           | Collision with mine vehicles on narrow access ramps/crests                                       | Fatigue<br>Human Error/Lack of awareness<br>Unsuitable ramps/crests for driving<br>Non-compliant/damaged equipment<br>Inadequate Traffic Management Plans  | Loss of 1-2 lives                          | No   | C          | 4           | 18             | Detailed Traffic Management Plans provided for all stages of construction<br>Ensure sufficiently wide ramps/crests for 2 way access, or establish and demarcate a 1-way circuit<br>Maintain positive communications when travelling up/down narrow ramps<br>Dedicated two-way communication channel for construction<br>Ensure equipment is maintained in a safe and functional manner<br>Regularly clean and maintain access ramps<br>Vehicles to have spotter when reversing or dumping on crest<br>Speed limit of max 10km/hr to be set and enforced  | E             | 3           | 6              |          |
| Con8      |              | Interaction with Powerlines  | Contact with overhead powerlines during removal  | Human Error/Lack of awareness<br>Poor planning (lines are still live)<br>Non-compliant/damaged equipment   | Loss of 1 life                             | No   | C          | 4           | 18             | Ensure lines to be removed prior to commencement of construction<br>Removal of powerlines to be conducted by Powercor  | E             | 1           | 1              |          |
| Con9      |              |  | Contact with newly buried electrical lines   | Human Error/Lack of awareness<br>Lack of knowledge of buried powerlines<br>Non-compliant/damaged equipment   | Loss of 1 life                             | No   | C          | 4           | 18             | Ensure all operators are aware of buried powerline location<br>Ensure location and extent of buried powerlines are clearly demarcated at surface level   | E             | 4           | 10             |          |
| Con10     |              | Falling vegetation   | Struck by vegetation during clearing of trees  | Human Error/Lack of awareness<br>Non-compliant/damaged equipment<br>Lack of suitable PPE   | Long term injury                           | No   | C          | 3           | 13             | Establish safe exclusion zones during clearing<br>Ensure all protective PPE and equipment cabins are suitable for use<br>Vegetation to be removed by specialist contractor prior to construction commencing<br>Use of specialised and fit-for-purpose machinery  | E             | 1           | 1              |          |
| Con11     |              | Lifting and Cranage  | Falling objects from suspended loads (installation of decant structures, geosynthetic liner etc) | Human Error/Lack of awareness<br>Non-compliant/damaged equipment<br>Lack of suitable PPE   | Long term injury                           | No   | C          | 3           | 13             | Establish safe exclusion zones during lifting<br>Use of a dog-man to control suspended loads<br>Ensure all protective PPE and equipment cabins are suitable for use<br>Ensure equipment is maintained in a safe and functional manner, and is suitable for use   | E             | 3           | 6              |          |
| Con12     |              | Working within an excavation   | Collapsing slope   | Unsuitable excavation slopes   | Long term injury                           | No   | B          | 3           | 17             | Deep excavation slopes designed to safe angles<br>Design excavation slopes to be adhered to<br>Establish safe offsets from excavation toe when not required to work nearby<br>All operators on site to be inducted and aware of the risks  | E             | 3           | 6              |          |
| Con13     |              | Dust and particulates  | Unacceptable dust emissions generated at the construction boundary                               | Dry construction work environment<br>High wind<br>Vehicles operating at high speed<br>Fine construction material   | Measurable impact to surrounding community | No   | A          | 2           | 16             | Vehicle movements limited to sealed/watered roads under windy conditions (≥30 km/h)<br>Set and enforce speed limits<br>Vehicles to have loads covered when exiting site to transfer materials<br>Soil stockpiles stabilised if not being used for 28 days or greater<br>Dust generating activities not undertaken when wind speeds ≥ 30 km/h.<br>Water cart in operation   | B             | 1           | 7              |          |
| Con14     |              |  | Personnel exposed to dust  | Personnel working outside<br>High wind<br>Dry construction work environment  | First Aid Treatment                        | No   | A          | 1           | 11             | Personnel to work in enclosed cabs (where possible)<br>Work areas to be watered down<br>External work to be rescheduled if being impacted by dust generating activities<br>Make ear protection PPE readily available   | B             | 1           | 7              |          |



|             |  |
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| Site        | Costerfield Gold Mine                            |
| Project     | Brunswick West Tailings Storage Facility         |
| Job No.     | 109014.15  |
| Title       | Design, Construction and Operation Risk Register |
| Prepared by | Alex Campbell (ATCW), Shannon Green (MRCO)       |
| Date        | 31-Oct-2022                                      |

| Reference | Phase        | Identified Hazard or Risk                | Hazard/Risk Event   | Causes  | Potential Impacts  | Will this lead to catastrophic failure of the TSF? | Risk       |             |                | Control Measures   | Residual Risk |             |                | Comments |
|-----------|--------------|--|---|---|--|--|------------|-------------|----------------|--|---------------|-------------|----------------|----------|
|           |              |  |   |   |  |  | Likelihood | Consequence | Classification |  | Likelihood    | Consequence | Classification |          |
| Con15     | Construction | Noise                                    | Unacceptable noise emissions from site  | Machine noise   | Measurable but limited impact to surrounding community                   | No   | A          | 2           | 16             | Work during daylight hours and noise daytime limits<br>High noise activities to be located away from sensitive receptors<br>High noise activities to be undertaken behind bunding to limit noise emission<br>Construction period/time noise allowances<br>Squashed duck reverse alarm  | B             | 1           | 7              |          |
| Con16     |              | Erosion and sedimentation                | Sediment runoff   | High rainfall<br>No sediment/erosion controls<br>Lack of sediment/erosion controls<br>Dispersive materials exposed  | Measurable but limited environmental damage                              | No   | A          | 2           | 16             | Implement erosion/sediment control plan<br>Limit amount of exposed areas<br>Monitor weather forecast and take additional control measures prior to rainfall<br>Stabilise exposed materials and direct run-off to sediment control measures<br>Management in accordance with SEPP Waters of Victoria (section 42 - Management of construction activities) | C             | 2           | 8              |          |
| Con17     |              | Soil biological activity                 | Loss of soil biological activity  | Compaction of soil  | Substantial impact to environment  | No   | B          | 3           | 17             | Limit topsoil stockpiling to no greater than 2 metres in height<br>Stabilise stockpiles and promote vegetation growth  | D             | 3           | 9              |          |
| Con18     |              | Fuel, lubricants and hazardous materials | Release of fuel, lubricants and/or hazardous materials to the environment         | Leaks, spills and through stormwater run-off  | Measurable impact to surrounding environment                             | No   | C          | 2           | 8              | Store lubricants and hazardous materials in bunded areas within containers that can hold 125% of hazardous material<br>Locate storage areas away from waterways or areas prone to flooding<br>Minimise amount of lubricants and hazardous materials stored on site<br>Use existing MRCO fuelling facilities<br>Spill kits to be available                | D             | 2           | 5              |          |
| Con19     |              | Fire                                     | Ignition of fire and escape to surrounding properties                             | Fire ignition<br>Flammable materials  | Substantial impact to surrounding community                              | No   | B          | 3           | 17             | Implement hot work procedures<br>No hot-work on Total Fire Ban days<br>Water carts on-site to have the capability to extinguish fires<br>Flammable and combustible wastes to be removed from site as soon as practicable<br>Establish fire breaks around high fire risk areas<br>Fire suppression on equipment   | D             | 3           | 9              |          |
| Con20     |              | Non-mineral waste                        | Embankment seepage<br>Acid drainage   | Placement of non-mineral waste in non-free draining areas of embankment   | Routine inspections of Spillway area for signs of degradation of Rip-Rap | No   | C          | 2           | 8              | Design by suitably qualified dam engineer<br>Full time Construction QA/QC to ensure design intent of materials and compaction is met   | E             | 2           | 3              |          |
| Con21     |              | Pests                                    | Pest/vermin increase  | Poorly management of rubbish/waste attracting pest/vermin   | Measurable impact to surrounding environment                             | No   | C          | 2           | 8              | Regular removal of waste/rubbish to dedicated bins at Brunswick  | D             | 2           | 5              |          |
| Con22     |              | Water                                    | Site activities adversely affect local surface water                              | Site activities impact local waterways  | Measurable impact to surrounding environment                             | No   | A          | 2           | 16             | Installation of clean water diversion drains up-gradient of work area<br>Design onsite diversion drains to accommodate the surface water flows for a 1 in 10 year storm event (10% AEP), based on the area of the up-gradient catchment area<br>Divert surface drainage into erosion/control measures  | C             | 2           | 8              |          |
| Con23     |              | Imported materials                       | Contamination of the site by importing hazardous materials or soils               | Soils carry seeds of declared weeds or infested with soil-borne plant diseases  | Substantial impact to environment  | No   | D          | 3           | 9              | All imported material to be clean fill (known to be free of pathogens or declared weeds)<br>No topsoil to be imported  | E             | 3           | 16             |          |
| Con24     |              | Vehicle sediment transport               | Dust, silt and clay on public roads<br>Spread of weeds/pests                      | Vehicles carrying sediment, weeds, pests  | Substantial impact to environment  | No   | B          | 3           | 17             | All imported earthmoving equipment to be clean and free of soil on delivery to site<br>All imported earthmoving equipment to be clean and free of soil on departure from site<br>Light vehicles accessing site to be regularly cleaned and free of soil when departing site  | E             | 3           | 6              |          |
| Con25     |              | Visual amenity                           | Loss of amenity value by sensitive receptors                                      | No consideration of visual amenity loss<br>No identification of potential sensitive receptors<br>Removal of existing visual amenity controls - Brunswick planted vegetation | Measurable impact to surrounding community                               | No   | A          | 2           | 16             | Implement Community Engagement Plan<br>Limit height of Brunswick West TSF to height of existing TSFs (i.e. 200 mRL AHD)<br>Construct external batters to closure slope angle (4H:1V) and establish pasture   | D             | 2           | 5              |          |
| Con26     |              | Site access                              | Prevent unauthorised access to work area<br>Wildlife access onto the work area    | Site not secure   | Short term disabling injury  | No   | D          | 2           | 5              | Erect security fencing/signage around the site boundary<br>Fencing to be suitable sized to eliminate access by wildlife<br>Lock all gates when site is unattended<br>Control access to site when site is attended  | E             | 2           | 3              |          |
| Con27     |              | Stormwater                               | Installation of HDPE liner in RWP and/or BGM liner is delayed                     | Rainfall captured in TSF or RWP prevents installation of liner  | Major financial outset due to delay in TSF construction                  | No   | B          | 4           | 21             | Install piping infrastructure to permit pumping from construction site to existing TSFs<br>Construct TSF during drier weather period   | B             | 2           | 12             |          |
| Con28     |              | Extreme ambient temperature              | Installation of HDPE liner in RWP and/or BGM liner is delayed                     | High temperatures prevent welding of liner  | Major financial outset due to delay in TSF construction                  | No   | B          | 4           | 21             | Plan installation of liner during cooler, but dry, periods   | B             | 2           | 12             |          |
| Con29     |              | Material delivery                        | Delayed supply of liners and/or DN630 HDPE piping for decant structure            | Delayed international shipping<br>Small pipe quantities difficult to source or require a larger process run   | Major financial outset due to delay in TSF construction                  | No   | B          | 4           | 21             | Identify delivery timeframes for these long lead items (liner currently 6-7 months (as of Oct 22))<br>Procure items early and store to ensure they are available for construction  | E             | 4           | 10             |          |
| Con30     |              | Liner material faulty                    | Liner material does not meet specification  | Manufacturer defects<br>Damage during shipping  | Major financial outset due to delay in TSF construction                  | No   | B          | 4           | 21             | Manufacturer QAQC process to be established to ensure rolls meet specifications<br>Identify emergency alternative sources (if they exist)<br>Ensure defined patching process is outlined in specification  | E             | 4           | 10             |          |
| Con31     |              | Underground connection                   | Exploration drill connects TSF to underground works (whether current or historic) | UngROUTED drill hole  | Some financial outset required   | No   | C          | 2           | 8              | Check diamond drill hole database and ensure all holes in TSF and RWP footprint are grouted<br>For holes partially grouted, undertake field inspection to confirm grout status once cut undertaken to TSF floor RL   | E             | 2           | 3              |          |

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| Job No.     | 109014.15  |
| Title       | Design, Construction and Operation Risk Register |
| Prepared by | Alex Campbell (ATCW), Shannon Green (MRCO)       |
| Date        | 31-Oct-2022                                      |

| Reference | Phase      | Identified Hazard or Risk                                    | Hazard/Risk Event  | Causes   | Potential Impacts  | Will this lead to catastrophic failure of the TSF? | Risk       |             |                | Control Measures   | Residual Risk |             |                | Comments   |
|-----------|------------|--|--|--|--|--|------------|-------------|----------------|--|---------------|-------------|----------------|--|
|           |            |  |  |  |  |  | Likelihood | Consequence | Classification |  | Likelihood    | Consequence | Classification |  |
| Op1       | Operations | Fall down embankment slope                                   | Fall/trip down embankment slope while walking  | Human Error/Lack of awareness<br>Uneven surfaces   | Broken limb  | No   | A          | 2           | 11             | Provisions of safety bunds against all edges at completion of construction<br>Ensure surfaces are even, with no abrupt changes which may cause a tripping hazard<br>Ensure personnel on foot are alert, aware and fit for work.<br><b>All operators on site to be inducted and access approved by MRCO</b>   | C             | 2           | 8              | Isolation of ground personnel from the tailings surface reduces likelihood of entrapment     |
| Op2       |            |  | Fall down embankment slope while driving vehicle (LV)  | Human Error/Lack of awareness<br>Unsuitable driving surface<br>Non-compliant/damaged equipment<br>Lack of protective measures      | Loss of 1 life   | No   | C          | 4           | 18             | Provisions of safety bunds against all edges at completion of construction<br>Ensure equipment is maintained in a safe and functional manner<br>Ensure personnel are alert, aware and fit for work<br>Sufficient room provided on ramps and embankment crests to allow vehicles to turn around and reverse if needed<br>Safety bunds to be at least half the largest vehicle tyre using that work area<br>Speed limits to be set and enforced<br><b>All operators on site to be inducted and access approved by MRCO</b>   | B             | 2           | 12             | Isolation of vehicles from the tailings surface reduces likelihood of entrapment             |
| Op3       |            | Fall into Tailings/decant water                              | Fall into saturated tailings while walking along embankment crest  | Human Error/Lack of awareness<br>Uneven surfaces   | Long term injury   | No   | B          | 3           | 17             | Provision of life safety floatation rings<br>Access around the TSF at critical areas (near decant) to be undertaken in pairs<br>Ensure personnel on foot are alert, aware and fit for work<br>Two-way radio to be carried<br>Access points for tailings deposition and decant pumps to be located on embankment crest  | C             | 2           | 8              | Isolation of ground personnel from the tailings surface reduces likelihood of entrapment     |
| Op4       |            |  | Fall into saturated tailings while working around decant chute   | Human Error/Lack of awareness<br>Uneven/slippery surfaces  | Long term injury   | No   | B          | 3           | 17             | Provision of life safety floatation rings<br>Access down decant chute to be undertaken in pairs<br>Ensure personnel on foot are alert, aware and fit for work<br><b>Two-way radio to be carried</b>  | C             | 2           | 8              | Isolation of ground personnel from the tailings surface reduces likelihood of entrapment     |
| Op5       |            |  | Fall into saturated tailings while driving vehicle (LV)  | Human Error/Lack of awareness<br>Unsuitable driving surface<br>Non-compliant/damaged equipment<br>Lack of protective measures      | Long term injury, potentially loss of life                               | No   | C          | 4           | 18             | Provisions of safety bunds against all edges at completion of construction<br>Ensure equipment is maintained in a safe and functional manner<br>Ensure personnel are alert, aware and fit for work<br>Sufficient room provided on ramps and embankment crests to allow vehicles to turn around and reverse if needed<br>Safety bunds to be at least half the largest vehicle tyre using that work area<br>Speed limits to be set and enforced<br><b>All operators on site to be inducted and access approved by MRCO</b><br>Provision of window break kit within cab | D             | 3           | 9              | Isolation of vehicles from the tailings surface reduces likelihood of entrapment             |
| Op6       |            | Excessive water stored in TSF                                | Increase seepage<br>Tailings settling density not achieved (delay to closure)  | High rainfall<br>No other locations to store process water<br>Decant pump undersize/not functional                                 | Substantial impact to the environment                                    | No   | C          | 3           | 13             | Full site water balance assessment completed<br>Return Water Pond designed accordingly & constructed<br>Decant pump sized correctly and redundant pump kept as critical stock  | D             | 2           | 5              |  |
| Op7       |            | TSF reaches capacity early                                   | Hiatus of operations   | Insufficient monitoring of tailings placement against designed storage<br>Tailings placed are not in accordance with design intent | Serious impact to company reputation                                     | No   | C          | 4           | 18             | TSF bi-monthly monitoring of storage capacity<br>Annual audit of TSF for independent monitoring of storage capacity<br>Tailings placement undertaken in a manner to maximise tailings settling density<br>Decant water continually removed from decant sump to maximise density<br>Tailings from tailings thickener is in accordance with design intent of tailings placement specification  | E             | 4           | 10             |  |
| Op8       |            | Tailings dust generation (during operation and post closure) | Human health impacted<br>Impact to air quality   | High winds<br>Exposed tailings<br>Dry tailings   | Measurable impact to surrounding community                               | No   | D          | 2           | 5              | Dust monitoring during construction/operation<br>Operate tailings deposition as per operations manual to meet design intent<br>Stabilise tailings surface  | E             | 2           | 3              | Proposed controls will reduce potential for dust to become airborne                          |
| Op9       |            | Unauthorised site access                                     | Unrestricted access to TSF by members of the public or unauthorised staff resulting in injury due to various TSF hazards                 | Site access not controlled   | Loss of 1 life   | No   | C          | 4           | 18             | Control entry points to site during operation<br>Site fencing and signage around extents of TSF during operation and following closure<br><b>Site personnel must be inducted to gain access to TSF</b>   | E             | 4           | 10             | Strict protocols reduces likelihood of unauthorised or inadvertent access to site            |
| Op10      |            | Rockfall from embankment slope                               | Injury to personnel from rockfall  | Personnel operating at toe of embankment slope   | Long term injury   | No   | C          | 3           | 13             | Ground personnel to avoid toes of downstream embankment slopes, unless undertaking specific inspections/monitoring<br>Embankment downstream batter slopes designed flatter than residual angle of repose of rockfill, and covered with topsoil to reduce risk of loose rockfill mobilisation down slope<br><b>Signage and restriction of access to TSF and surrounds</b>   | E             | 3           | 6              | Isolation of ground personnel from the toe of embankment slopes reduces likelihood of injury |
| Op11      |            | Damage to tailings delivery pipelines                        | Release of tailings outside of the TSF leading to contamination of the surrounding environment   | Pipeline not maintained<br>Failure of pipeline join<br>Leak not detected   | Measurable impact to surrounding community                               | No   | C          | 2           | 8              | Routine inspection of tailings delivery pipelines to be carried out on a regular basis by appropriately trained and experienced personnel<br>Daily inspections of pipe conditions<br>Assessment of pipe corridor for potential flow directions<br><b>Double walled pipeline to aid containment</b>   | E             | 2           | 3              |  |
| Op12      |            | Poor communication   | Potential hazards not identified or not communicated<br>Management plans not communicated<br>TSF not operated in line with design intent | Insufficient governance of tailings management<br>Lack of training   | Loss of 6 or more lives  | Yes  | B          | 5           | 24             | Tailings Management Plan to be updated and communicated<br>Annual surveillance of TSF by independent dam engineer<br>Tailings Dam operating, maintenance and surveillance manual to be created and followed  | E             | 5           | 15             |  |
| Op13      |            | Regulatory non-compliance                                    | TSF operated not in accordance with approval conditions  | Approval conditions not fully understood<br>Approval conditions not followed   | Substantial impact to company reputation<br>Substantial financial outset | No   | C          | 3           | 13             | Open communication with regulatory bodies<br>Annual surveillance of TSF by independent dam engineer to ensure compliance with approval conditions<br>Tailings strategy to be annual updated to ensure sufficient timelines to obtain approvals/permit<br><b>Clear communication of requirements with all parties</b>   | E             | 3           | 6              |  |
| Op14      |            | Groundwater  | Groundwater contamination  | Seepage  | Serious impact to the environment  | No   | C          | 4           | 18             | Installation of seepage bores<br>Groundwater monitoring on monthly basis<br>Management of TSF in accordance with operating, maintenance and surveillance manual<br>Installation of BGM/HDPE liner on walls, and clay liner on impoundment floor of TSF<br><b>Installation of BGM/HDPE liner for RWP</b>  | E             | 4           | 10             |  |
| Op15      |            | Embankment instability                                       | Failure of TSF embankment  | Water ponding at embankment toe  | Loss of 6 or more lives  | Yes  | B          | 5           | 24             | Toe areas to be shaped during construction to be free draining<br>Daily TSF inspections<br><b>Removal of any water ponding and earthworks to prevent reoccurrence</b>  | E             | 5           | 15             |  |

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| Reference | Phase   | Identified Hazard or Risk               | Hazard/Risk Event   | Causes  | Potential Impacts                                | Will this lead to catastrophic failure of the TSF? | Risk       |             |                | Control Measures  | Residual Risk |             |                | Comments |
|-----------|---------|---|---|---|--|--|------------|-------------|----------------|---|---------------|-------------|----------------|----------|
|           |         |   |   |   |  |  | Likelihood | Consequence | Classification |   | Likelihood    | Consequence | Classification |          |
| Clo1      | Closure | Tailings left exposed on closure        | Future dust loss/contaminated surface water runoff<br>Unhabitable habitat for future land use | Poor execution of closure plan<br>Poor landform design                                | Substantial impact to the environment            | No   | C          | 3           | 13             | Closure plan includes a cover system and vegetation plan<br>Closure plan to be reviewed prior to closure works commencing<br>Sufficient thickness of inert soils allowed for tailings cover<br>Survey to be undertaken of final tailings surface and top of capping layer to measure thickness of cover soils | E             | 3           | 6              |          |
| Clo2      |         | Root penetration through capping system | Penetration of cap by vegetation roots  | Vegetation establishes on landform  | Measurable but limited impact to the environment | No   | D          | 2           | 5              | Vegetation to be pasture<br>Sheep grazing will remove any tree suckers<br>Post closure monitoring to identify the establishment of any trees/shrubs and remove  | E             | 2           | 3              |          |
| Clo3      |         | Suitability of cover soils              | Unsuccessful revegetation   | Cover soil not suitable<br>Landform design inadequate                                 | Substantial impact to the environment            | No   | D          | 2           | 5              | Use of stockpiled topsoil from site<br>Closure plan including cover system and vegetation plan to be refined as closure approaches<br>Engage speciality consultant to aid closure planning process  | E             | 2           | 3              |          |
| Clo4      |         | Unforeseen deterioration of liner       | Failure of liner  | Undocumented placement of contaminated material in TSF                                | Substantial impact to the environment            | No   | C          | 3           | 8              | Annual surveillance of TSF by independent dam engineer<br>Tailings Dam operating, maintenance and surveillance manual to be created and followed<br>Closure plan to be reviewed prior to closure works commencing   | E             | 3           | 6              |          |
| Clo5      |         | Future unsuitable land use proposed     | Rehabilitation disturbed  | Change in ownership   | Measurable but limited impact to the environment | No   | C          | 2           | 8              | S173 agreement to set out future restrictions for future development of the land  | E             | 2           | 3              |          |
| Clo6      |         | Erosion                                 | Failure of terminal slopes  | Landform design inadequate<br>High rainfall event during rehabilitation establishment | Substantial impact to the environment            | No   | D          | 3           | 9              | Slopes to be constructed to terminal slopes on initial construction to aid trials during operation of the facility  | E             | 3           | 6              |          |

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## APPENDIX B – BRUNSWICK WEST TSF DATA SHEET

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# TAILINGS STORAGE DATA SHEET

## Project Data

|                                |  |       |  |
|--------------------------------|--|-------|--|
| Licence/Work Authority:        | <input type="text"/>   | Date  | <input type="text"/>                     |
| Licensee                       | <input type="text"/>   |       |  |
| Operation/Site name            | <input type="text" value="Mandalay Resources Costerfield Operations Costerfield Gold Mine"/> |       |  |
| TSF name                       | <input type="text" value="Brunswick West TSF"/>  |       |  |
| Location                       | <input type="text" value="Costerfield"/>   |       |  |
| Municipality                   | <input type="text" value="City of Bendigo"/>   |       |  |
| TSF centre coordinates (GDA94) | <input type="text" value="5915690"/>   | North | <input type="text" value="302960"/> East |
| Name data provider             | <input type="text" value="ATC Williams"/>  |       |  |
| Telephone                      | <input type="text" value="03 8587 0900"/>  |       |  |

## TSF Data

### TSF Status

Proposed ☒ Operational ☐ Care and Maintenance ☐ Part rehabilitated ☐ Rehabilitated ☐

|  |  |                                |                |                                    |   |                |  |
|--|--|--------------------------------|----------------|------------------------------------|---|----------------|--|
| Type of TSF <sup>1</sup>                   | <input type="text" value="Paddock"/>                           |                                |                | Number of Cells <sup>2</sup>       | <input type="text" value="1"/>                            |                |  |
| Catchment area <sup>3</sup>                | <input type="text" value="6.1 ha"/>                            |                                |                | Nearest watercourse                | <input type="text" value="Wappentake Creek"/>             |                |  |
| Date deposition started (mm/yy)            | <input type="text" value="1/10/2023"/>                         |                                |                | Date deposition completed          | <input type="text" value="-"/>                            |                |  |
| Tailings discharge method <sup>4</sup>     | <input type="text" value="Multi-spigot"/>                      |                                |                | Water recovery method <sup>5</sup> | <input type="text" value="Gravity fed decant"/>           |                |  |
| Bottom of facility sealed or lined?<br>Y/N | <input type="text" value="Y"/>                                 |                                |                | Type of seal or liner <sup>6</sup> | <input type="text" value="Compacted clay and synthetic"/> |                |  |
| Depth to original groundwater level        | <input type="text" value="12"/>                                | m                              |                | Original groundwater TDS           | <input type="text" value="1000-3500"/>                    | mg/l           |  |
| Ore process <sup>7</sup>                   | <input type="text" value="Crushing and Screening, flotation"/> |                                |                | Material storage rate <sup>8</sup> | <input type="text" value="153,000"/>                      |                |  |
| IMPOUNDMENT VOLUME                         | Present  | <input type="text" value="0"/> | m <sup>3</sup> | Expected maximum                   | <input type="text" value="584,000"/>                      | m <sup>3</sup> |  |
| MASS OF SOLIDS STORED                      | Present  | <input type="text" value="0"/> | tonnes         | Expected maximum                   | <input type="text" value="759,000"/>                      | tonnes         |  |

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TAILINGS STORAGE DATA SHEET

Foundation soils

Foundaton rocks

MAX WALL HEIGHT (AGL)<sup>9</sup>

CREST LENGTH

IMPOUNDMENT AREA

Wall lifting by

Upstream ☐

Downstream ☒

Centre line ☐

Present m Expected 14.5 m

Present m Expected max 980 m

Present m Expected max 6.1 ha m

Properties of Tailings

TDS<sup>10</sup> mg/l

pH 6.8

Solids content% 45-50

Deposited density 0.98 t/m<sup>3</sup>

WAD CN<sup>11</sup> mg/l

Total CN 0.723 mg/l

Chemical Constituents of tailings<sup>12</sup>

| Constituent | Solid/Liquid | Conc.(units) <sup>13</sup> | Constituent | Solid/Liquid | Conc.(units) <sup>11</sup> |
|-------------|--------------|----------------------------|-------------|--------------|----------------------------|
| Arsenic     | Solid        | 294 mg/kg                  |             |              |                            |
| Copper      | Solid        | 10 mg/kg                   |             |              |                            |
| Lead        | Solid        | 510 mg/kg                  |             |              |                            |
| Zinc        | Solid        | 37 mg/kg                   |             |              |                            |
|             |              |                            |             |              |                            |
|             |              |                            |             |              |                            |
|             |              |                            |             |              |                            |

ADVERTISED  
PLAN





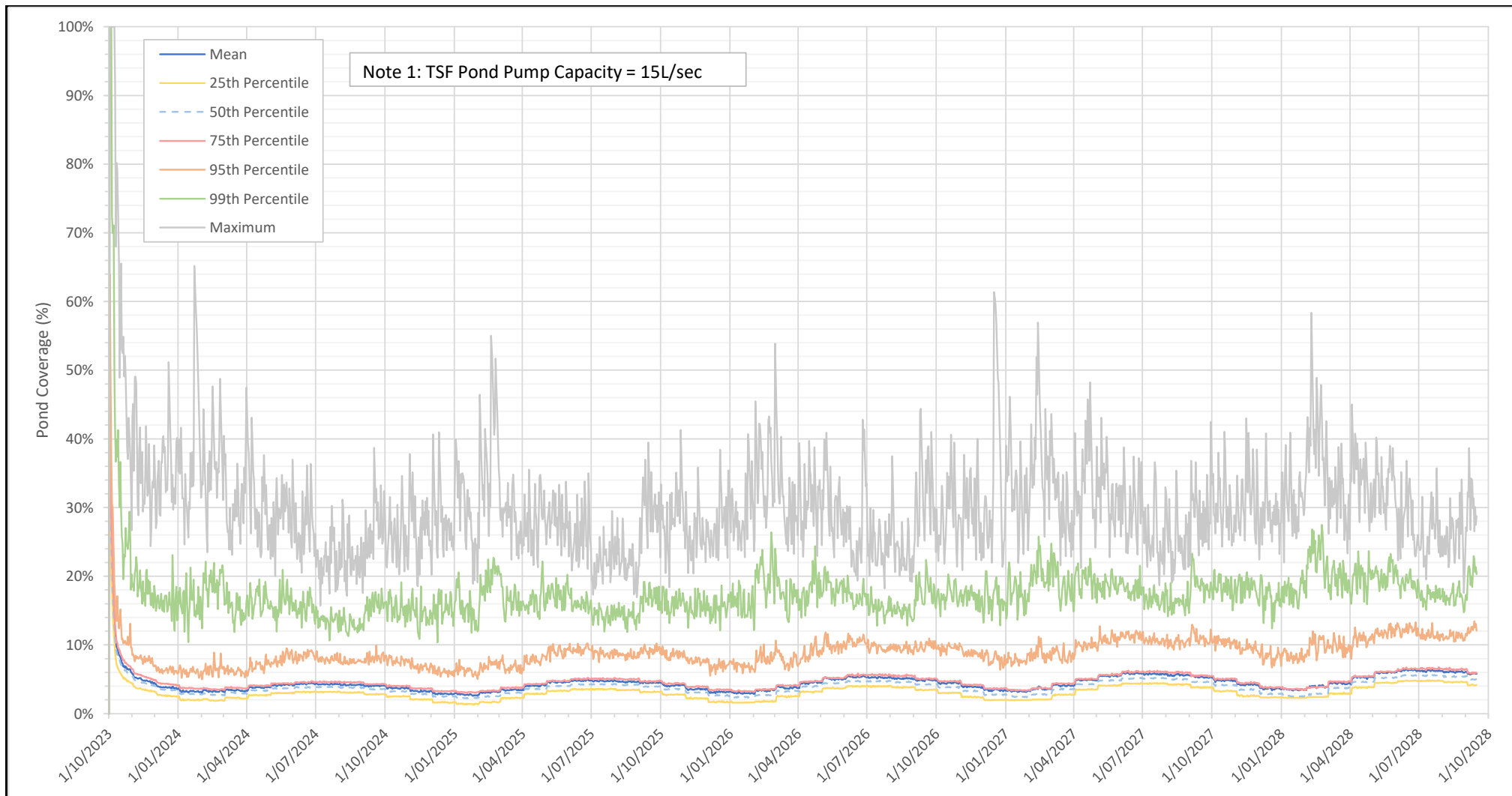
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## APPENDIX C – WATER BALANCE ASSESSMENT RESULTS

**ADVERTISED  
PLAN**



# ADVERTISED PLAN



## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfiled Gold Mine

#### Brunswick West Tailings Storage Facility

#### Water Balance Assessment - TSF Pond Coverage

Date: 1/03/2023 Job No: 109014.15

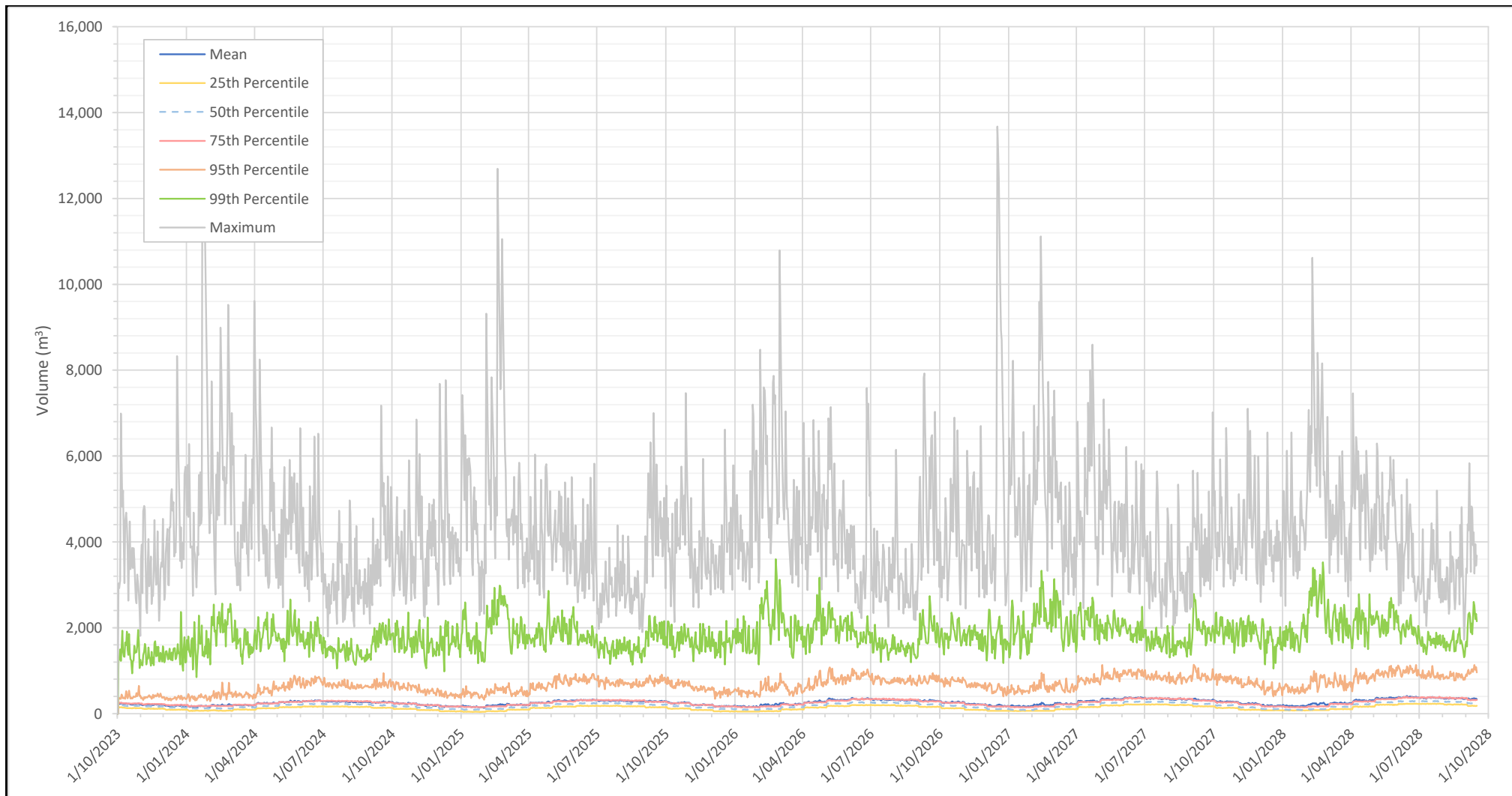
FIGURE C1



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# ADVERTISED PLAN



## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfiled Gold Mine

#### Brunswick West Tailings Storage Facility

#### Water Balance Assessment - TSF Pond Volume

**Date:** 1/03/2023 **Job No:** 109014.15

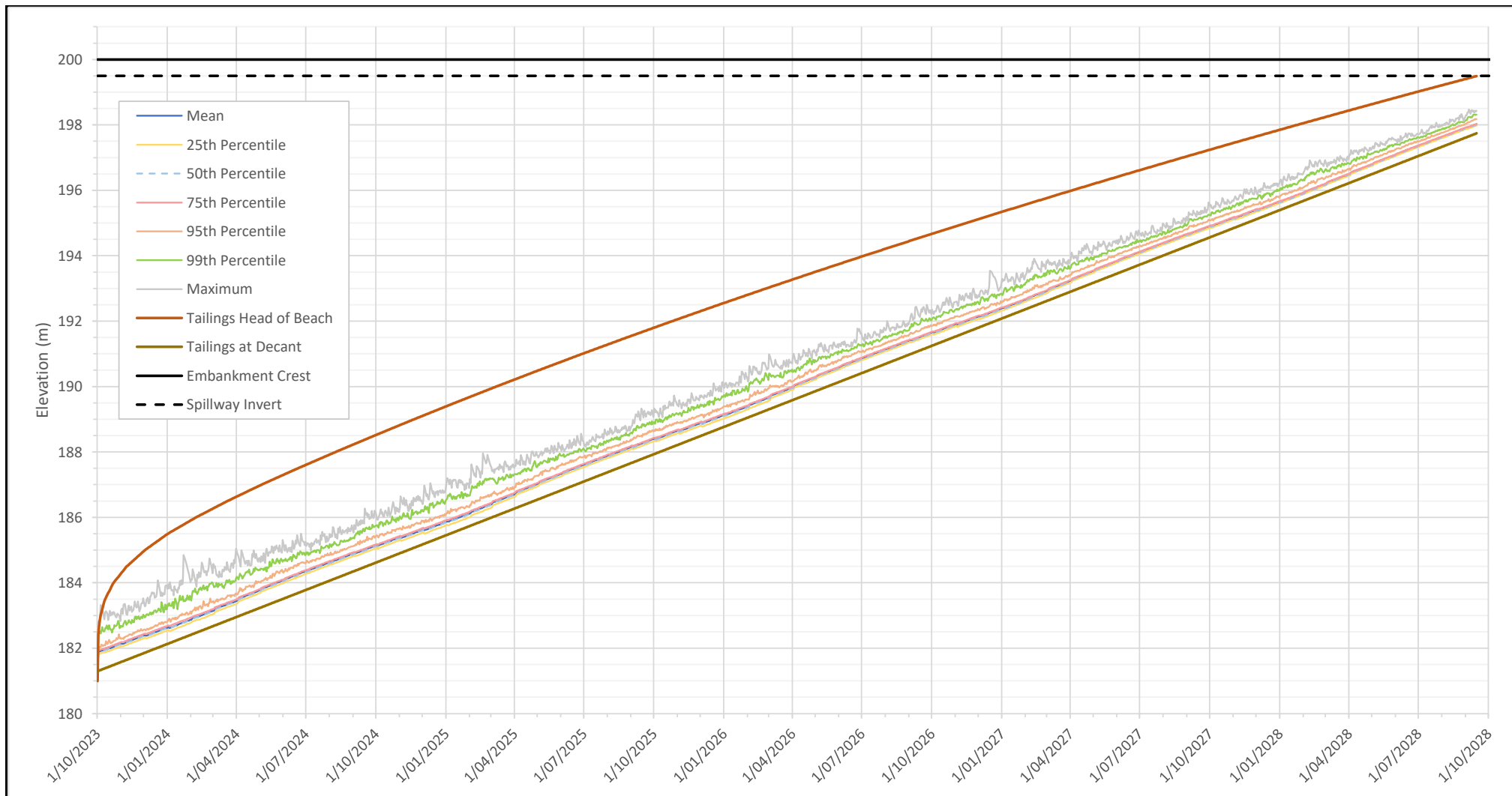
**FIGURE C2**



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# ADVERTISED PLAN



## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfiled Gold Mine

#### Brunswick West Tailings Storage Facility

#### Water Balance Assessment - TSF Pond Elevation

**Date:** 1/03/2023 **Job No:** 109014.15

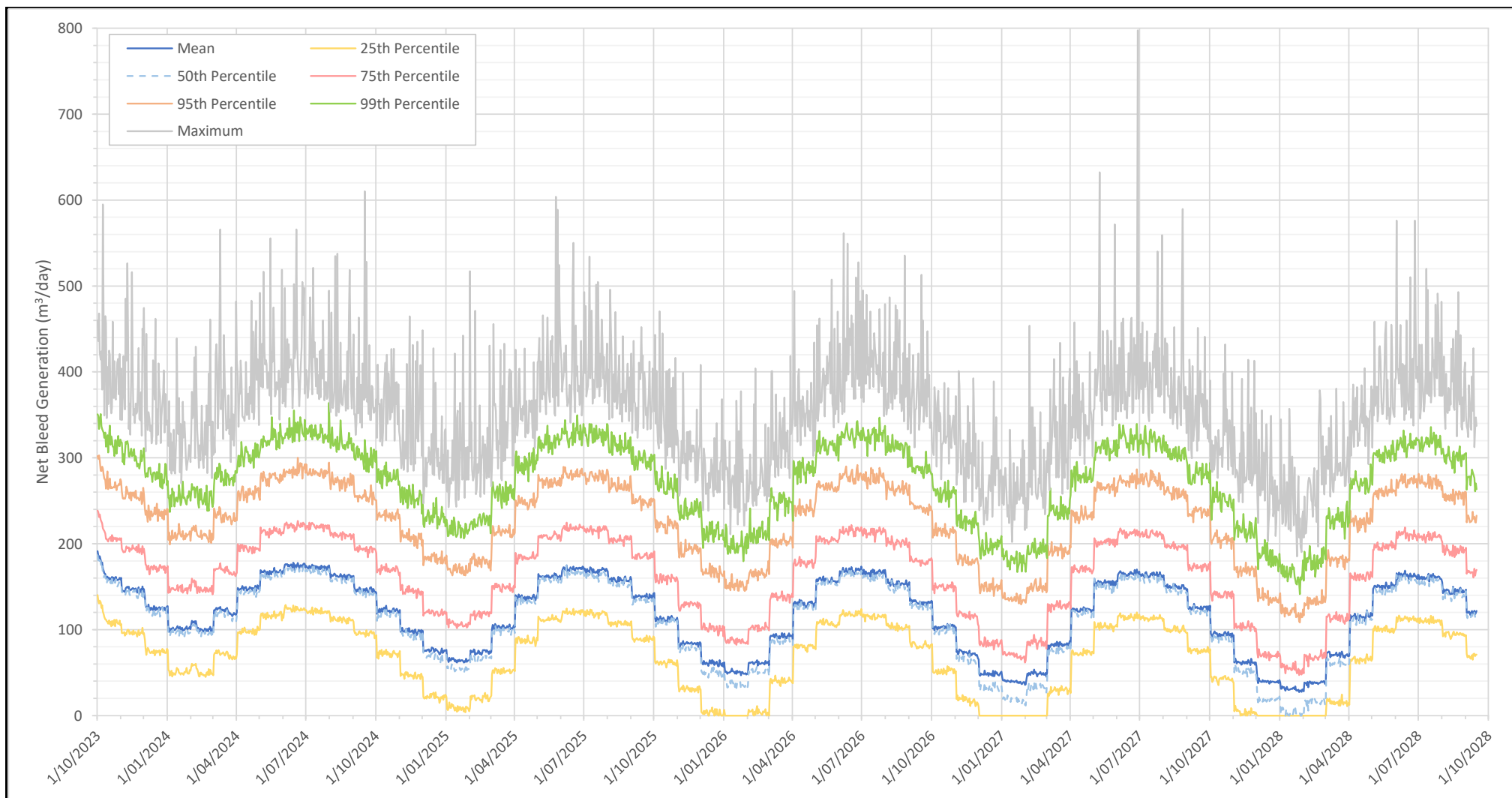
**FIGURE C3**



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# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfiled Gold Mine

#### Brunswick West Tailings Storage Facility

#### Water Balance Assessment - Net Bleed Generated

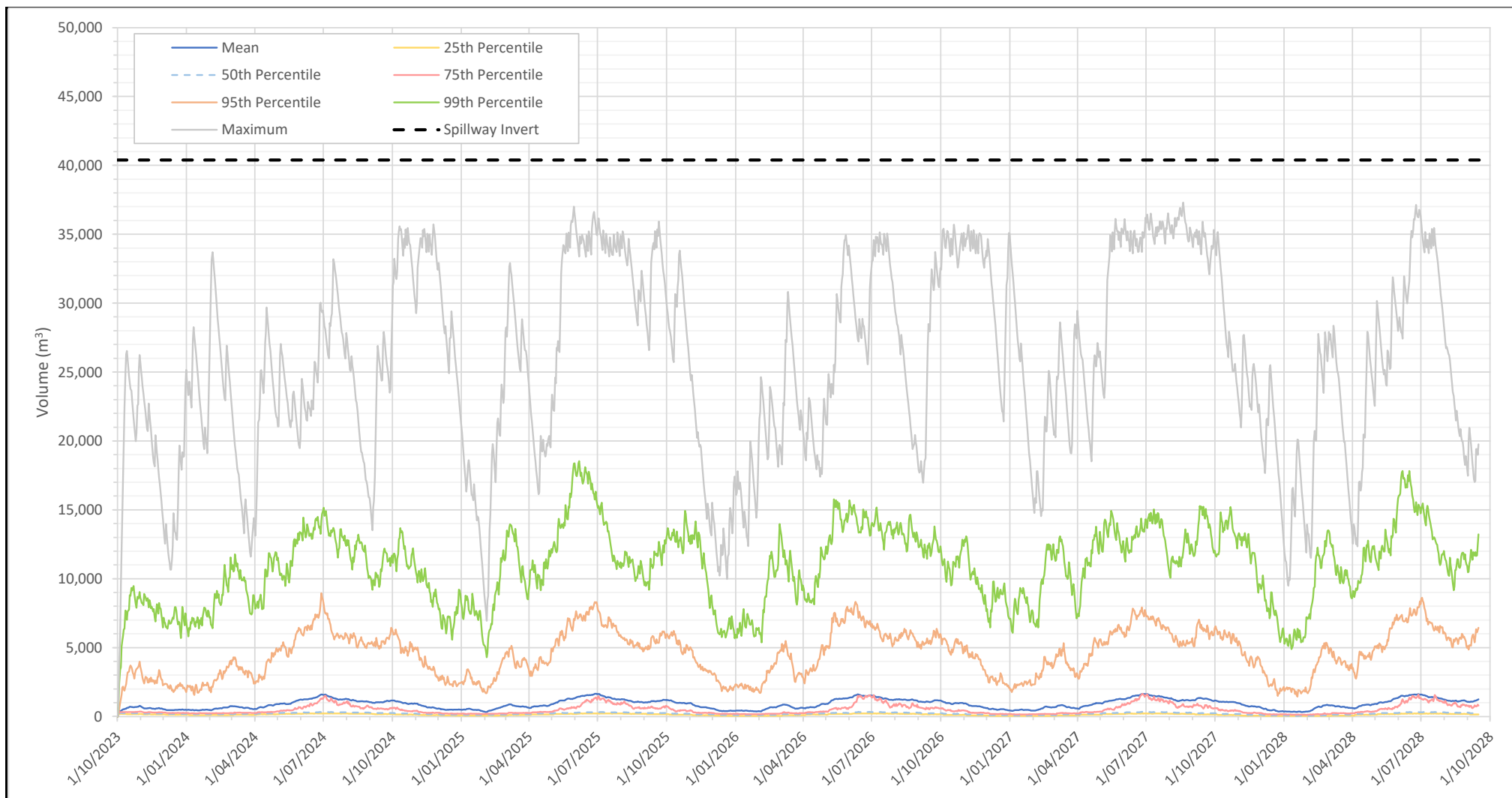
Date: 1/03/2023

Job No: 109014.15

FIGURE C4



# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfiled Gold Mine

#### Brunswick West Tailings Storage Facility

#### Water Balance Assessment - RWP Pond Volume

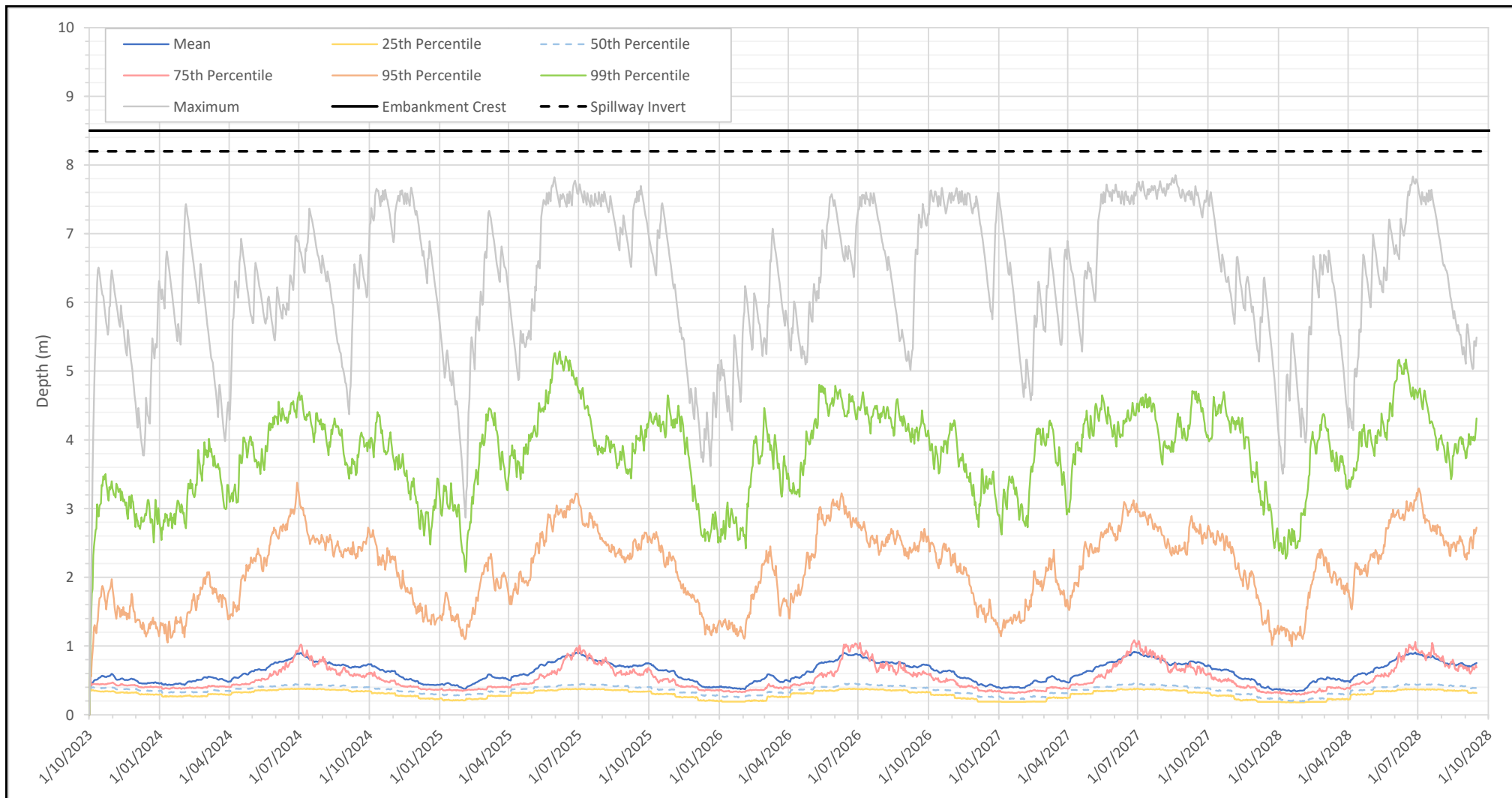
Date: 1/03/2023

Job No: 109014.15

**FIGURE C5**



# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfiled Gold Mine

#### Brunswick West Tailings Storage Facility

#### Water Balance Assessment - RWP Pond Depth

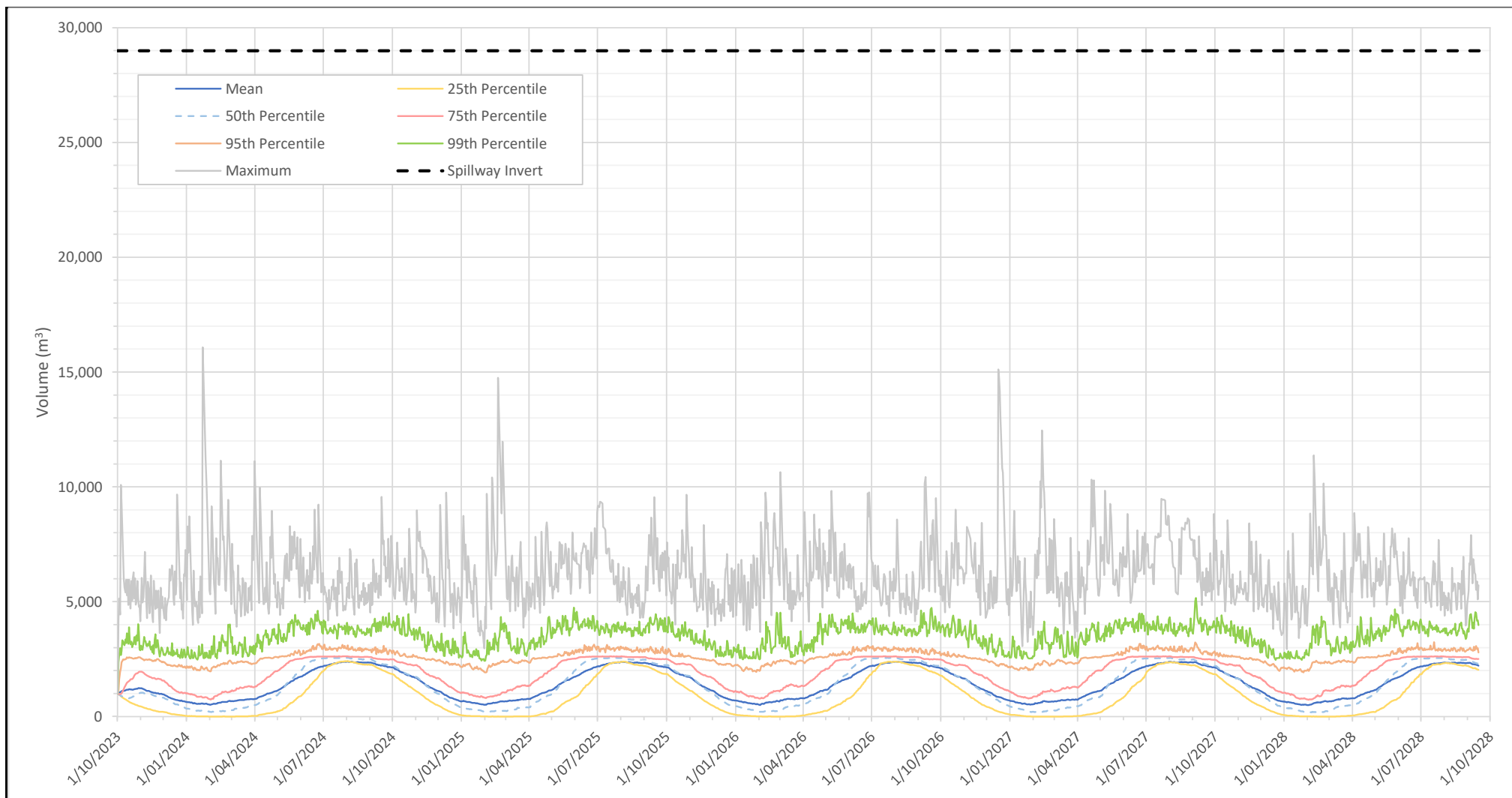
**Date:** 1/03/2023

**Job No:** 109014.15

**FIGURE C6**



# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfiled Gold Mine

#### Brunswick West Tailings Storage Facility

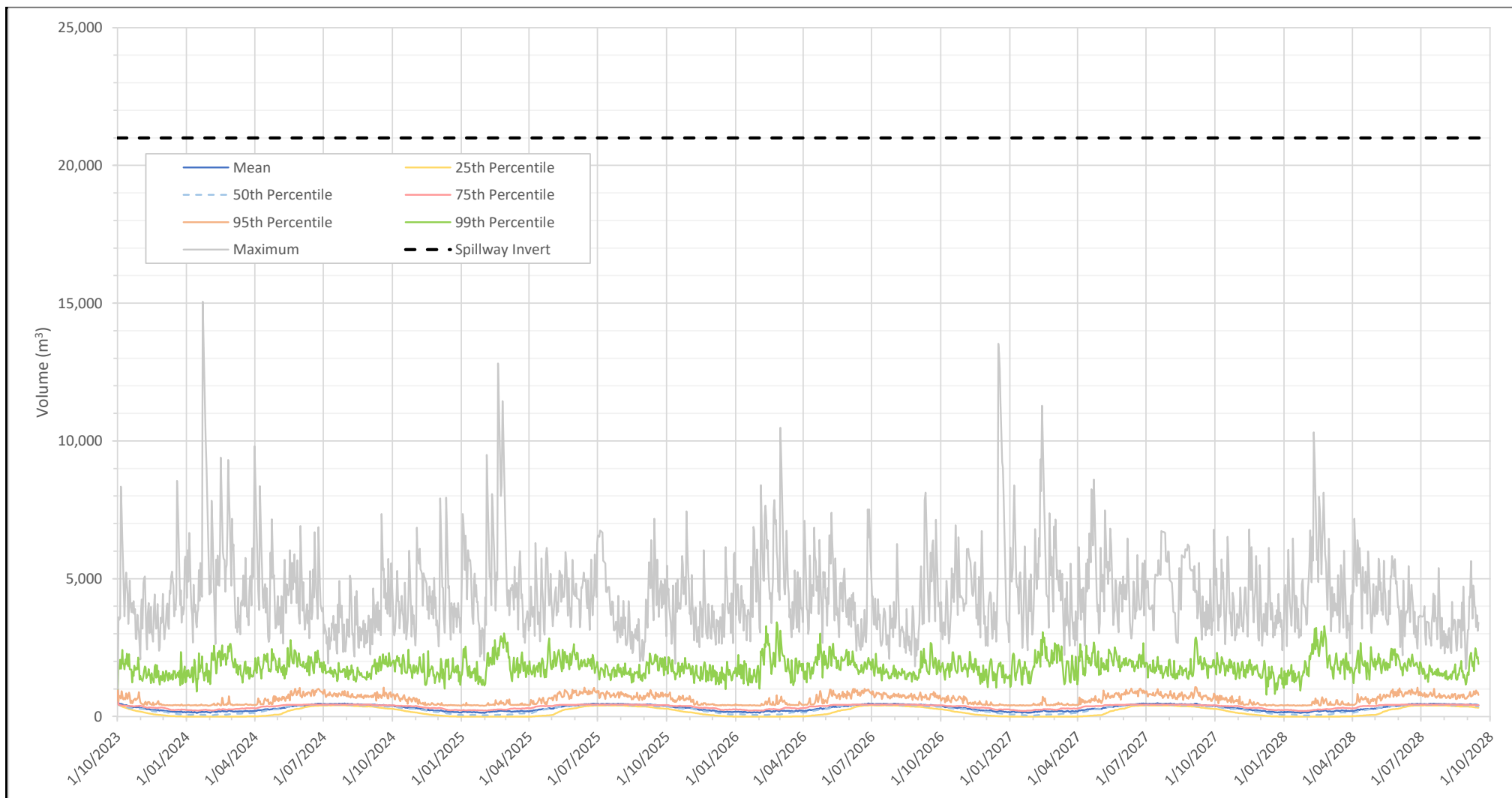
#### Water Balance Assessment - Bombay TSF Pond Volume

Date: 1/03/2023 Job No: 109014.15

FIGURE C7



# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

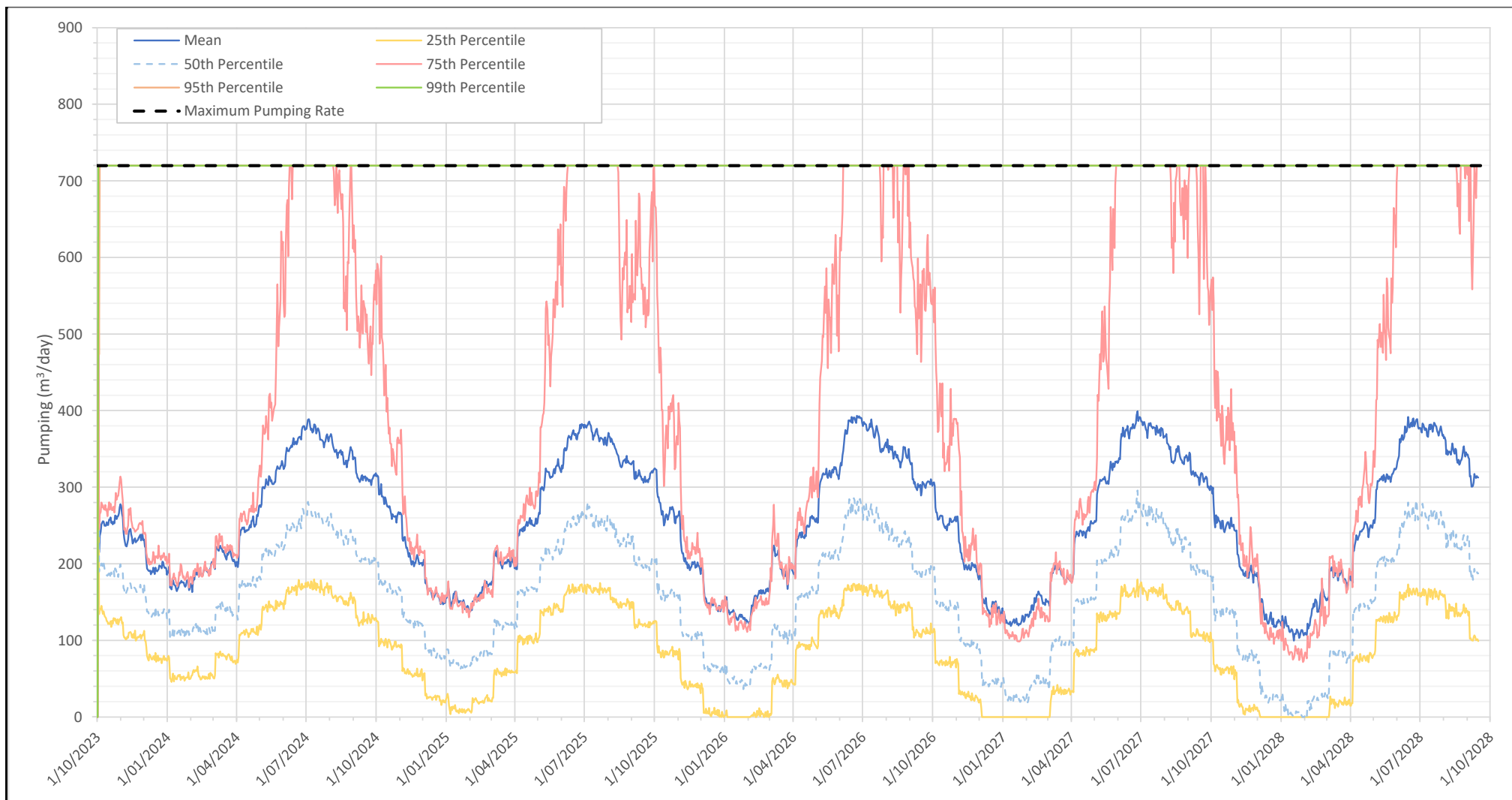
#### Water Balance Assessment - Brunswick TSF Pond Volume

Date: 1/03/2023 Job No: 109014.15

FIGURE C8



# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Water Balance Assessment - Pumping out from External RWP

**Date:** 1/03/2023 **Job No:** 109014.15

**FIGURE C9**





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## APPENDIX D – CLEAN WATER SURFACE DRAINAGE VERIFICATION

**ADVERTISED  
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# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### COSTERFIELD GOLD MINE

Brunswick West Tailings Storage Facility Detailed Design

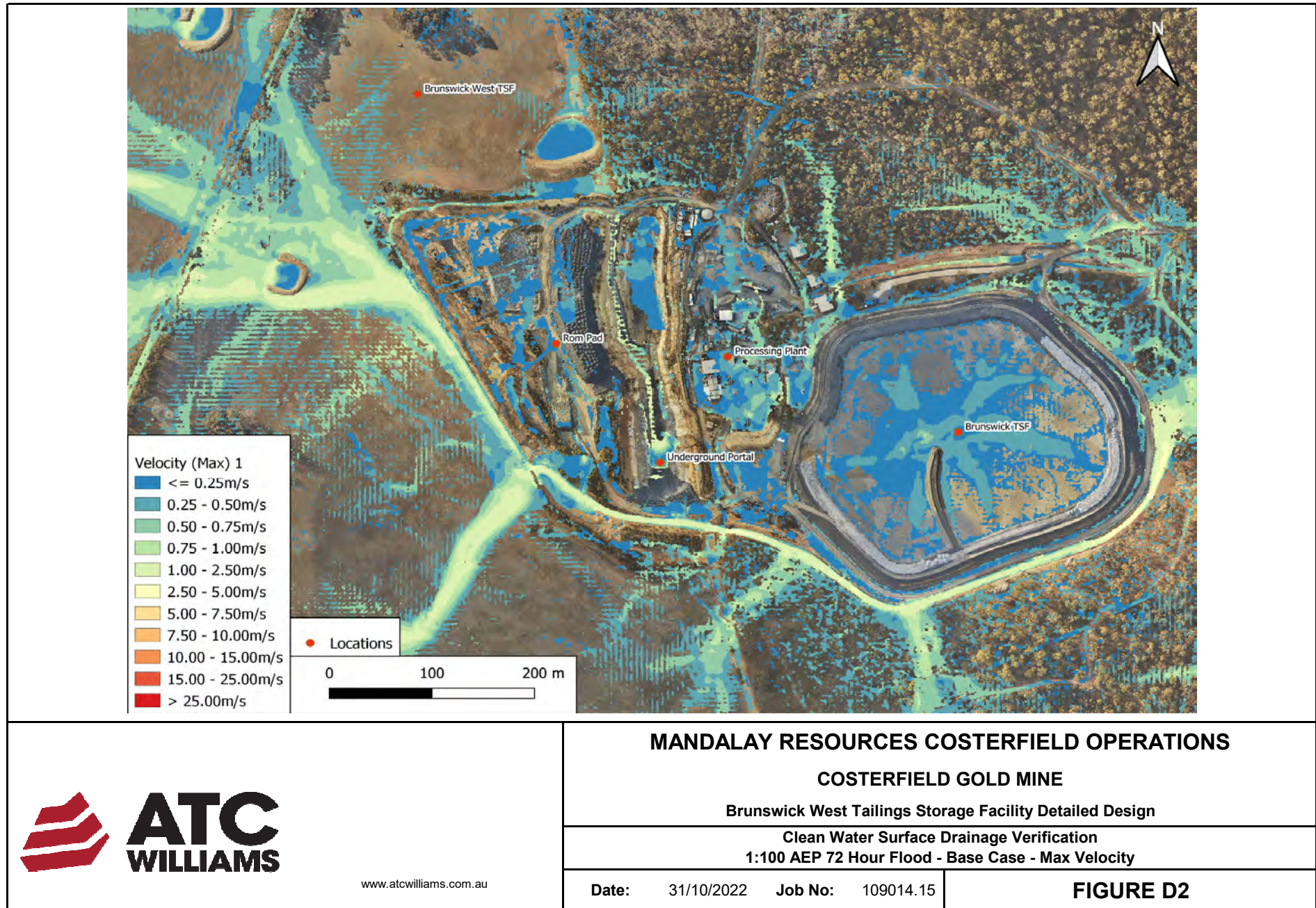
Clean Water Surface Drainage Verification  
1:100 AEP 72 Hour Flood - Base Case - Max Depth

Date: 31/10/2022 Job No: 109014.15

FIGURE D1



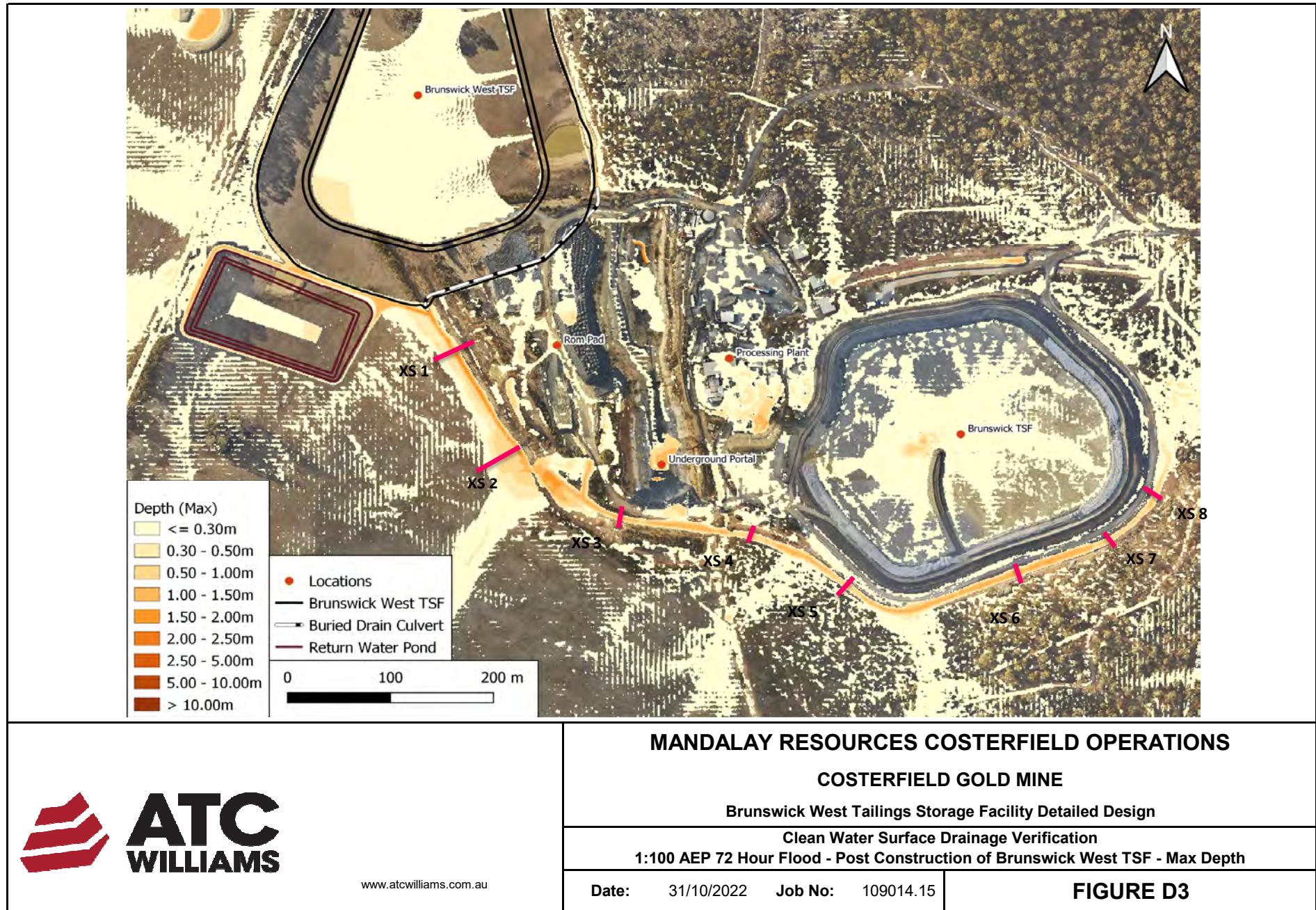
# ADVERTISED PLAN



[www.atcwilliams.com.au](http://www.atcwilliams.com.au)

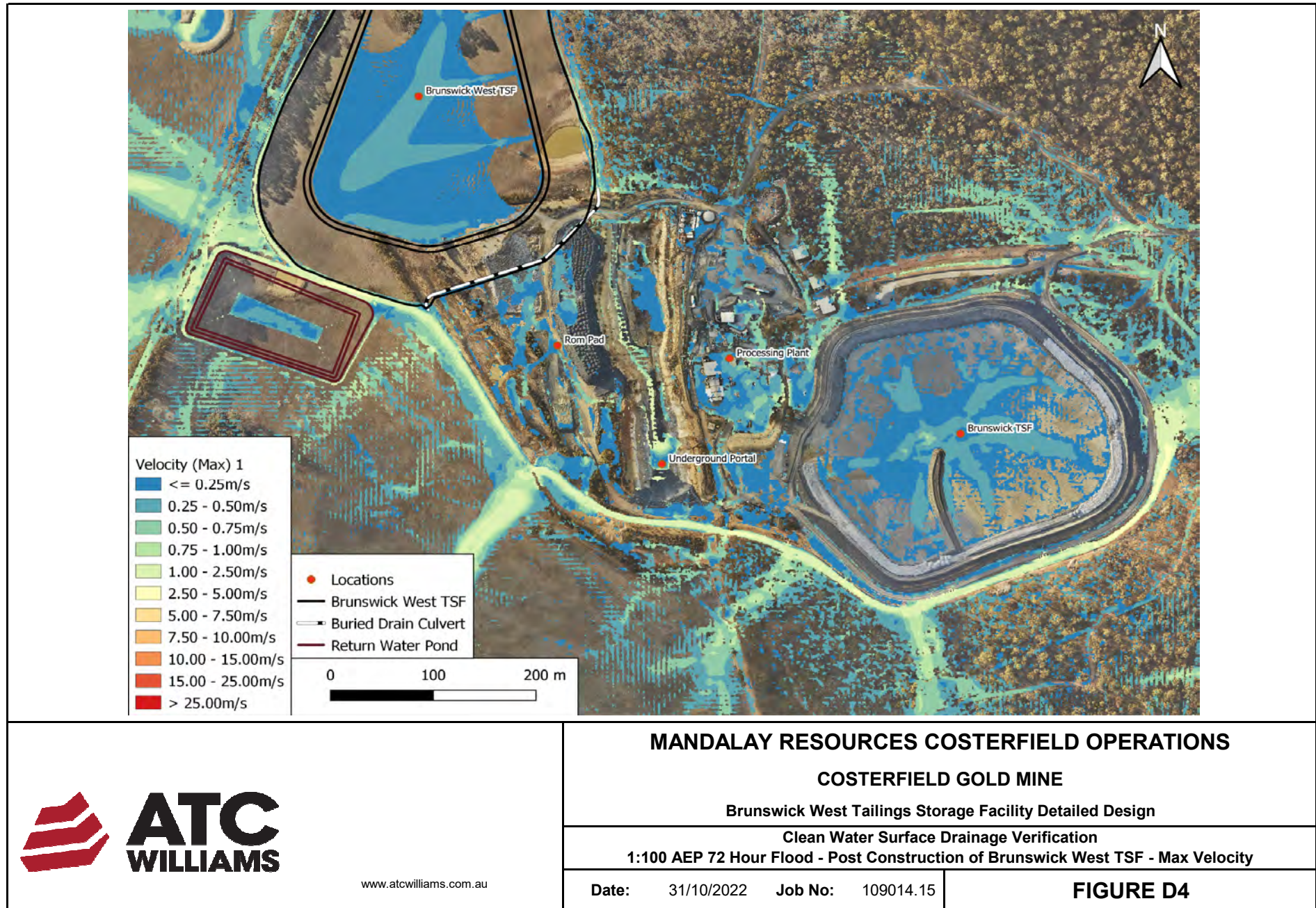


# ADVERTISED PLAN



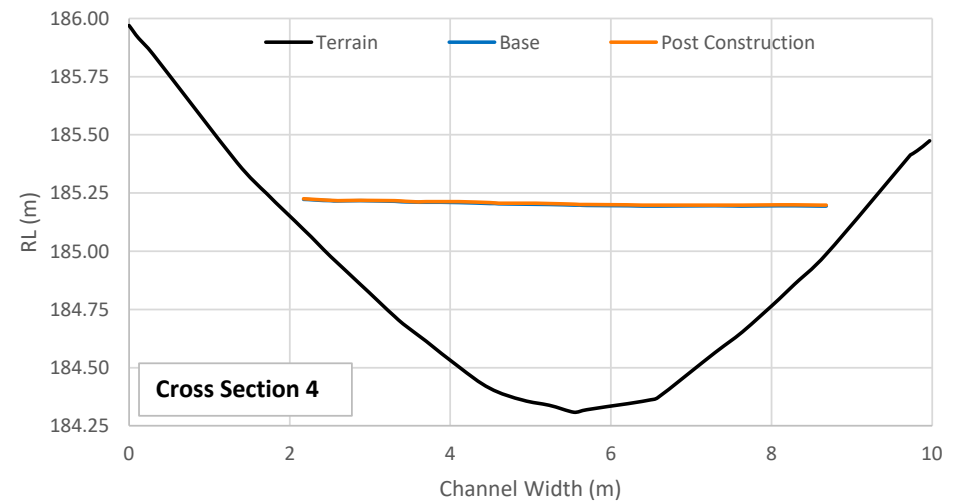
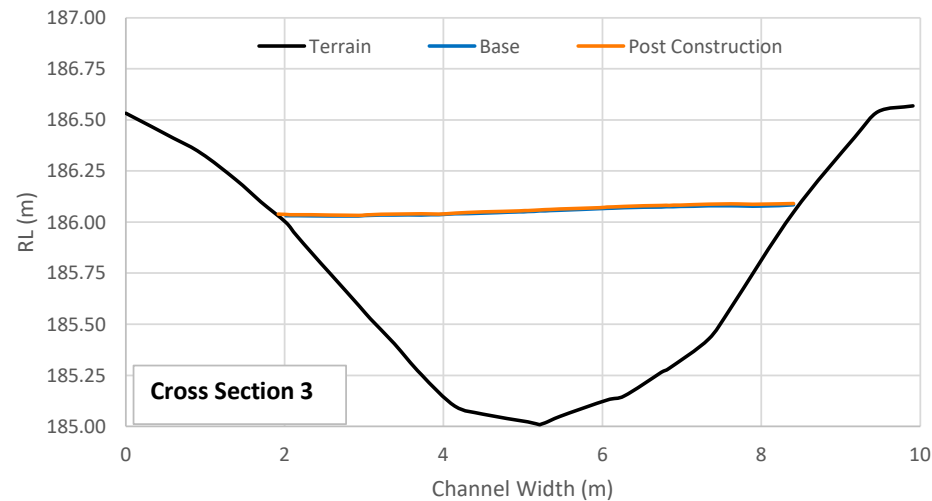
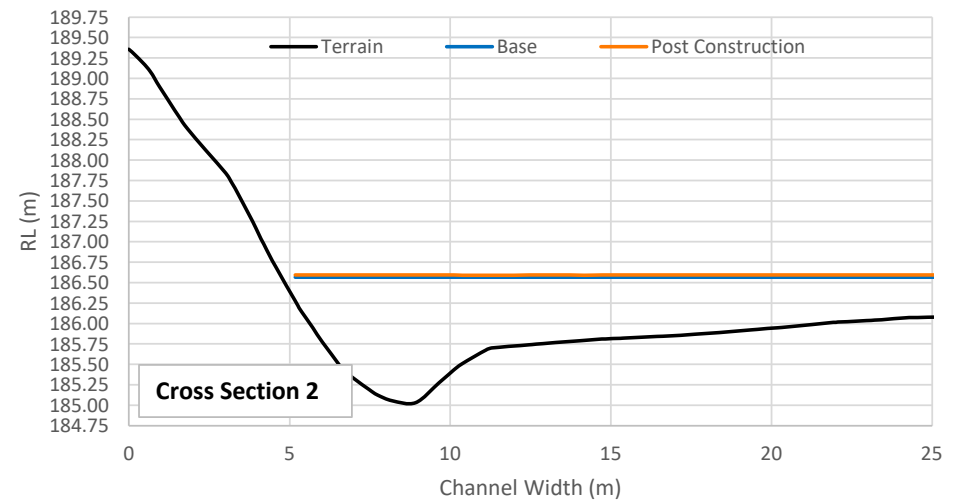
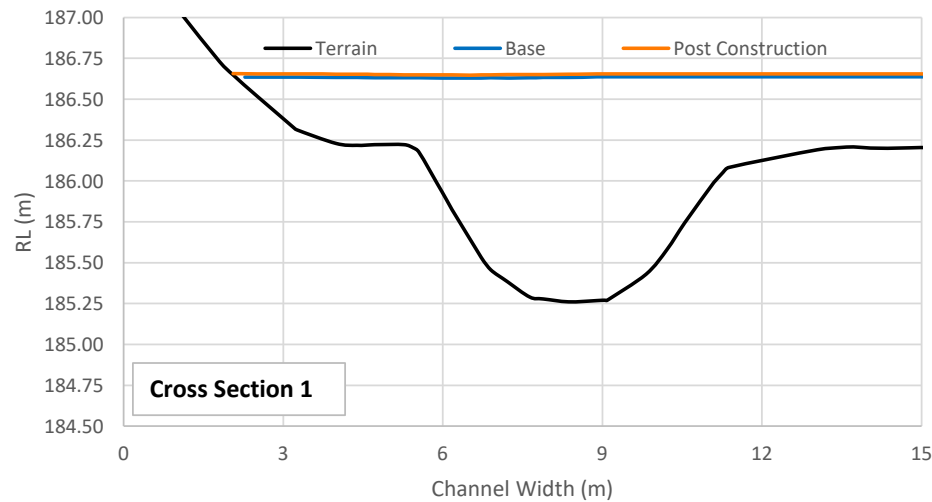


# ADVERTISED PLAN





# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### COSTERFIELD GOLD MINE

Brunswick West Tailings Storage Facility Detailed Design

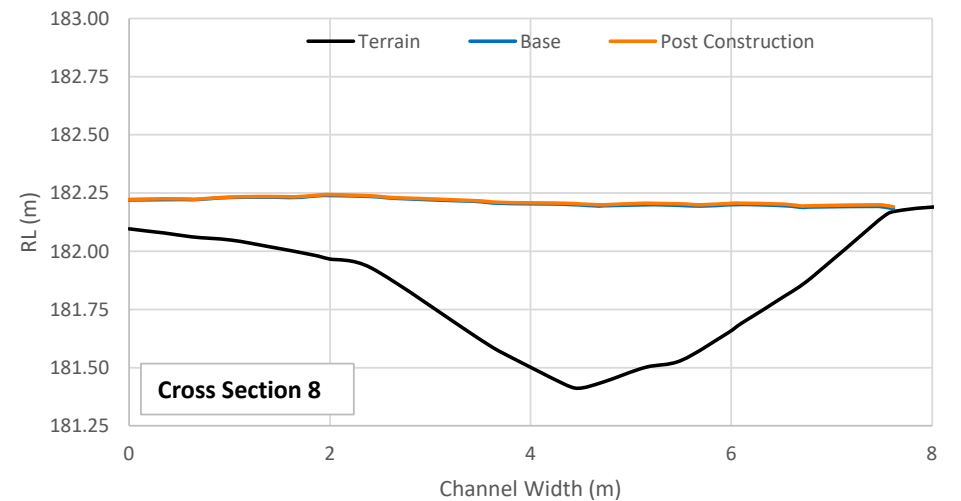
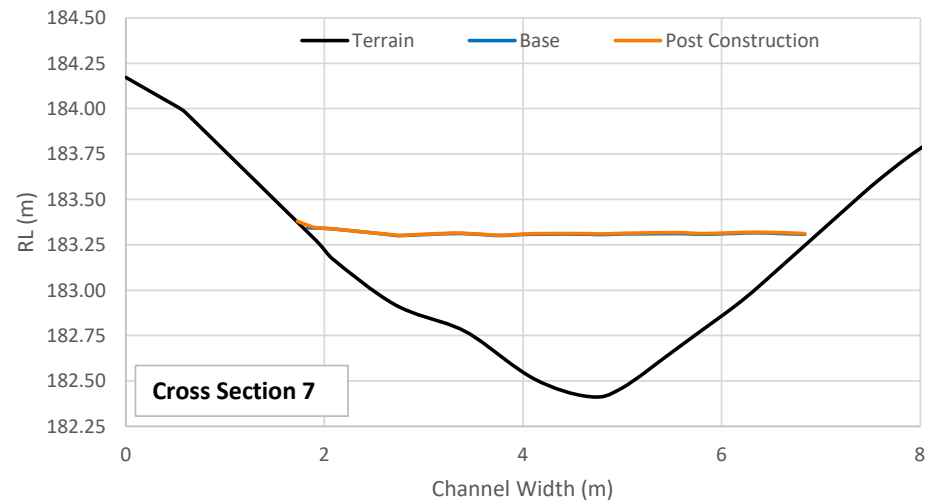
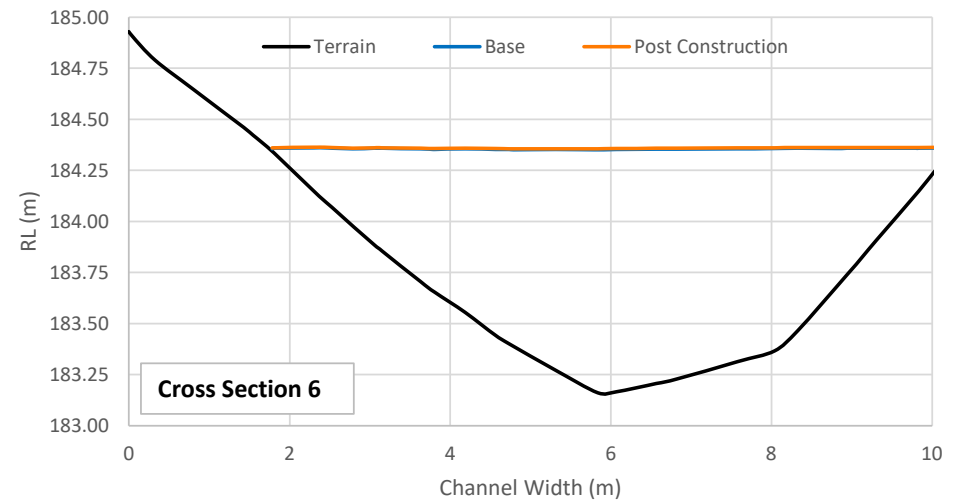
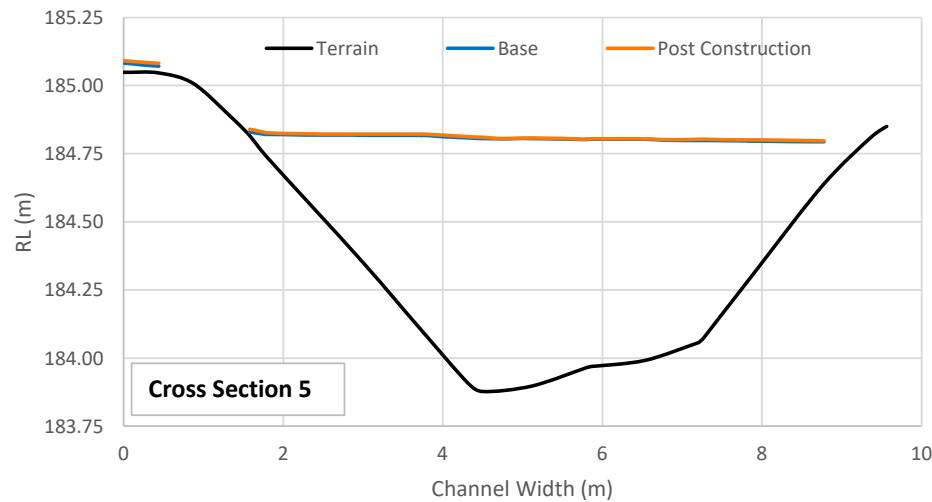
Clean Water Surface Drainage Verification - 1:100 AEP 72 Hour Flood - Sections 1 of 2

Date: 31/10/2022 Job No: 109014.15

FIGURE D5



# ADVERTISED PLAN



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### COSTERFIELD GOLD MINE

#### Brunswick West Tailings Storage Facility Detailed Design

#### Clean Water Surface Drainage Verification - 1:100 AEP 72 Hour Flood - Sections 2 of 2

Date: 31/10/2022 Job No: 109014.15

**FIGURE D6**





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## APPENDIX E – IN-SITU CLAY LIQUEFACTION ASSESSMENT

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| Test Conditions |                |      |               |    | Soil Conditions at End of Constructon and Filling          |   |   |                         |                                    | Cyclic Stress Ratio                |  |
|-----------------|----------------|------|---------------|----|--|---|---|-------------------------|------------------------------------|------------------------------------|--|
| Borehole        | Test Depth (m) |      | SPT Result    |    | Effective Stress on clay at time of test $\sigma'_v$ (kPa) | Thickness of Rockfill (Embankment Crest to top of Clay) (m) | Total Stress on clay layer $\sigma_v$ (kPa) | Pore Pressure $u$ (kPa) | Effective Stress $\sigma'_v$ (kPa) | Stress Reduction Coefficient $r_d$ | Cyclic Stress Ratio $CSR_M, \sigma'_v$ |
|                 | From           | To   | Field Records | N  |  |   |   |                         |                                    |                                    |  |
| BH-01           | 0.5            | 0.95 | 5, 9, 13      | 22 | 20.0   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-02           | 0.5            | 0.95 | 5, 12, 15     | 27 | 20.0   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-03           | 1              | 1.45 | 10, 13, 19    | 32 | 30.5   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-04           | 0.5            | 0.95 | 5, 16, 31     | 47 | 20.0   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-05           | 1              | 1.45 | 8, 10, 8      | 18 | 30.5   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-07           | 0.5            | 0.95 | 8, 11, 12     | 23 | 20.0   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-08           | 0.5            | 0.95 | 10, 12, 20    | 32 | 20.0   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-11           | 0.5            | 0.95 | 12, 20, 30    | 50 | 20.0   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |
| BH-12           | 0.5            | 0.95 | 7, 10, 15     | 25 | 20.0   | 15  | 351.0                                       | 24.5                    | 326.5                              | 0.81                               | 0.20                                   |

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|          | Standard Energy Blow Count        |                                       |                                       |   |   |                                   |  |
|----------|-----------------------------------|---------------------------------------|---------------------------------------|---|---|-----------------------------------|--|
| Borehole | Hammer Energy Correction<br>$C_E$ | Borehole Diameter Correction<br>$C_B$ | Rod Length Correction Factor<br>$C_R$ | Split Spoons, no Liners Correction<br>$C_S$ | Standardised, energy corrected Blow Count<br>$N_{60}$ | Overburden Normalisation<br>$C_N$ | Standardised Blow Count (at 1atm)<br>$(N1)_{60}$ |
| BH-01    | 0.7                               | 1                                     | 0.75                                  | 1   | 11.6  | 1.70                              | 19.6   |
| BH-02    | 0.7                               | 1                                     | 0.75                                  | 1   | 14.2  | 1.70                              | 24.1   |
| BH-03    | 0.7                               | 1                                     | 0.75                                  | 1   | 22.4  | 1.50                              | 33.5   |
| BH-04    | 0.7                               | 1                                     | 0.75                                  | 1   | 32.9  | 1.49                              | 49.0   |
| BH-05    | 0.7                               | 1                                     | 0.75                                  | 1   | 12.6  | 1.67                              | 21.1   |
| BH-07    | 0.7                               | 1                                     | 0.75                                  | 1   | 16.1  | 1.70                              | 27.4   |
| BH-08    | 0.7                               | 1                                     | 0.75                                  | 1   | 22.4  | 1.66                              | 37.2   |
| BH-11    | 0.7                               | 1                                     | 0.75                                  | 1   | 35.0  | 1.46                              | 51.1   |
| BH-12    | 0.7                               | 1                                     | 0.75                                  | 1   | 17.5  | 1.70                              | 29.7   |

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|          | Standardisation to Clean Sands |   |   | Liquefaction Potential                                    |  |   |                              |   |
|----------|--------------------------------|---|---|---|--|---|------------------------------|---|
| Borehole | Fines Content %                | Equivalent Clean Sands Adjustment $\Delta(N1)_{60}$ | Fines Corrected Standard Blow Count $(N1)_{60\text{ CS}}$ | Cyclic Resistance Ratio $CRR_{7.5, \sigma'v=1\text{atm}}$ | Overburen Correction Factor $K_\sigma$ | Cyclic Resistance Ratio $CRR_{7.5, \sigma'v}$ | Magnitude Scaling Factor MSF | Factor of Safety Against Liquefaction FoS |
| BH-01    | 60                             | 5.6   | 25.2  | 0.30  | 0.81                                   | 0.24  | 1.0                          | 1.21                                      |
| BH-02    | 62                             | 5.6   | 29.7  | 0.47  | 0.76                                   | 0.36  | 1.0                          | 1.81                                      |
| BH-03    | 64                             | 5.6   | 39.1  | 3.14  | 0.65                                   | 2.03  | 1.0                          | 5.00                                      |
| BH-04    | 66                             | 5.6   | 45.0  | 31.13   | 0.65                                   | 20.08   | 1.0                          | 5.00                                      |
| BH-05    | 67                             | 5.6   | 26.6  | 0.33  | 0.79                                   | 0.27  | 1.0                          | 1.35                                      |
| BH-07    | 69                             | 5.6   | 32.9  | 0.75  | 0.72                                   | 0.54  | 1.0                          | 2.76                                      |
| BH-08    | 71                             | 5.6   | 42.8  | 11.62   | 0.65                                   | 7.49  | 1.0                          | 5.00                                      |
| BH-11    | 74                             | 5.6   | 45.0  | 31.13   | 0.65                                   | 20.08   | 1.0                          | 5.00                                      |
| BH-12    | 75                             | 5.6   | 35.3  | 1.18  | 0.68                                   | 0.81  | 1.0                          | 4.11                                      |

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## APPENDIX F – SEEPAGE ASSESSMENT RESULTS

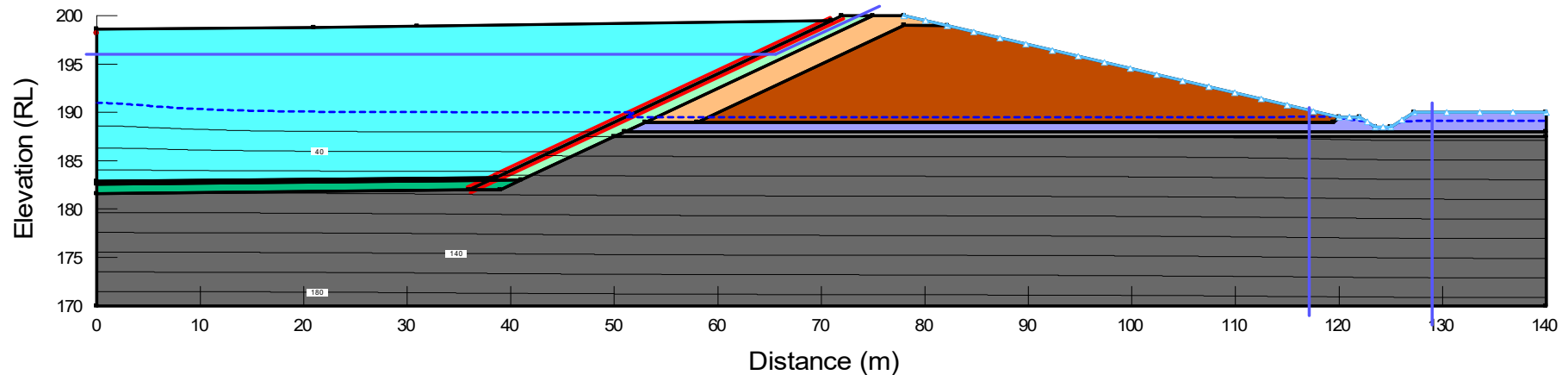
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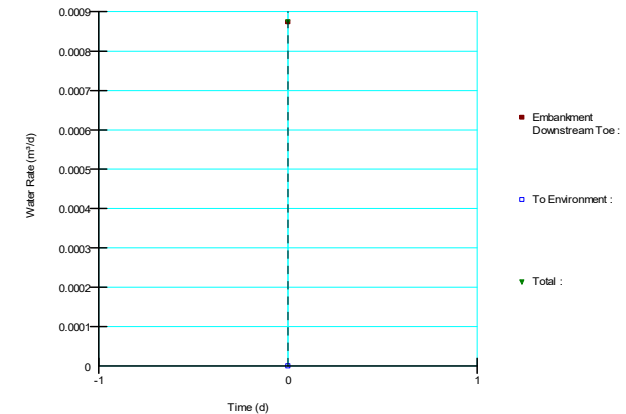
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 1.1 - Seepage - Pond RL 198.2 - No Underdrainage  
Date: 27/02/2023

| Color                               | Name                   | Category  | Kind             | Parameters |
|-------------------------------------|------------------------|-----------|------------------|------------|
| <span style="color: red;">■</span>  | Pond RL198.2m          | Hydraulic | Water Total Head | 198.2 m    |
| <span style="color: blue;">■</span> | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |



| Color                                     | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| <span style="color: red;">■</span>        | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| <span style="color: green;">■</span>      | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| <span style="color: lightgreen;">■</span> | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| <span style="color: grey;">■</span>       | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| <span style="color: purple;">■</span>     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| <span style="color: lightblue;">■</span>  | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| <span style="color: darkgrey;">■</span>   | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| <span style="color: orange;">■</span>     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
| <span style="color: brown;">■</span>      | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
BGM Liner, No Underdrainage - Pond RL 198.2 m

Date: 1/03/2022 Job No: 109014.15

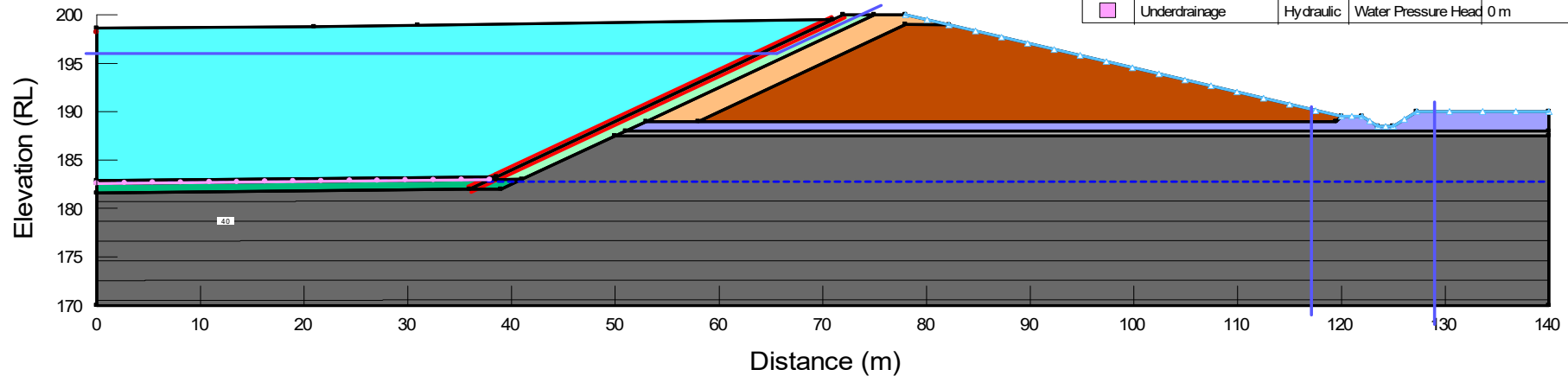
FIGURE F1.1.1



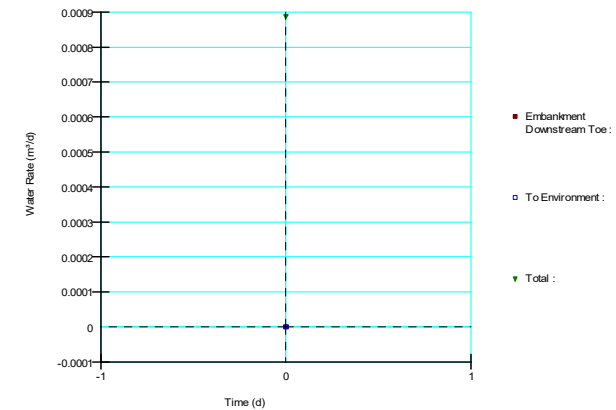
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 1.2 - Seepage - Pond RL 198.2 - With Underdrainage  
Date: 27/02/2023

| Color | Name                             | Category  | Kind                | Parameters |
|-------|----------------------------------|-----------|---------------------|------------|
| ■     | Pond RL198.2m                    | Hydraulic | Water Total Head    | 198.2 m    |
| ■     | Potential Seepage Face Hydraulic | Hydraulic | Water Rate          | 0 m³/d     |
| ■     | Underdrainage                    | Hydraulic | Water Pressure Head | 0 m        |



| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| ■     | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| ■     | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| ■     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
| ■     | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
BGM Liner + Underdrainage - Pond RL 198.2 m

Date: 1/03/2022 Job No: 109014.15

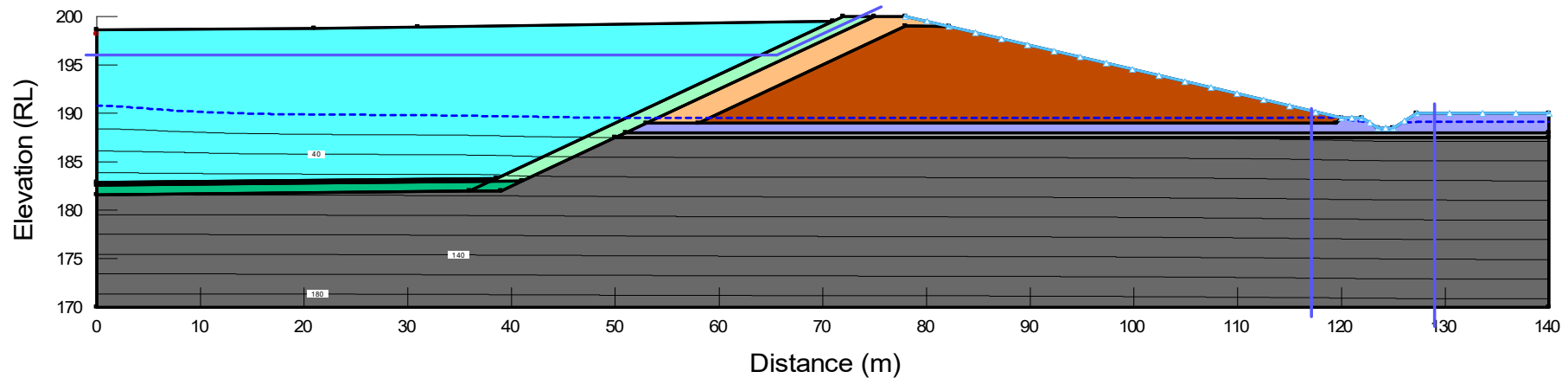
FIGURE F1.1.2



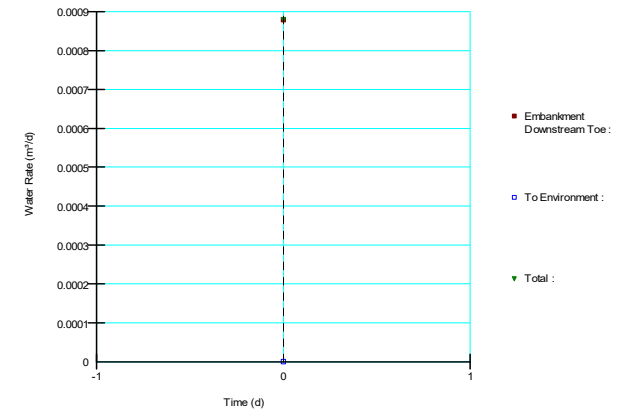
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 1.3 - Seepage - Pond RL 198.2 - No Underdrainage + failed liner  
Date: 27/02/2023

| Color                               | Name                   | Category  | Kind             | Parameters |
|-------------------------------------|------------------------|-----------|------------------|------------|
| <span style="color: red;">■</span>  | Pond RL198.2m          | Hydraulic | Water Total Head | 198.2 m    |
| <span style="color: blue;">■</span> | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |



| Color                                     | Name                     | Model                   | Sat Kx (m/sec) | Vol. WC. Function   | K-Function          | Ky/Kx' Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-------------------------|----------------|---------------------|---------------------|--------------|--------------|--------------------------|------------------------|
| <span style="color: green;">■</span>      | Compacted Clay (Zone 1)  | Saturated / Unsaturated |                | Clay                | Clay (1e-9)         | 1            | 0            |                          |                        |
| <span style="color: lightgreen;">■</span> | Compacted Clay (Zone 1A) | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1            | 0            |                          |                        |
| <span style="color: grey;">■</span>       | EW Siltstone Foundation  | Saturated / Unsaturated |                | Weathered Siltstone | Weathered Siltstone | 1            | 0            |                          |                        |
| <span style="color: blue;">■</span>       | Foundation Clay          | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1            | 0            |                          |                        |
| <span style="color: cyan;">■</span>       | Fresh Tailings           | Saturated / Unsaturated |                | Tailings            | Tailings            | 1            | 0            |                          |                        |
| <span style="color: darkgrey;">■</span>   | HW Siltstone Foundation  | Saturated / Unsaturated |                | Siltstone           | Siltstone           | 1            | 0            |                          |                        |
| <span style="color: orange;">■</span>     | Rockfill (Zone 3A)       | Saturated Only          | 1e-06          |                     |                     | 1            | 0            | 0                        | 0                      |
| <span style="color: brown;">■</span>      | Rockfill (Zone 3B)       | Saturated Only          | 1e-05          |                     |                     | 1            | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
No BGM Liner or Underdrainage - Pond RL 198.2 m

Date: 1/03/2022 Job No: 109014.15

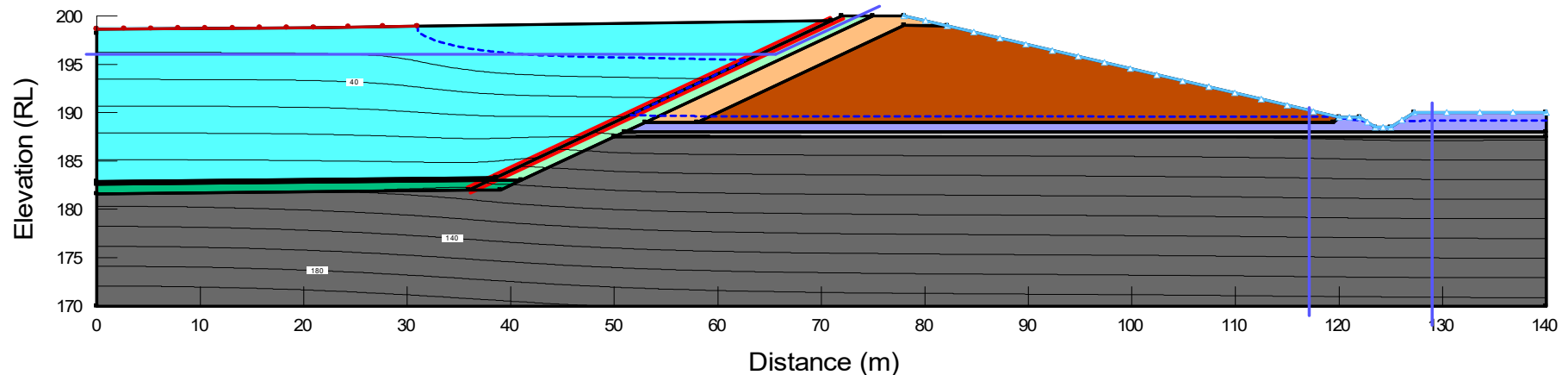
FIGURE F1.1.3



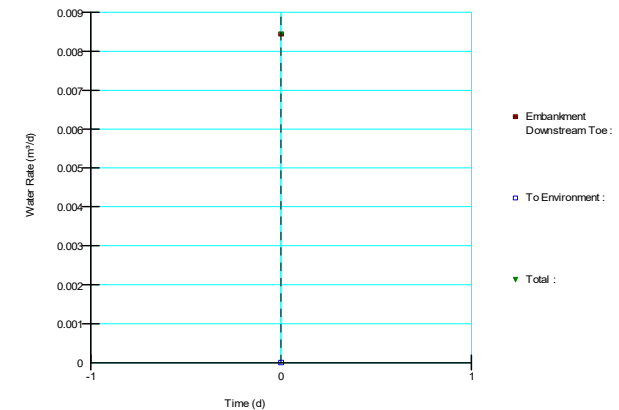
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 2.1 - Seepage - Pond RL 198.9 - No Underdrainage  
Date: 27/02/2023

| Color                               | Name                   | Category  | Kind             | Parameters |
|-------------------------------------|------------------------|-----------|------------------|------------|
| <span style="color: red;">■</span>  | Pond RL198.9m          | Hydraulic | Water Total Head | 198.9 m    |
| <span style="color: blue;">■</span> | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |



| Color                                     | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| <span style="color: red;">■</span>        | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| <span style="color: green;">■</span>      | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| <span style="color: lightgreen;">■</span> | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| <span style="color: grey;">■</span>       | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| <span style="color: blue;">■</span>       | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| <span style="color: cyan;">■</span>       | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| <span style="color: darkgrey;">■</span>   | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| <span style="color: orange;">■</span>     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
| <span style="color: brown;">■</span>      | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
BGM Liner, No Underdrainage - Pond RL 198.9 m

Date: 1/03/2022 Job No: 109014.15

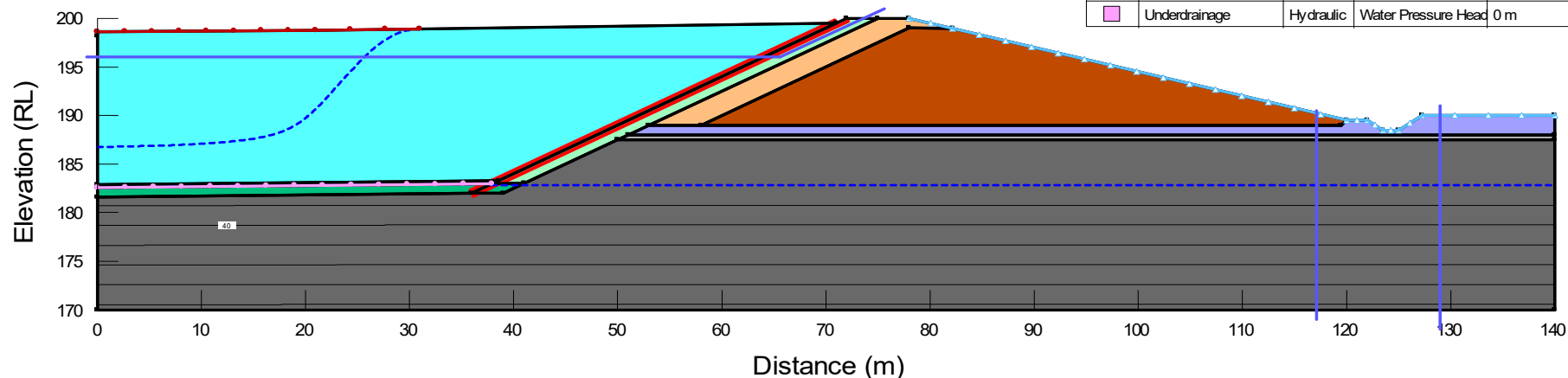
FIGURE F1.1.4



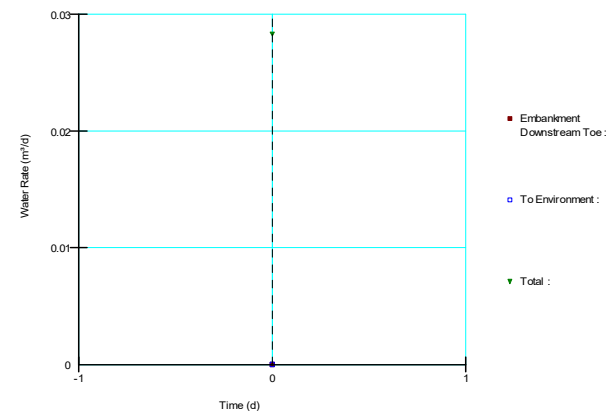
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 2.2 - Seepage - Pond RL 198.9 - With Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind                | Parameters |
|-------|------------------------|-----------|---------------------|------------|
| ■     | Pond RL198.9m          | Hydraulic | Water Total Head    | 198.9 m    |
| ■     | Potential Seepage Face | Hydraulic | Water Rate          | 0 m³/d     |
| ■     | Underdrainage          | Hydraulic | Water Pressure Head | 0 m        |



| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx' Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|--------------|--------------|--------------------------|------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1            | 0            | 0                        | 0                      |
| ■     | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1            | 0            |                          |                        |
| ■     | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1            | 0            |                          |                        |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| ■     | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1            | 0            |                          |                        |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1            | 0            |                          |                        |
| ■     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1            | 0            | 0                        | 0                      |
| ■     | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1            | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
BGM Liner + Underdrainage - Pond RL 198.9 m

Date: 1/03/2022 Job No: 109014.15

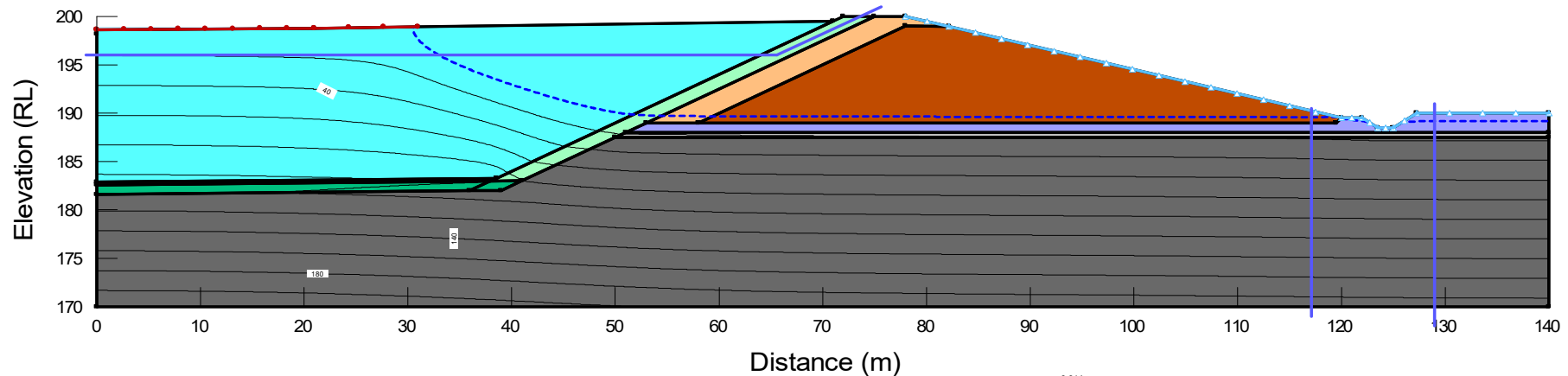
FIGURE F1.1.5



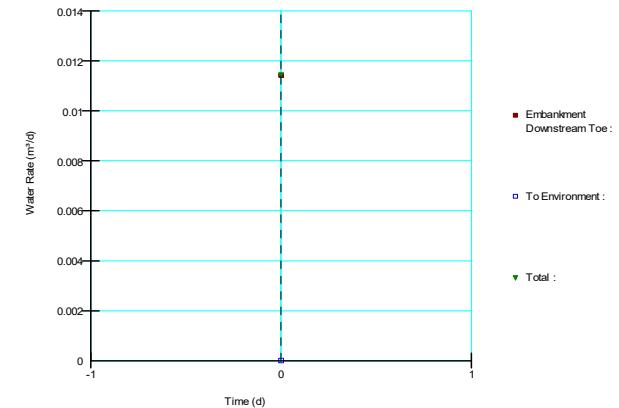
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 2.3 - Seepage - Pond RL 198.9 - No Underdrainage + failed liner  
Date: 27/02/2023

| Color                               | Name                   | Category  | Kind             | Parameters |
|-------------------------------------|------------------------|-----------|------------------|------------|
| <span style="color: red;">■</span>  | Pond RL198.9m          | Hydraulic | Water Total Head | 198.9 m    |
| <span style="color: blue;">■</span> | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |



| Color                                     | Name                     | Model                   | Sat Kx (m/sec) | Vol. WC. Function   | K-Function          | Ky/Kx' Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-------------------------|----------------|---------------------|---------------------|--------------|--------------|--------------------------|------------------------|
| <span style="color: green;">■</span>      | Compacted Clay (Zone 1)  | Saturated / Unsaturated |                | Clay                | Clay (1e-9)         | 1            | 0            |                          |                        |
| <span style="color: lightgreen;">■</span> | Compacted Clay (Zone 1A) | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1            | 0            |                          |                        |
| <span style="color: grey;">■</span>       | EW Siltstone Foundation  | Saturated / Unsaturated |                | Weathered Siltstone | Weathered Siltstone | 1            | 0            |                          |                        |
| <span style="color: blue;">■</span>       | Foundation Clay          | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1            | 0            |                          |                        |
| <span style="color: cyan;">■</span>       | Fresh Tailings           | Saturated / Unsaturated |                | Tailings            | Tailings            | 1            | 0            |                          |                        |
| <span style="color: darkgrey;">■</span>   | HW Siltstone Foundation  | Saturated / Unsaturated |                | Siltstone           | Siltstone           | 1            | 0            |                          |                        |
| <span style="color: orange;">■</span>     | Rockfill (Zone 3A)       | Saturated Only          | 1e-06          |                     |                     | 1            | 0            | 0                        | 0                      |
| <span style="color: brown;">■</span>      | Rockfill (Zone 3B)       | Saturated Only          | 1e-05          |                     |                     | 1            | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
No BGM Liner or Underdrainage - Pond RL 198.9 m

Date: 1/03/2022 Job No: 109014.15

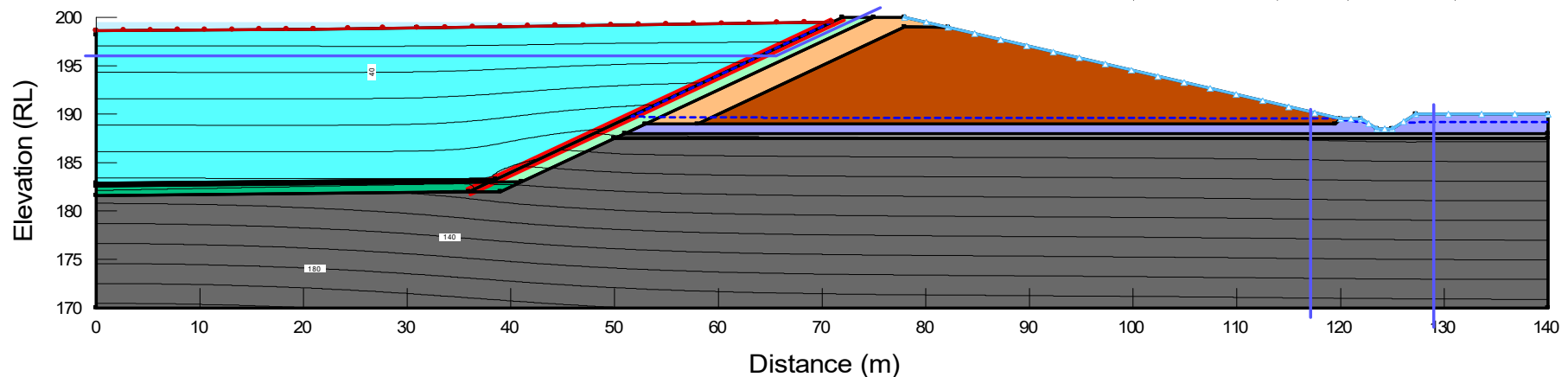
FIGURE F1.1.6



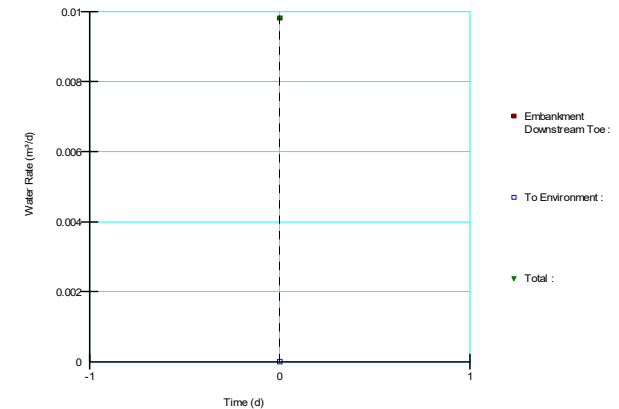
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 3.1 - Seepage - Pond RL 199.5 - No Underdrainage  
Date: 27/02/2023

| Color                               | Name                   | Category  | Kind             | Parameters |
|-------------------------------------|------------------------|-----------|------------------|------------|
| <span style="color: red;">■</span>  | Pond RL199.5m          | Hydraulic | Water Total Head | 199.5 m    |
| <span style="color: blue;">■</span> | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |



| Color                                     | Name                     | Model                             | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-----------------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| <span style="color: red;">■</span>        | BGM Liner                | Saturated Only                    |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| <span style="color: green;">■</span>      | Compacted Clay (Zone 1)  | Saturated / Unsaturated Clay      |                     | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| <span style="color: lightgreen;">■</span> | Compacted Clay (Zone 1A) | Saturated / Unsaturated Clay      |                     | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| <span style="color: grey;">■</span>       | EW Siltstone Foundation  | Saturated / Unsaturated           | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| <span style="color: blue;">■</span>       | Foundation Clay          | Saturated / Unsaturated Clay      |                     | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| <span style="color: cyan;">■</span>       | Fresh Tailings           | Saturated / Unsaturated Tailings  |                     | Tailings            |                | 1           | 0            |                          |                        |
| <span style="color: darkgrey;">■</span>   | HW Siltstone Foundation  | Saturated / Unsaturated Siltstone |                     | Siltstone           |                | 1           | 0            |                          |                        |
| <span style="color: orange;">■</span>     | Rockfill (Zone 3A)       | Saturated Only                    |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
| <span style="color: brown;">■</span>      | Rockfill (Zone 3B)       | Saturated Only                    |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
BGM Liner, No Underdrainage - Pond RL 199.5 m

Date: 1/03/2022 Job No: 109014.15

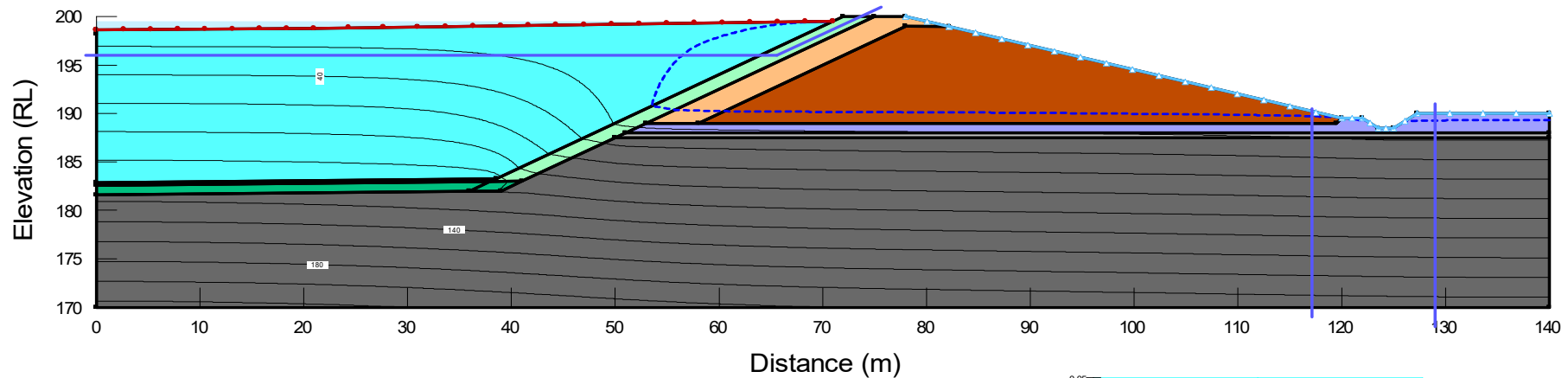
FIGURE F1.1.7



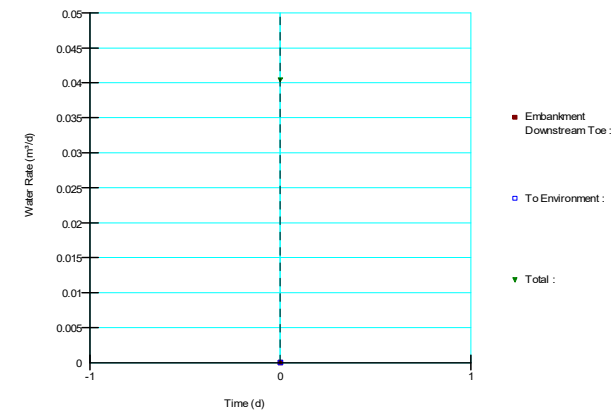
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 3.3 - Seepage - Pond RL 199.5 - No Underdrainage + failed liner  
Date: 27/02/2023

| Color                               | Name                   | Category  | Kind             | Parameters |
|-------------------------------------|------------------------|-----------|------------------|------------|
| <span style="color: red;">■</span>  | Pond RL199.5m          | Hydraulic | Water Total Head | 199.5 m    |
| <span style="color: blue;">■</span> | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |



| Color                                     | Name                     | Model                   | Sat Kx (m/sec) | Vol. WC. Function   | K-Function          | Ky/Kx' Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-------------------------|----------------|---------------------|---------------------|--------------|--------------|--------------------------|------------------------|
| <span style="color: green;">■</span>      | Compacted Clay (Zone 1)  | Saturated / Unsaturated |                | Clay                | Clay (1e-9)         | 1            | 0            |                          |                        |
| <span style="color: lightgreen;">■</span> | Compacted Clay (Zone 1A) | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1            | 0            |                          |                        |
| <span style="color: grey;">■</span>       | EW Siltstone Foundation  | Saturated / Unsaturated |                | Weathered Siltstone | Weathered Siltstone | 1            | 0            |                          |                        |
| <span style="color: blue;">■</span>       | Foundation Clay          | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1            | 0            |                          |                        |
| <span style="color: cyan;">■</span>       | Fresh Tailings           | Saturated / Unsaturated |                | Tailings            | Tailings            | 1            | 0            |                          |                        |
| <span style="color: darkgrey;">■</span>   | HW Siltstone Foundation  | Saturated / Unsaturated |                | Siltstone           | Siltstone           | 1            | 0            |                          |                        |
| <span style="color: orange;">■</span>     | Rockfill (Zone 3A)       | Saturated Only          | 1e-06          |                     |                     | 1            | 0            | 0                        | 0                      |
| <span style="color: brown;">■</span>      | Rockfill (Zone 3B)       | Saturated Only          | 1e-05          |                     |                     | 1            | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
BGM Liner + Underdrainage - Pond RL 199.5 m

Date: 1/03/2022 Job No: 109014.15

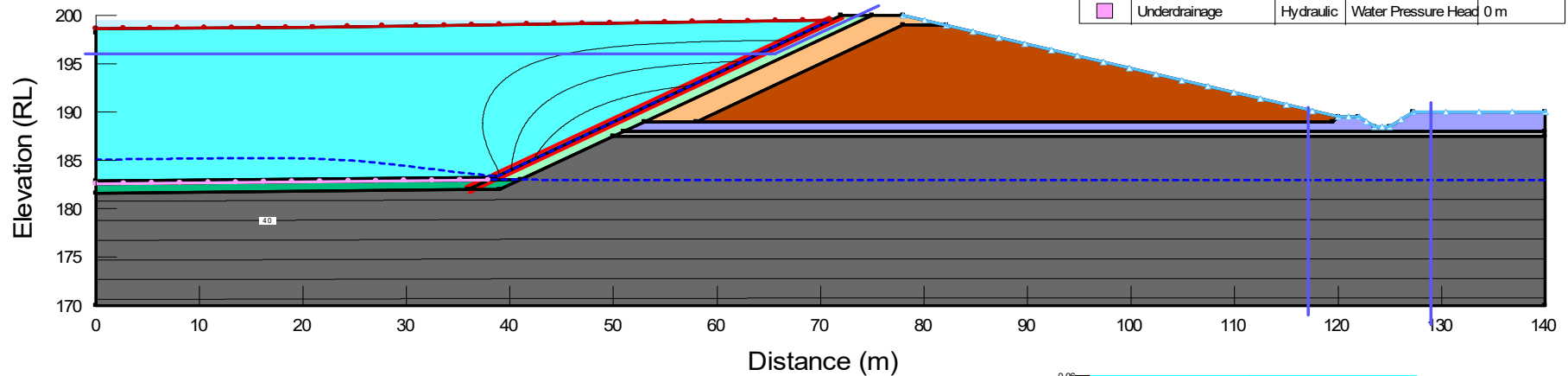
FIGURE F1.1.8



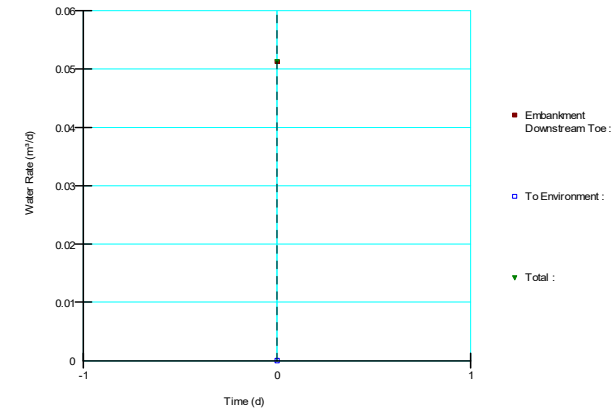
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - East Embankment.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 3.2 - Seepage - Pond RL 199.5 - With Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind                | Parameters |
|-------|------------------------|-----------|---------------------|------------|
|       | Pond RL199.5m          | Hydraulic | Water Total Head    | 199.5 m    |
|       | Potential Seepage Face | Hydraulic | Water Rate          | 0 m³/d     |
|       | Underdrainage          | Hydraulic | Water Pressure Head | 0 m        |



| Color | Name                     | Model                        | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|------------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
|       | BGM Liner                | Saturated Only               |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
|       | Compacted Clay (Zone 1)  | Saturated / Unsaturated Clay |                     | Clay (1e-9)         |                | 1           | 0            |                          |                        |
|       | Compacted Clay (Zone 1A) | Saturated / Unsaturated Clay |                     | Clay (5e-8)         |                | 1           | 0            |                          |                        |
|       | EW Siltstone Foundation  | Saturated / Unsaturated      | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
|       | Foundation Clay          | Saturated / Unsaturated Clay |                     | Clay (5e-8)         |                | 1           | 0            |                          |                        |
|       | Fresh Tailings           | Saturated / Unsaturated      | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
|       | HW Siltstone Foundation  | Saturated / Unsaturated      | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
|       | Rockfill (Zone 3A)       | Saturated Only               |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
|       | Rockfill (Zone 3B)       | Saturated Only               |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 1 - Eastern Embankment Typical Section  
No BGM Liner or Underdrainage - Pond RL 199.5 m

Date: 1/03/2022 Job No: 109014.15

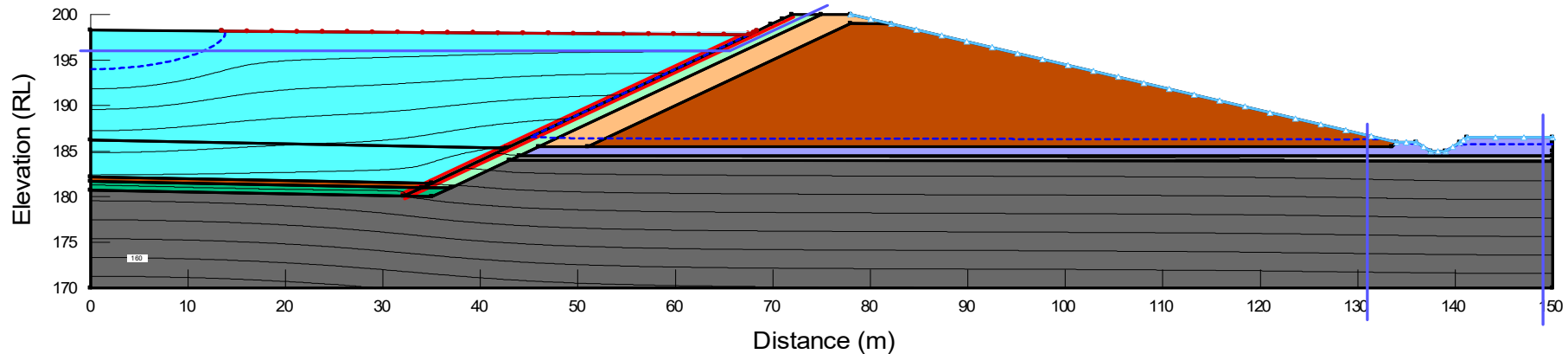
FIGURE F1.1.9



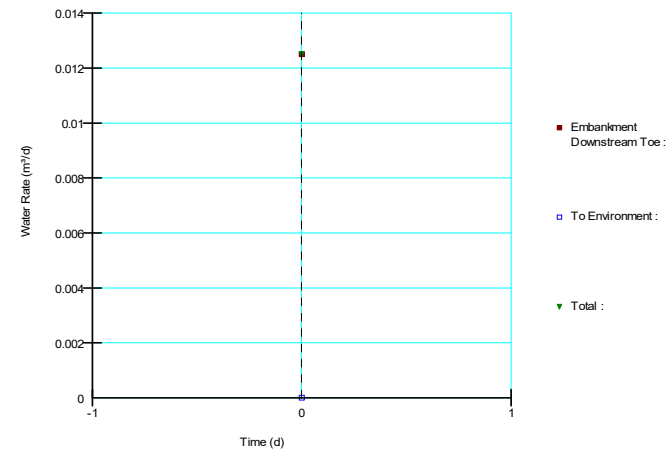
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 1.1 - Seepage - Pond RL 198.2 - No Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind             | Parameters          |
|-------|------------------------|-----------|------------------|---------------------|
| ■     | Pond RL198.2m          | Hydraulic | Water Total Head | 198.2 m             |
| ■     | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                       |
| ■     | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                         |
| ■     | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                         |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| ■     | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                         |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                         |
| ■     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                       |
| ■     | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                       |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 2 - Decant Area Typical Section  
BGM Liner, No Underdrainage - Pond RL 198.2 m

Date: 1/03/2022 Job No: 109014.15

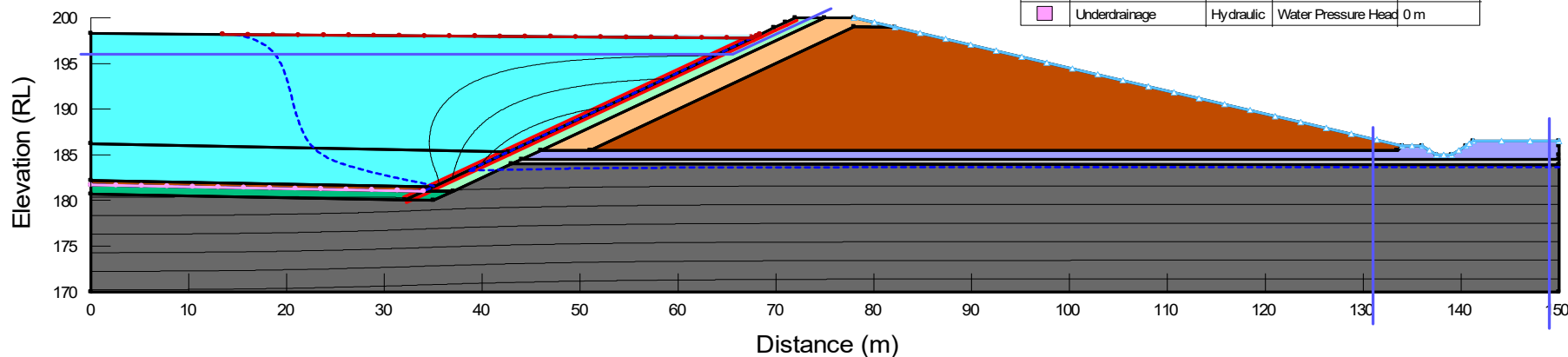
FIGURE F1.2.1



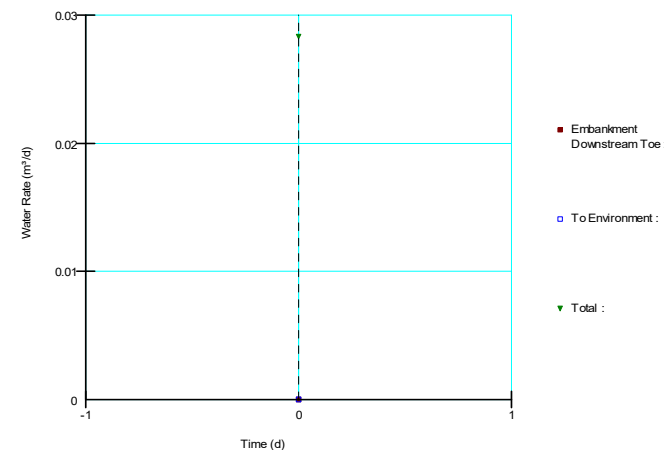
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 1.2 - Seepage - Pond RL 198.2 - With Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind                | Parameters |
|-------|------------------------|-----------|---------------------|------------|
| ■     | Pond RL198.2m          | Hydraulic | Water Total Head    | 198.2 m    |
| ■     | Potential Seepage Face | Hydraulic | Water Rate          | 0 m³/d     |
| ■     | Underdrainage          | Hydraulic | Water Pressure Head | 0 m        |



| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| ■     | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| ■     | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| ■     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
| ■     | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 2 - Decant Area Typical Section  
BGM Liner + Underdrainage - Pond RL 198.2 m

Date: 1/03/2022 Job No: 109014.15

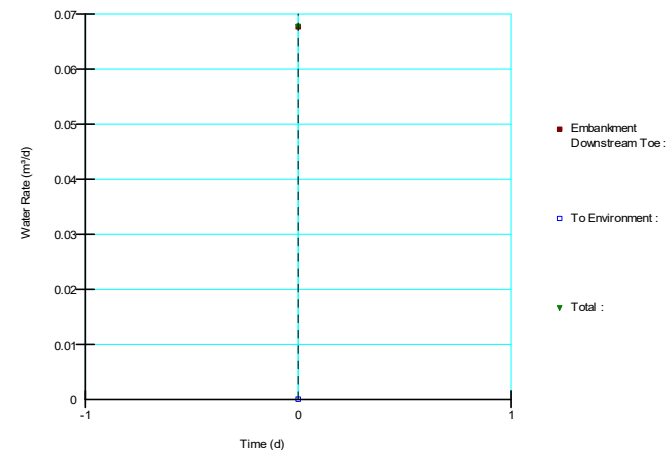
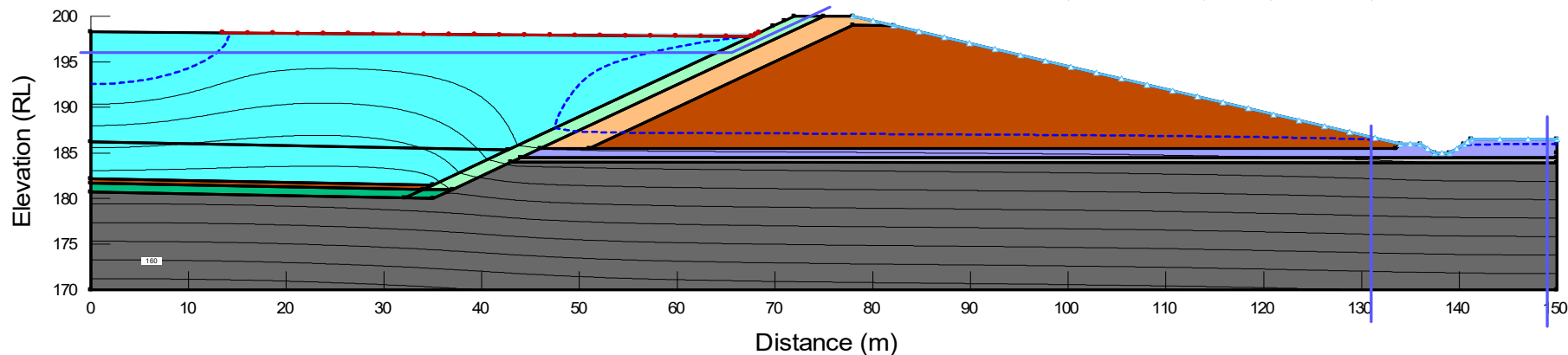
FIGURE F1.2.2



# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 1.3 - Seepage - Pond RL 198.2 - No Underdrainage + failed liner  
Date: 27/02/2023

| Color | Name                   | Category  | Kind             | Parameters          |
|-------|------------------------|-----------|------------------|---------------------|
| ■     | Pond RL198.2m          | Hydraulic | Water Total Head | 198.2 m             |
| ■     | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 2 - Decant Area Typical Section  
No BGM Liner or Underdrainage - Pond RL 198.2 m

Date: 1/03/2022 Job No: 109014.15

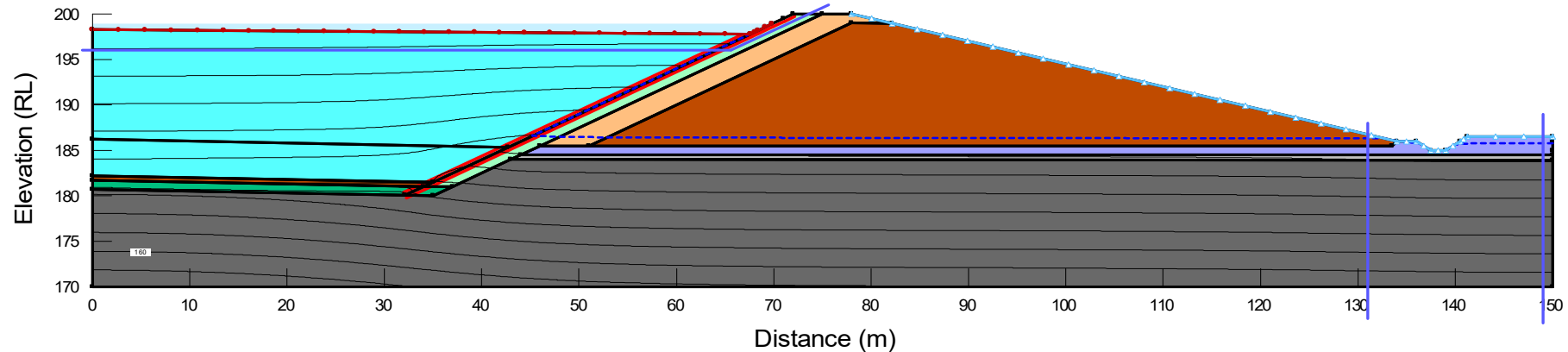
FIGURE F1.2.3



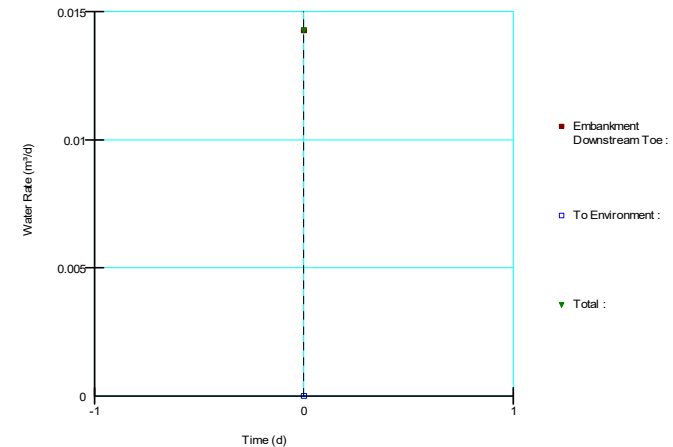
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 2.1 - Seepage - Pond RL 198.9 - No Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind             | Parameters          |
|-------|------------------------|-----------|------------------|---------------------|
| ■     | Pond RL 198.9m         | Hydraulic | Water Total Head | 198.9 m             |
| ■     | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| ■     | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| ■     | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| ■     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
| ■     | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 2 - Decant Area Typical Section  
BGM Liner, No Underdrainage - Pond RL 198.9 m

Date: 1/03/2022 Job No: 109014.15

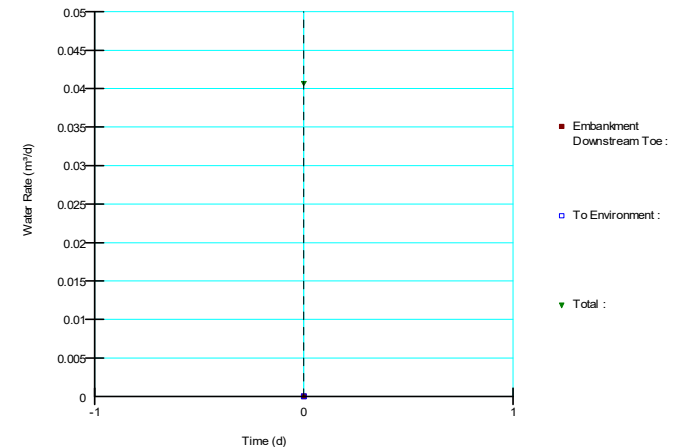
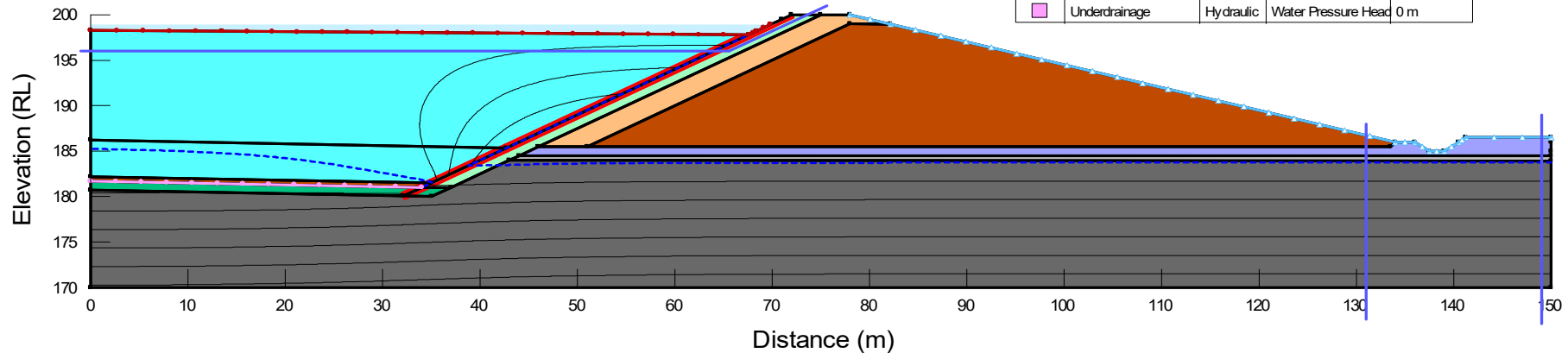
FIGURE F1.2.4



# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 2.2 - Seepage - Pond RL 198.9 - With Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind                | Parameters          |
|-------|------------------------|-----------|---------------------|---------------------|
| ■     | Pond RL198.9m          | Hydraulic | Water Total Head    | 198.9 m             |
| ■     | Potential Seepage Face | Hydraulic | Water Rate          | 0 m <sup>3</sup> /d |
| ■     | Underdrainage          | Hydraulic | Water Pressure Head | 0 m                 |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### TSF Seepage Assessment - Section 2 - Decant Area Typical Section

#### BGM Liner + Underdrainage - Pond RL 198.9 m

Date: 1/03/2022 Job No: 109014.15

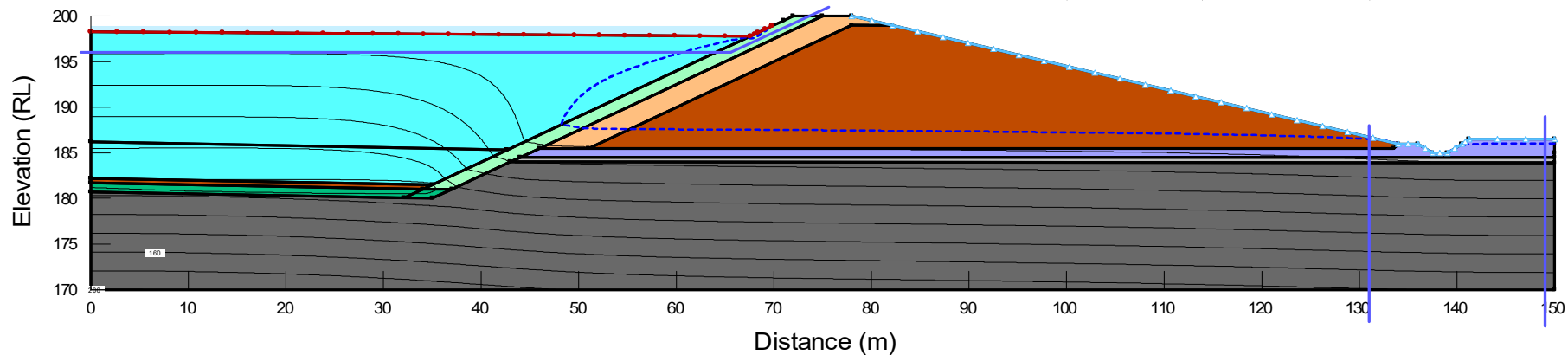
FIGURE F1.2.5



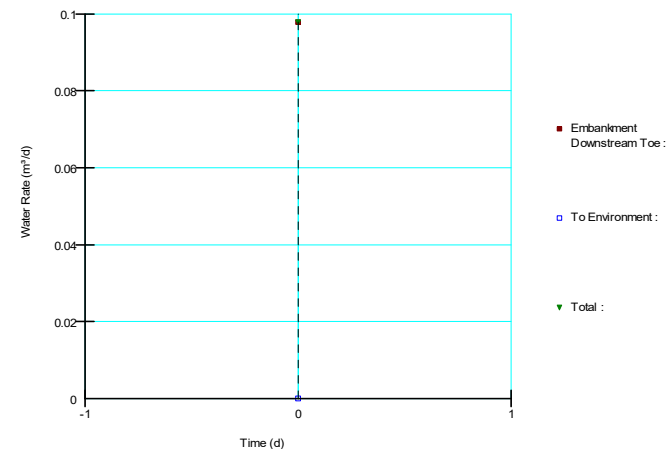
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 2.3 - Seepage - Pond RL 198.9 - No Underdrainage + failed liner  
Date: 27/02/2023

| Color                               | Name                   | Category  | Kind             | Parameters |
|-------------------------------------|------------------------|-----------|------------------|------------|
| <span style="color: red;">■</span>  | Pond RL198.9m          | Hydraulic | Water Total Head | 198.9 m    |
| <span style="color: blue;">■</span> | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |



| Color                                     | Name                     | Model                   | Sat Kx (m/sec) | Vol. WC. Function   | K-Function          | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-------------------------|----------------|---------------------|---------------------|-------------|--------------|--------------------------|------------------------|
| <span style="color: green;">■</span>      | Compacted Clay (Zone 1)  | Saturated / Unsaturated |                | Clay                | Clay (1e-9)         | 1           | 0            |                          |                        |
| <span style="color: lightgreen;">■</span> | Compacted Clay (Zone 1A) | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1           | 0            |                          |                        |
| <span style="color: grey;">■</span>       | EW Siltstone Foundation  | Saturated / Unsaturated |                | Weathered Siltstone | Weathered Siltstone | 1           | 0            |                          |                        |
| <span style="color: blue;">■</span>       | Foundation Clay          | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1           | 0            |                          |                        |
| <span style="color: cyan;">■</span>       | Fresh Tailings           | Saturated / Unsaturated |                | Tailings            | Tailings            | 1           | 0            |                          |                        |
| <span style="color: darkgrey;">■</span>   | HW Siltstone Foundation  | Saturated / Unsaturated |                | Siltstone           | Siltstone           | 1           | 0            |                          |                        |
| <span style="color: orange;">■</span>     | Rockfill (Zone 3A)       | Saturated Only          | 1e-06          |                     |                     | 1           | 0            | 0                        | 0                      |
| <span style="color: brown;">■</span>      | Rockfill (Zone 3B)       | Saturated Only          | 1e-05          |                     |                     | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### TSF Seepage Assessment - Section 2 - Decant Area Typical Section

No BGM Liner or Underdrainage - Pond RL 198.9 m

Date: 1/03/2022 Job No: 109014.15

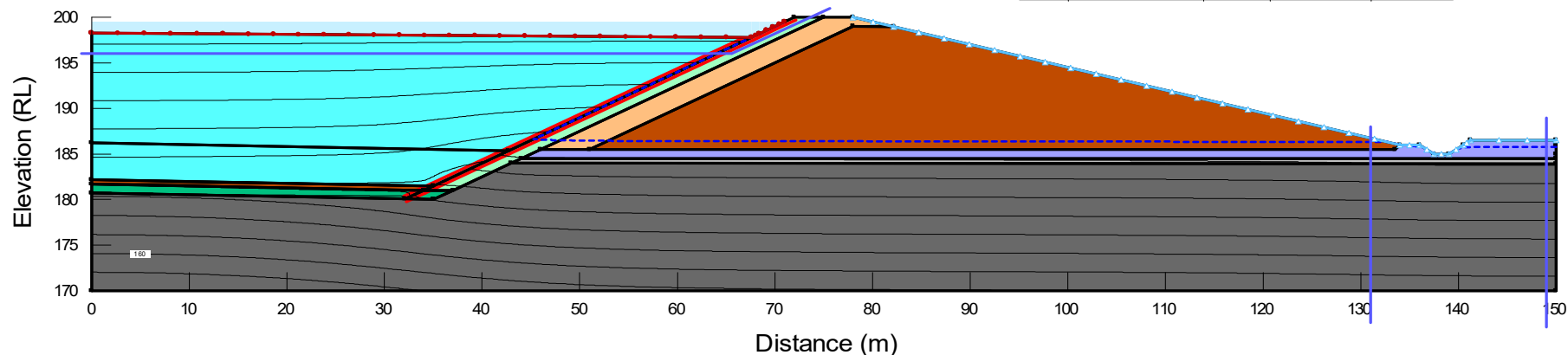
FIGURE F1.2.6



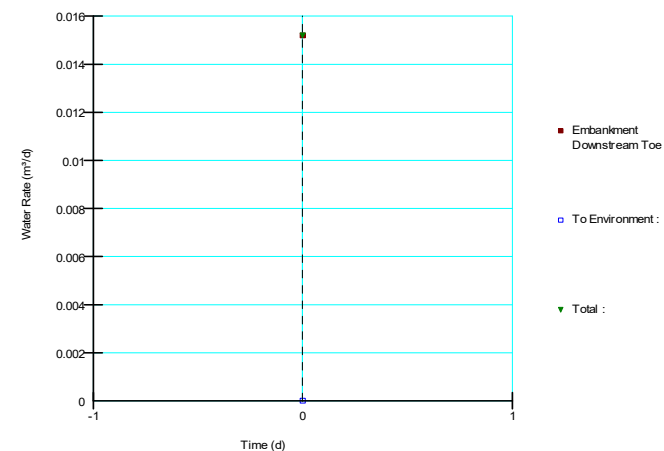
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 3.1 - Seepage - Pond RL 199.5 - No Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind             | Parameters          |
|-------|------------------------|-----------|------------------|---------------------|
|       | Pond RL 199.5m         | Hydraulic | Water Total Head | 199.5 m             |
|       | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-----------------------|
|       | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                     |
|       | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                       |
|       | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                       |
|       | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                       |
|       | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                       |
|       | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                       |
|       | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                       |
|       | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                     |
|       | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 2 - Decant Area Typical Section  
BGM Liner, No Underdrainage - Pond RL 199.5 m

Date: 1/03/2022 Job No: 109014.15

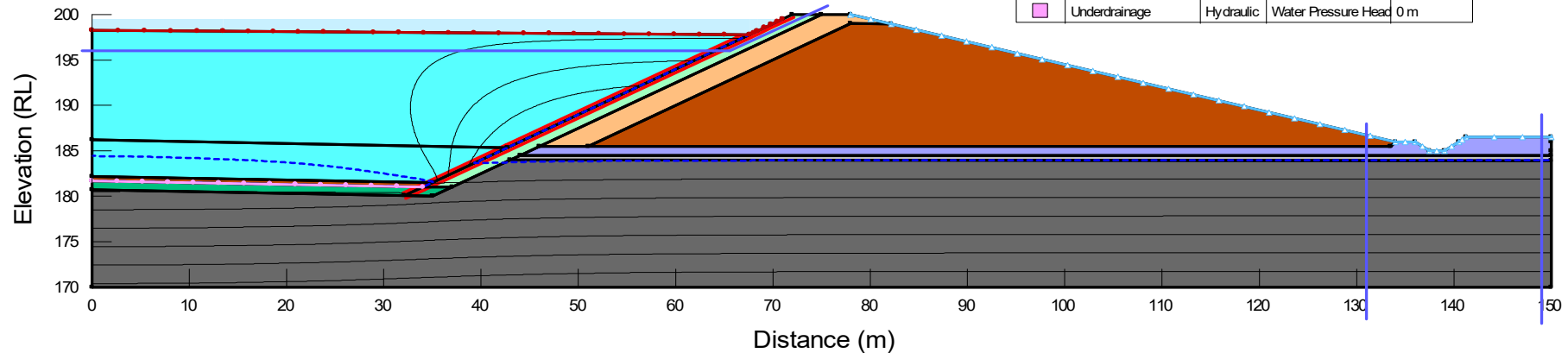
FIGURE F1.2.7



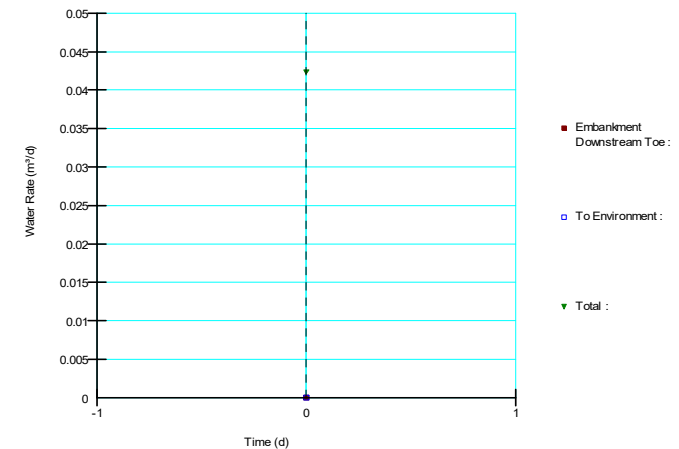
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 3.2 - Seepage - Pond RL 199.5 - With Underdrainage  
Date: 27/02/2023

| Color | Name                   | Category  | Kind                | Parameters          |
|-------|------------------------|-----------|---------------------|---------------------|
| ■     | Pond RL199.5m          | Hydraulic | Water Total Head    | 199.5 m             |
| ■     | Potential Seepage Face | Hydraulic | Water Rate          | 0 m <sup>3</sup> /d |
| ■     | Underdrainage          | Hydraulic | Water Pressure Head | 0 m                 |



| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| ■     | Compacted Clay (Zone 1)  | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| ■     | Compacted Clay (Zone 1A) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| ■     | Fresh Tailings           | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| ■     | Rockfill (Zone 3A)       | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |
| ■     | Rockfill (Zone 3B)       | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 2 - Decant Area Typical Section  
BGM Liner + Underdrainage - Pond RL 199.5 m

Date: 1/03/2022 Job No: 109014.15

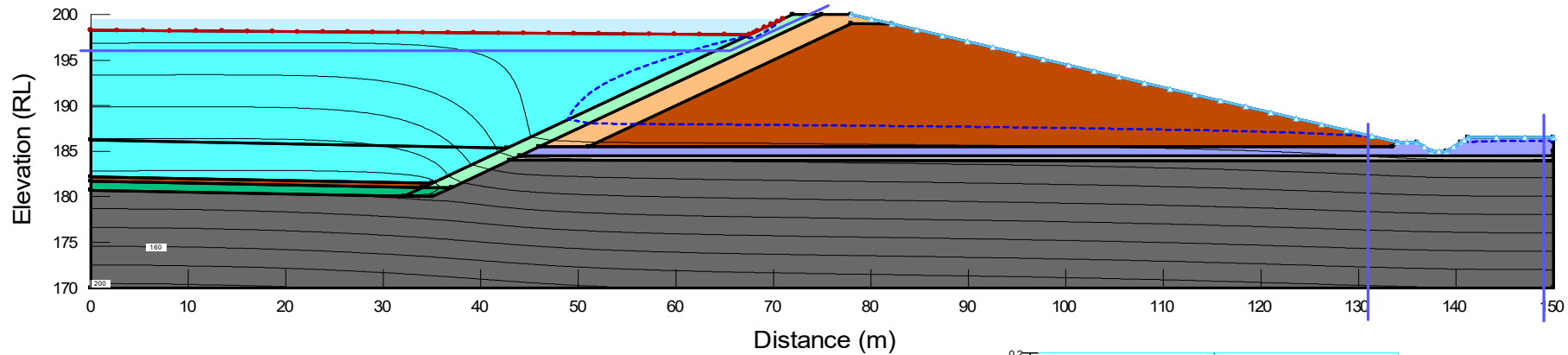
FIGURE F1.2.8



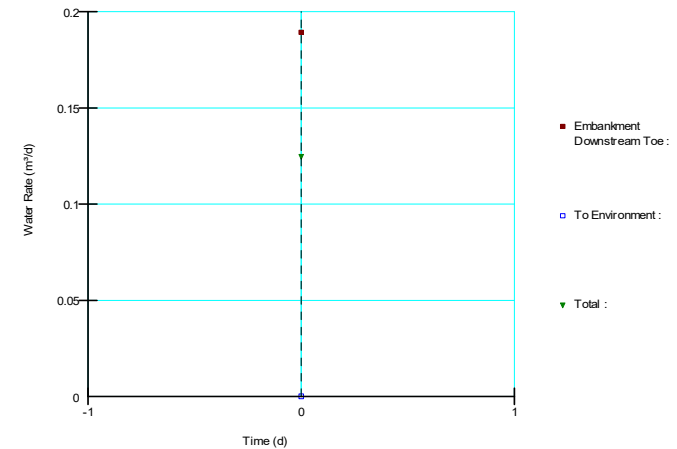
# ADVERTISED PLAN

Costerfield Brunswick West TSF Design  
File Name: Brunswick TSF - Embankment Seepage - Decant Area.gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
Name: 3.3 - Seepage - Pond RL 199.5 - No Underdrainage + failed liner  
Date: 27/02/2023

| Color | Name                   | Category  | Kind             | Parameters          |
|-------|------------------------|-----------|------------------|---------------------|
|       | Pond RL199.5m          | Hydraulic | Water Total Head | 199.5 m             |
|       | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



| Color | Name                     | Model                   | Sat Kx (m/sec) | Vol. WC. Function   | K-Function          | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (kPa) |
|-------|--------------------------|-------------------------|----------------|---------------------|---------------------|-------------|--------------|--------------------------|-----------------------|
|       | Compacted Clay (Zone 1)  | Saturated / Unsaturated |                | Clay                | Clay (1e-9)         | 1           | 0            |                          |                       |
|       | Compacted Clay (Zone 1A) | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1           | 0            |                          |                       |
|       | EW Siltstone Foundation  | Saturated / Unsaturated |                | Weathered Siltstone | Weathered Siltstone | 1           | 0            |                          |                       |
|       | Foundation Clay          | Saturated / Unsaturated |                | Clay                | Clay (5e-8)         | 1           | 0            |                          |                       |
|       | Fresh Tailings           | Saturated / Unsaturated |                | Tailings            | Tailings            | 1           | 0            |                          |                       |
|       | HW Siltstone Foundation  | Saturated / Unsaturated |                | Siltstone           | Siltstone           | 1           | 0            |                          |                       |
|       | Rockfill (Zone 3A)       | Saturated Only          | 1e-06          |                     |                     | 1           | 0            | 0                        | 0                     |
|       | Rockfill (Zone 3B)       | Saturated Only          | 1e-05          |                     |                     | 1           | 0            | 0                        | 0                     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

TSF Seepage Assessment - Section 2 - Decant Area Typical Section  
No BGM Liner or Underdrainage - Pond RL 199.5 m

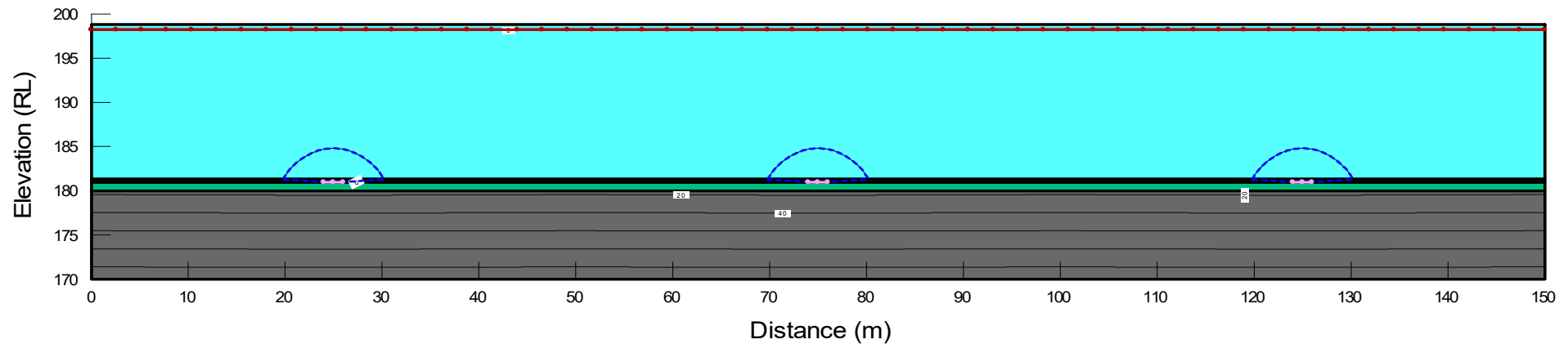
Date: 1/03/2022 Job No: 109014.15

FIGURE F1.2.9



Costerfield Brunswick West TSF Design  
 File Name: Brunswick West TSF - Typical Underdrainage Interaction.gsz  
 Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\  
 Name: 1 - Pond RL 198.2 - 2.0m wide strips, 50m typ spacing  
 Date: 27/02/2023

| Color                                  | Name          | Category  | Kind                | Parameters |
|--|---------------|-----------|---------------------|------------|
| <span style="color: red;">■</span>     | Pond RL198.2m | Hydraulic | Water Total Head    | 198.2 m    |
| <span style="color: magenta;">■</span> | Underdrainage | Hydraulic | Water Pressure Head | 0 m        |



| Color                                 | Name                    | Model                   | Sat Kx (m/sec) | Vol. WC. Function | K-Function  | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---------------------------------------|-------------------------|-------------------------|----------------|-------------------|-------------|-------------|--------------|--------------------------|------------------------|
| <span style="color: green;">■</span>  | Compacted Clay (Zone 1) | Saturated / Unsaturated |                | Clay              | Clay (1e-9) | 1           | 0            |                          |                        |
| <span style="color: cyan;">■</span>   | Fresh Tailings          | Saturated / Unsaturated |                | Tailings          | Tailings    | 1           | 0            |                          |                        |
| <span style="color: grey;">■</span>   | HW Siltstone Foundation | Saturated / Unsaturated |                | Siltstone         | Siltstone   | 1           | 0            |                          |                        |
| <span style="color: orange;">■</span> | Rockfill (Zone 3B)      | Saturated Only          | 1e-05          |                   |             | 1           | 0            | 0                        | 0                      |

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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Typical Underdrainage Section

Date: 1/03/2022 Job No: 109014.15

**FIGURE F1.3.1**



# ADVERTISED PLAN

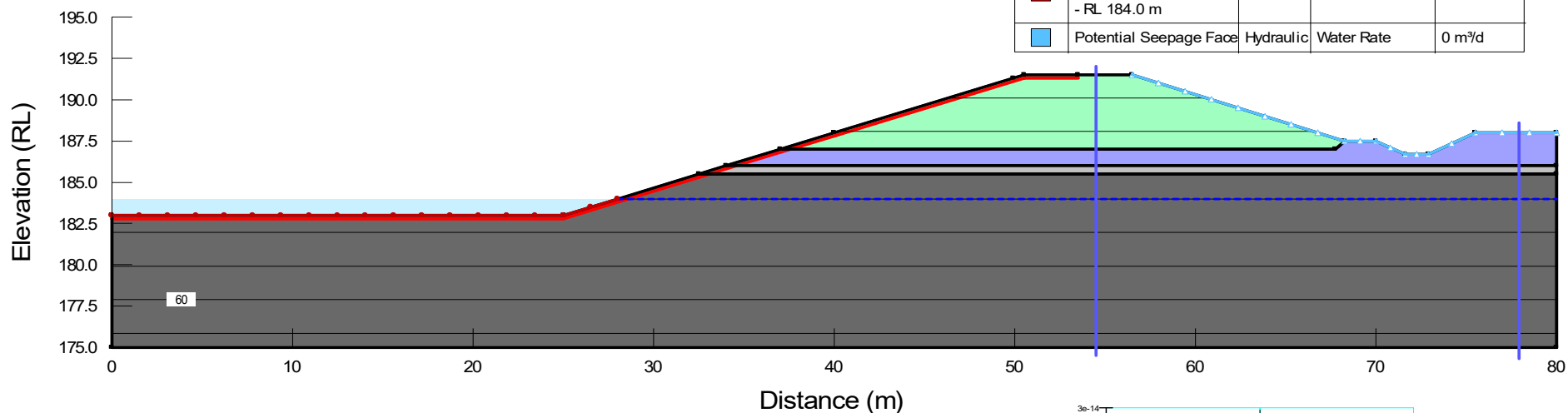
Costerfield Brunswick West TSF Design

File Name: Brunswick TSF - External RWP.gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\

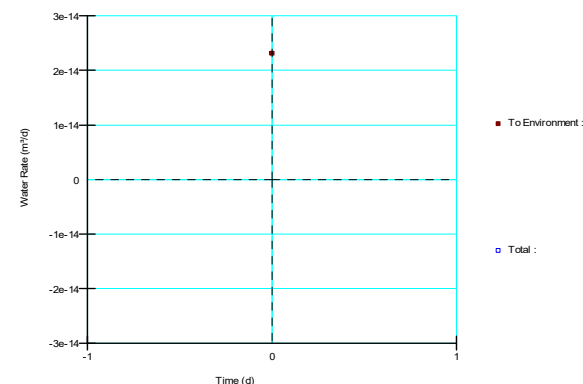
Name: 1.1 - Seepage - Pond RL 184.0 m

Date: 27/02/2023



| Color | Name                               | Category  | Kind             | Parameters |
|-------|------------------------------------|-----------|------------------|------------|
| ■     | Normal Operating Pond - RL 184.0 m | Hydraulic | Water Total Head | 184 m      |
| ■     | Potential Seepage Face             | Hydraulic | Water Rate       | 0 m³/d     |

| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx' Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|--------------|--------------|--------------------------|------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1            | 0            | 0                        | 0                      |
| ■     | Compacted Clay (Zone 1B) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1            | 0            |                          |                        |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1            | 0            |                          |                        |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### External RWP Seepage Assessment - Normal Operating Pond RL 184.0 m

Date: 1/03/2022 Job No: 109014.15

FIGURE F1.4.1



# ADVERTISED PLAN

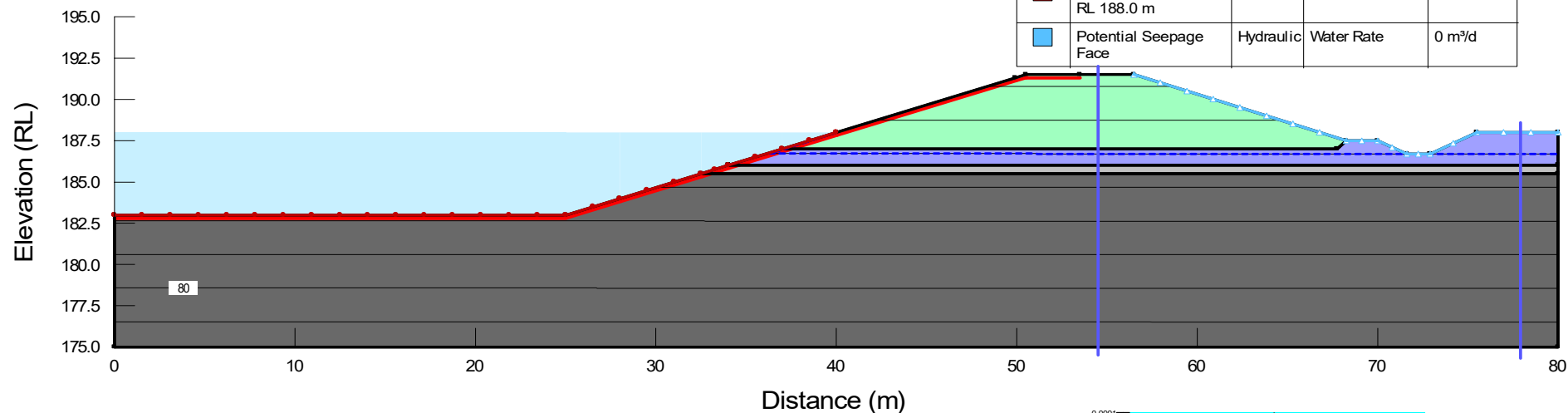
Costerfield Brunswick West TSF Design

File Name: Brunswick TSF - External RWP.gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\

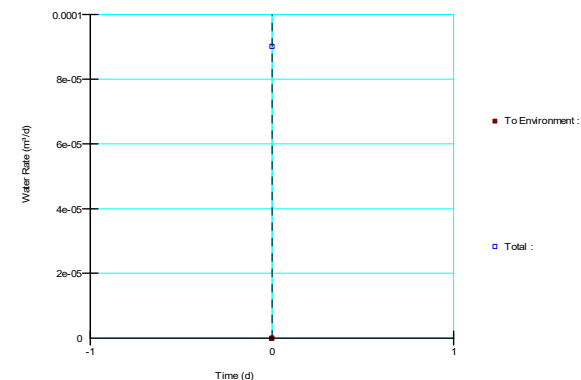
Name: 1.2 - Seepage - Pond RL 188.0 m

Date: 27/02/2023



| Color | Name                              | Category  | Kind             | Parameters |
|-------|-----------------------------------|-----------|------------------|------------|
| ■     | 99th Percentile Pond - RL 188.0 m | Hydraulic | Water Total Head | 188 m      |
| ■     | Potential Seepage Face            | Hydraulic | Water Rate       | 0 m³/d     |

| Color | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx' Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------|--------------------------|-------------------------|---------------------|---------------------|----------------|--------------|--------------|--------------------------|------------------------|
| ■     | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1            | 0            | 0                        | 0                      |
| ■     | Compacted Clay (Zone 1B) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| ■     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1            | 0            |                          |                        |
| ■     | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| ■     | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1            | 0            |                          |                        |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

Costerfield Gold Mine

Brunswick West Tailings Storage Facility

External RWP Seepage Assessment - 99th Percentile Pond RL 188.0 m

Date: 1/03/2022 Job No: 109014.15

FIGURE F1.4.2



# ADVERTISED PLAN

Costerfield Brunswick West TSF Design

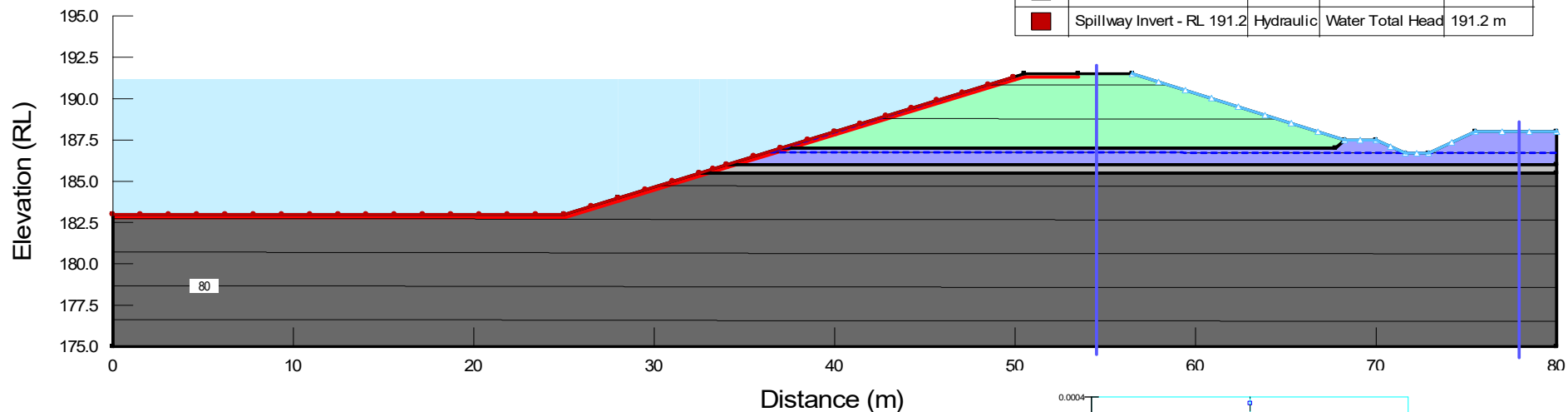
File Name: Brunswick TSF - External RWP.gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\Rev 2\

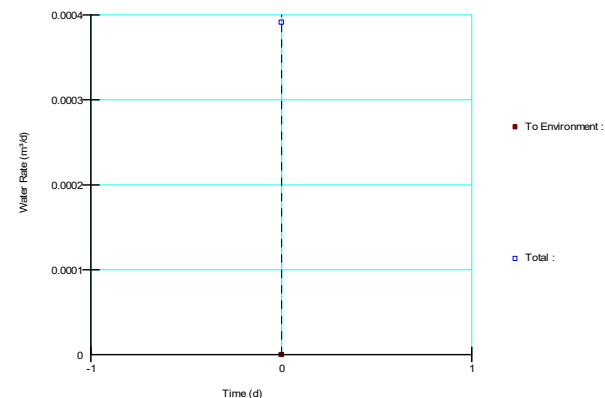
Name: 1.3 - Seepage - Pond RL 191.2 m

Date: 27/02/2023

| Color                                    | Name                       | Category  | Kind             | Parameters |
|--|----------------------------|-----------|------------------|------------|
| <span style="color: lightblue;">■</span> | Potential Seepage Face     | Hydraulic | Water Rate       | 0 m³/d     |
| <span style="color: red;">■</span>       | Spillway Invert - RL 191.2 | Hydraulic | Water Total Head | 191.2 m    |



| Color                                   | Name                     | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx' Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|---|--------------------------|-------------------------|---------------------|---------------------|----------------|--------------|--------------|--------------------------|------------------------|
| <span style="color: red;">■</span>      | BGM Liner                | Saturated Only          |                     |                     | 1e-12          | 1            | 0            | 0                        | 0                      |
| <span style="color: green;">■</span>    | Compacted Clay (Zone 1B) | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| <span style="color: grey;">■</span>     | EW Siltstone Foundation  | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1            | 0            |                          |                        |
| <span style="color: purple;">■</span>   | Foundation Clay          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1            | 0            |                          |                        |
| <span style="color: darkgrey;">■</span> | HW Siltstone Foundation  | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1            | 0            |                          |                        |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### External RWP Seepage Assessment - Pond at Spillway Invert Level RL 191.2m

Date: 1/03/2022 Job No: 109014.15

FIGURE F1.4.3



# ADVERTISED PLAN

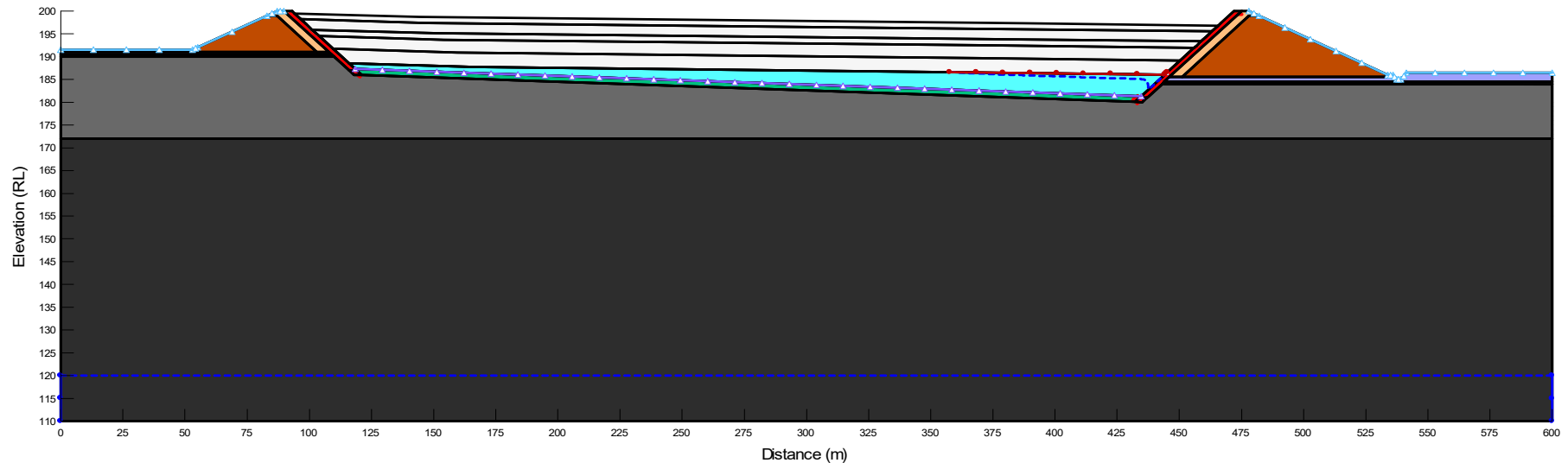
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 1 (End Apr 2025)

Date: 13/09/2022



| Color       | Name                               | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------------|------------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-------------------------|
| Red         | BGM Liner                          | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                       |
| Green       | Compacted Clay (Zone 1)            | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                         |
| Light Green | Compacted Clay (Zone 1A)           | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Grey        | EW Siltstone Foundation            | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                         |
| Blue        | Foundation Clay                    | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Cyan        | Fresh Tailings                     | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                         |
| Dark Grey   | HW/MV Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                         |
| Black       | HW/MV Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone           | Siltstone (Lower)   |                | 0.1         | 0            |                          |                         |
| Orange      | Rockfill (Zone 3A)                 | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                       |
| Brown       | Rockfill (Zone 3B)                 | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                       |

| Color  | Name                   | Category  | Kind             | Parameters          |
|--------|------------------------|-----------|------------------|---------------------|
| Blue   | GW RL 120 m            | Hydraulic | Water Total Head | 120 m               |
| Red    | Pond RL 186.6 m        | Hydraulic | Water Total Head | 186.6 m             |
| Cyan   | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |
| Purple | Underdrainage          | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 1

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.1



# ADVERTISED PLAN

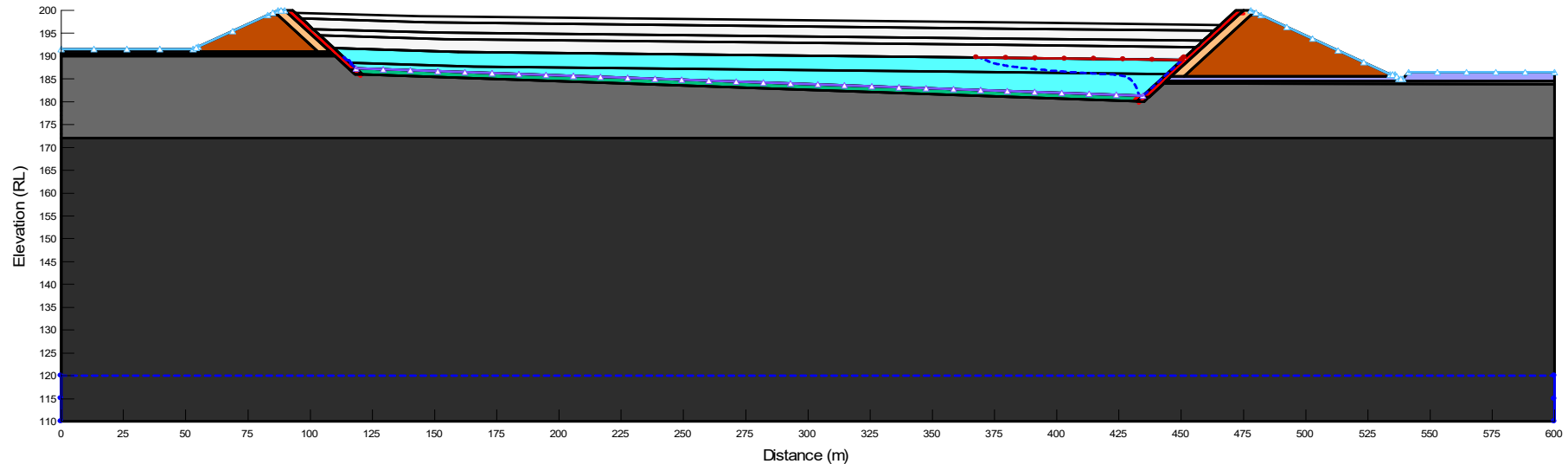
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 2 (End Apr 2026)

Date: 13/09/2022



| Color       | Name                               | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------------|------------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-------------------------|
| Red         | BGM Liner                          | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                       |
| Green       | Compacted Clay (Zone 1)            | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                         |
| Light Green | Compacted Clay (Zone 1A)           | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Grey        | EW Siltstone Foundation            | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                         |
| Blue        | Foundation Clay                    | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Cyan        | Fresh Tailings                     | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                         |
| Dark Grey   | HW/MV Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                         |
| Black       | HW/MV Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone           | Siltstone (Lower)   |                | 0.1         | 0            |                          |                         |
| Orange      | Rockfill (Zone 3A)                 | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                       |
| Brown       | Rockfill (Zone 3B)                 | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                       |

| Color      | Name                   | Category  | Kind             | Parameters |
|------------|------------------------|-----------|------------------|------------|
| Blue       | GW RL 120 m            | Hydraulic | Water Total Head | 120 m      |
| Red        | Pond RL 189.7 m        | Hydraulic | Water Total Head | 189.7 m    |
| Light Blue | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |
| Purple     | Underdrainage          | Hydraulic | Water Rate       | 0 m³/d     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 2

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.2



# ADVERTISED PLAN

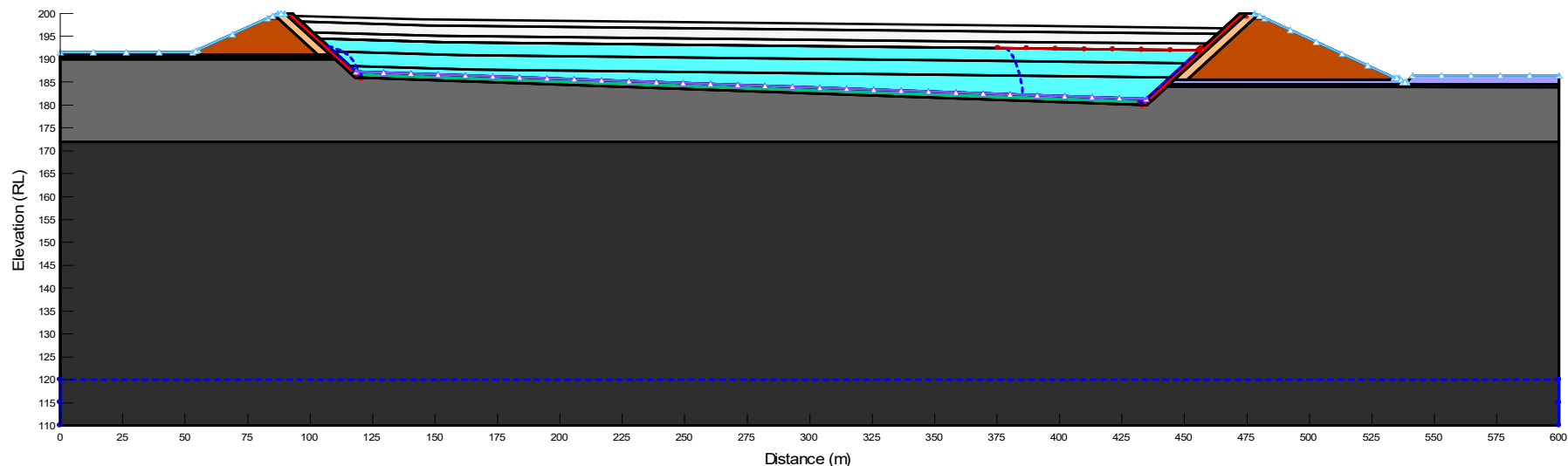
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 3 (End Apr 2027)

Date: 13/09/2022



| Color       | Name                              | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------------|-----------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-------------------------|
| Red         | BGM Liner                         | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                       |
| Green       | Compacted Clay (Zone 1)           | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                         |
| Light Green | Compacted Clay (Zone 1A)          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Grey        | EW Siltstone Foundation           | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                         |
| Blue        | Foundation Clay                   | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Cyan        | Fresh Tailings                    | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                         |
| Dark Grey   | HWMW Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                         |
| Black       | HWMW Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone (Lower)   | Siltstone (Lower)   |                | 0.1         | 0            |                          |                         |
| Orange      | Rockfill (Zone 3A)                | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                       |
| Dark Orange | Rockfill (Zone 3B)                | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                       |

| Color      | Name                   | Category  | Kind             | Parameters |
|------------|------------------------|-----------|------------------|------------|
| Blue       | GW RL 120 m            | Hydraulic | Water Total Head | 120 m      |
| Red        | Pond RL 192.4 m        | Hydraulic | Water Total Head | 192.4 m    |
| Light Blue | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |
| Dark Blue  | Underdrainage          | Hydraulic | Water Rate       | 0 m³/d     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 3

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.3



# ADVERTISED PLAN

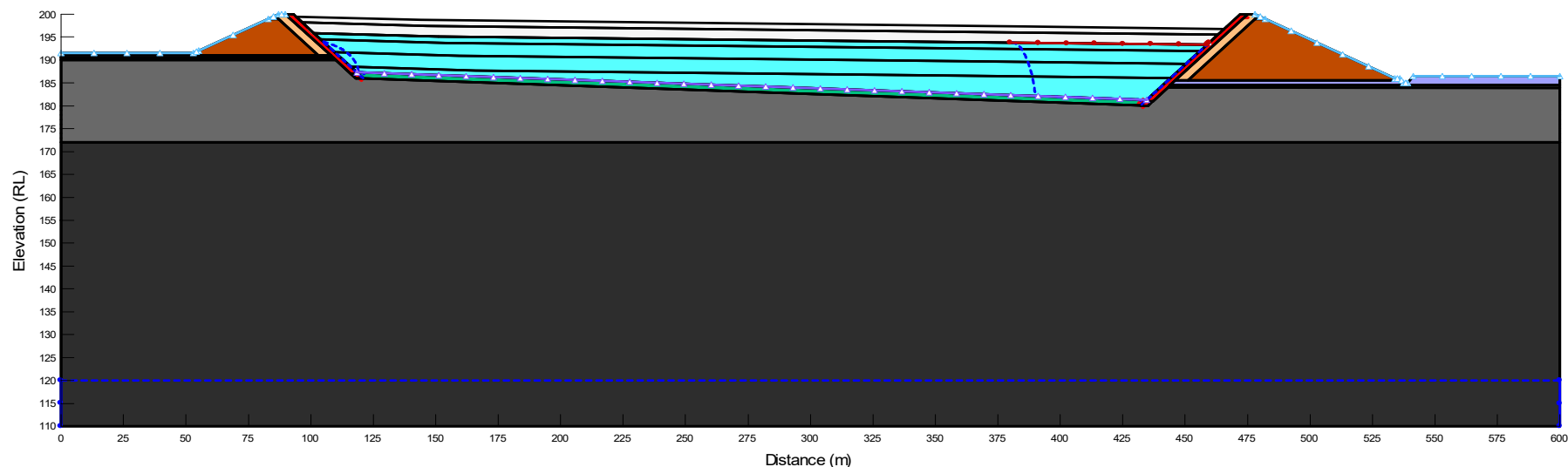
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 3.5 (End Sept 2027)

Date: 13/09/2022



| Color       | Name                              | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (kPa) |
|-------------|-----------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-----------------------|
| Red         | BGM Liner                         | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                     |
| Green       | Compacted Clay (Zone 1)           | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                       |
| Light Green | Compacted Clay (Zone 1A)          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                       |
| Grey        | EW Siltstone Foundation           | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                       |
| Blue        | Foundation Clay                   | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                       |
| Cyan        | Fresh Tailings                    | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                       |
| Dark Grey   | HWMW Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                       |
| Black       | HWMW Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone (Lower)   | Siltstone (Lower)   |                | 0.1         | 0            |                          |                       |
| Orange      | Rockfill (Zone 3A)                | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                     |
| Brown       | Rockfill (Zone 3B)                | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                     |

| Color      | Name                   | Category  | Kind             | Parameters |
|------------|------------------------|-----------|------------------|------------|
| Blue       | G/W RL 120 m           | Hydraulic | Water Total Head | 120 m      |
| Red        | Pond RL 193.8 m        | Hydraulic | Water Total Head | 193.8 m    |
| Light Blue | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |
| Purple     | Underdrainage          | Hydraulic | Water Rate       | 0 m³/d     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 3.5

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.4



# ADVERTISED PLAN

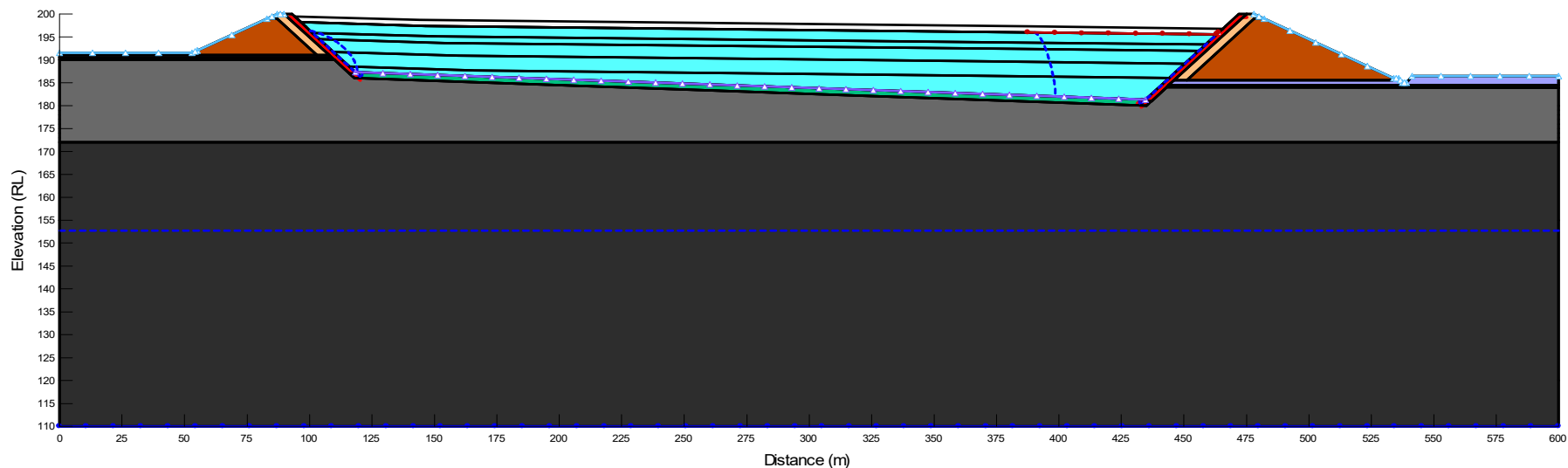
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 4.5 (End Sept 2028)

Date: 13/09/2022



| Color       | Name                               | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------------|------------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-------------------------|
| Red         | BGM Liner                          | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                       |
| Green       | Compacted Clay (Zone 1)            | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                         |
| Light Green | Compacted Clay (Zone 1A)           | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Grey        | EW Siltstone Foundation            | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                         |
| Blue        | Foundation Clay                    | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Light Blue  | Fresh Tailings                     | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                         |
| Dark Grey   | HW/MV Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                         |
| Black       | HW/MV Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone           | Siltstone (Lower)   |                | 0.1         | 0            |                          |                         |
| Orange      | Rockfill (Zone 3A)                 | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                       |
| Dark Orange | Rockfill (Zone 3B)                 | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                       |

| Color      | Name                   | Category  | Kind             | Parameters |
|------------|------------------------|-----------|------------------|------------|
| Blue       | GW RL 155 m            | Hydraulic | Water Total Head | 155 m      |
| Red        | Pond RL 196.0 m        | Hydraulic | Water Total Head | 196 m      |
| Light Blue | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |
| Dark Blue  | Underdrainage          | Hydraulic | Water Rate       | 0 m³/d     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 4.5

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.5



# ADVERTISED PLAN

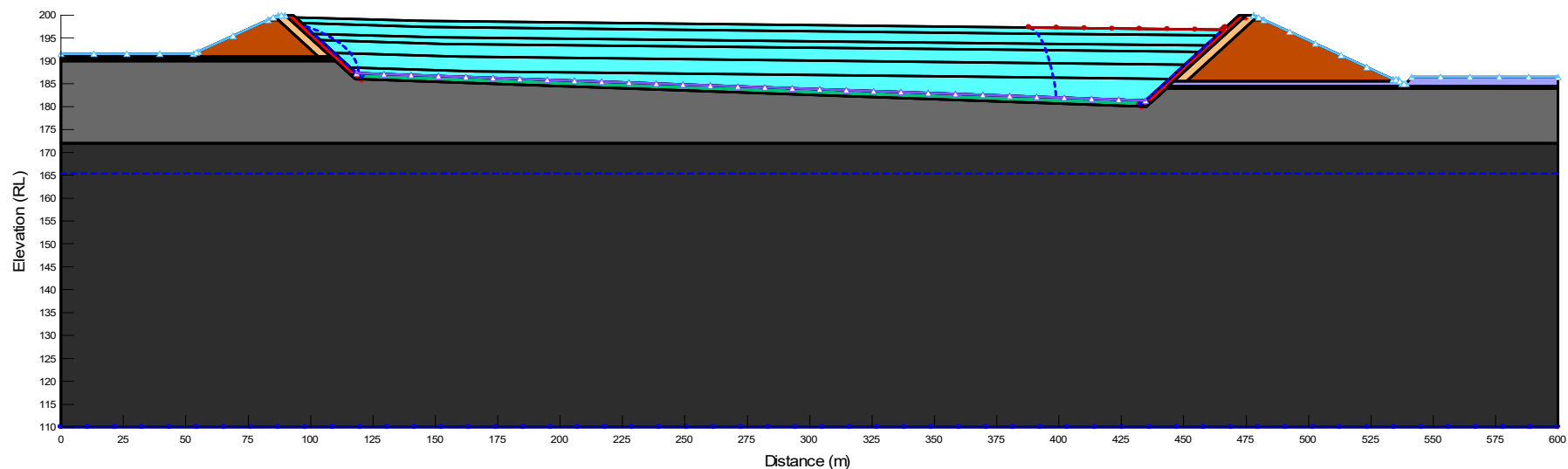
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 5 (End Apr 2029)

Date: 13/09/2022



| Color       | Name                              | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------------|-----------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| Red         | BGM Liner                         | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| Green       | Compacted Clay (Zone 1)           | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| Light Green | Compacted Clay (Zone 1A)          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| Grey        | EW Siltstone Foundation           | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| Blue        | Foundation Clay                   | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| Cyan        | Fresh Tailings                    | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| Dark Grey   | HWMV Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| Black       | HWMV Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone           | Siltstone (Lower)   |                | 0.1         | 0            |                          |                        |
| Orange      | Rockfill (Zone 3A)                | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |
| Brown       | Rockfill (Zone 3B)                | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |

| Color      | Name                   | Category  | Kind             | Parameters |
|------------|------------------------|-----------|------------------|------------|
| Blue       | GW RL 172 m            | Hydraulic | Water Total Head | 172 m      |
| Red        | Pond RL 197.3 m        | Hydraulic | Water Total Head | 197.3 m    |
| Light Blue | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |
| Purple     | Underdrainage          | Hydraulic | Water Rate       | 0 m³/d     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 5

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.6



# ADVERTISED PLAN

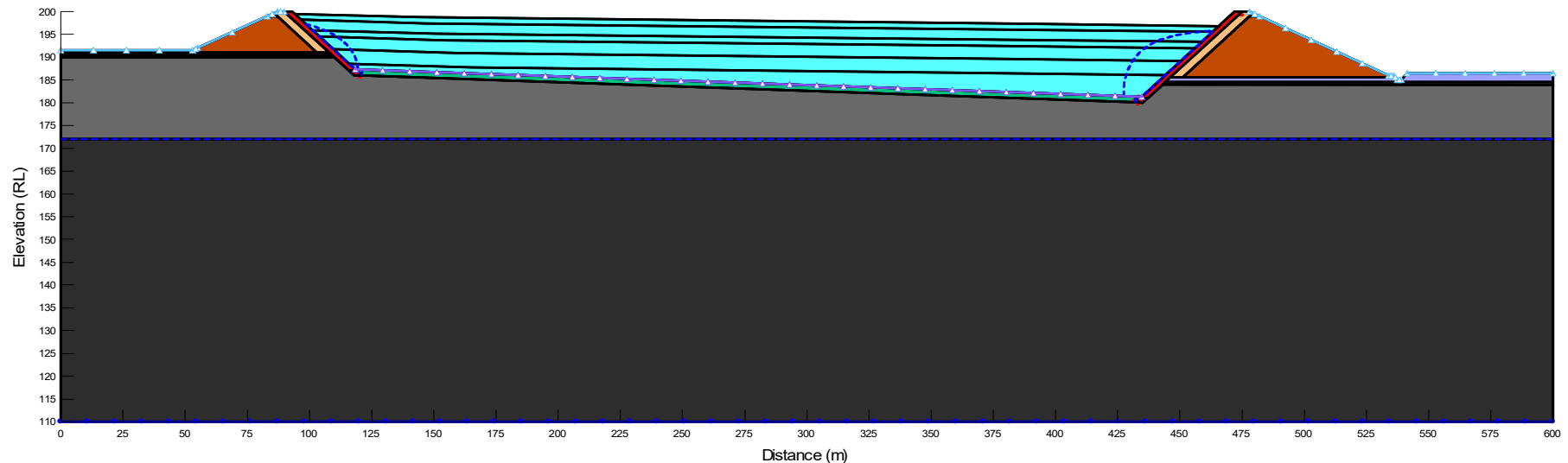
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 6

Date: 13/09/2022



| Color       | Name                               | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------------|------------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-------------------------|
| Red         | BGM Liner                          | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                       |
| Green       | Compacted Clay (Zone 1)            | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                         |
| Light Green | Compacted Clay (Zone 1A)           | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Grey        | EW Siltstone Foundation            | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                         |
| Blue        | Foundation Clay                    | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Cyan        | Fresh Tailings                     | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                         |
| Dark Grey   | HW/MW Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                         |
| Black       | HW/MW Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone           | Siltstone (Lower)   |                | 0.1         | 0            |                          |                         |
| Orange      | Rockfill (Zone 3A)                 | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                       |
| Brown       | Rockfill (Zone 3B)                 | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                       |

| Color  | Name                   | Category  | Kind             | Parameters |
|--------|------------------------|-----------|------------------|------------|
| Blue   | GW RL 173 m            | Hydraulic | Water Total Head | 173 m      |
| Cyan   | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |
| Purple | Underdrainage          | Hydraulic | Water Rate       | 0 m³/d     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 6

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.7



# ADVERTISED PLAN

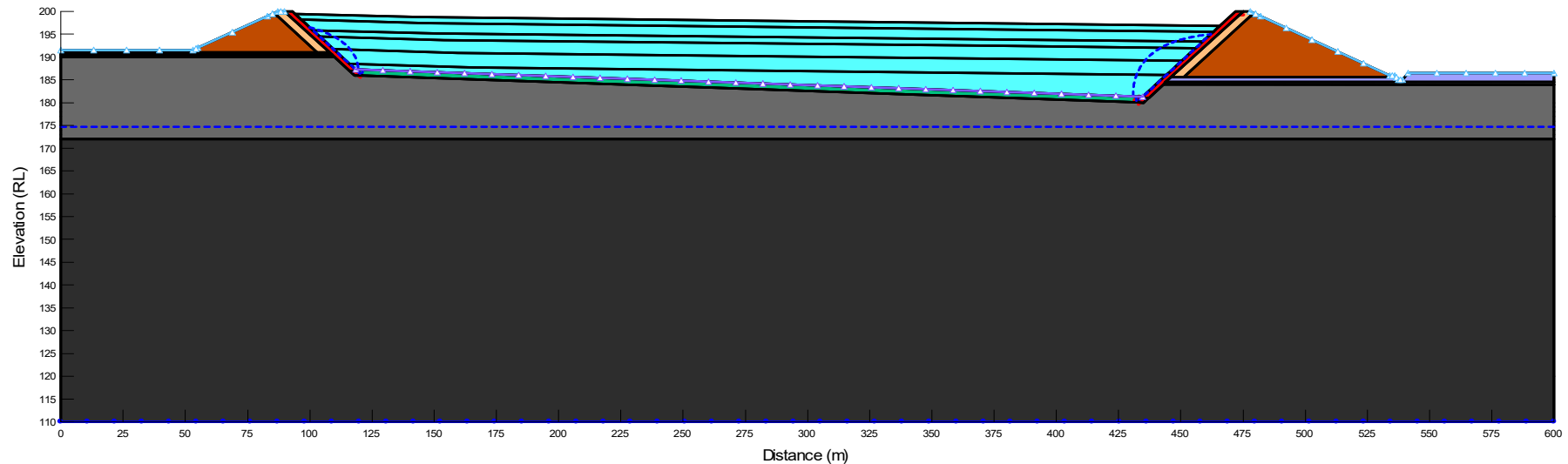
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 8

Date: 13/09/2022



| Color       | Name                              | Model                   | Vol. WC. Function   | K-Function          | Sat K <sub>x</sub> (m/sec) | K <sub>y</sub> /K <sub>x</sub> Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------------|-----------------------------------|-------------------------|---------------------|---------------------|----------------------------|--------------------------------------|--------------|--------------------------|-------------------------|
| Red         | BGM Liner                         | Saturated Only          |                     |                     | 1e-12                      | 1                                    | 0            | 0                        | 0                       |
| Green       | Compacted Clay (Zone 1)           | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                            | 1                                    | 0            |                          |                         |
| Light Green | Compacted Clay (Zone 1A)          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                            | 1                                    | 0            |                          |                         |
| Grey        | EW Siltstone Foundation           | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                            | 1                                    | 0            |                          |                         |
| Blue        | Foundation Clay                   | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                            | 1                                    | 0            |                          |                         |
| Cyan        | Fresh Tailings                    | Saturated / Unsaturated | Tailings            | Tailings            |                            | 1                                    | 0            |                          |                         |
| Dark Grey   | HWMV Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                            | 1                                    | 0            |                          |                         |
| Black       | HWMV Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone (Lower)   | Siltstone (Lower)   |                            | 0.1                                  | 0            |                          |                         |
| Orange      | Rockfill (Zone 3A)                | Saturated Only          |                     |                     | 1e-05                      | 1                                    | 0            | 0                        | 0                       |
| Brown       | Rockfill (Zone 3B)                | Saturated Only          |                     |                     | 1e-06                      | 1                                    | 0            | 0                        | 0                       |

| Color      | Name                   | Category  | Kind             | Parameters          |
|------------|------------------------|-----------|------------------|---------------------|
| Blue       | GW RL 175m             | Hydraulic | Water Total Head | 175 m               |
| Light Blue | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |
| Purple     | Underdrainage          | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 8

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.8



# ADVERTISED PLAN

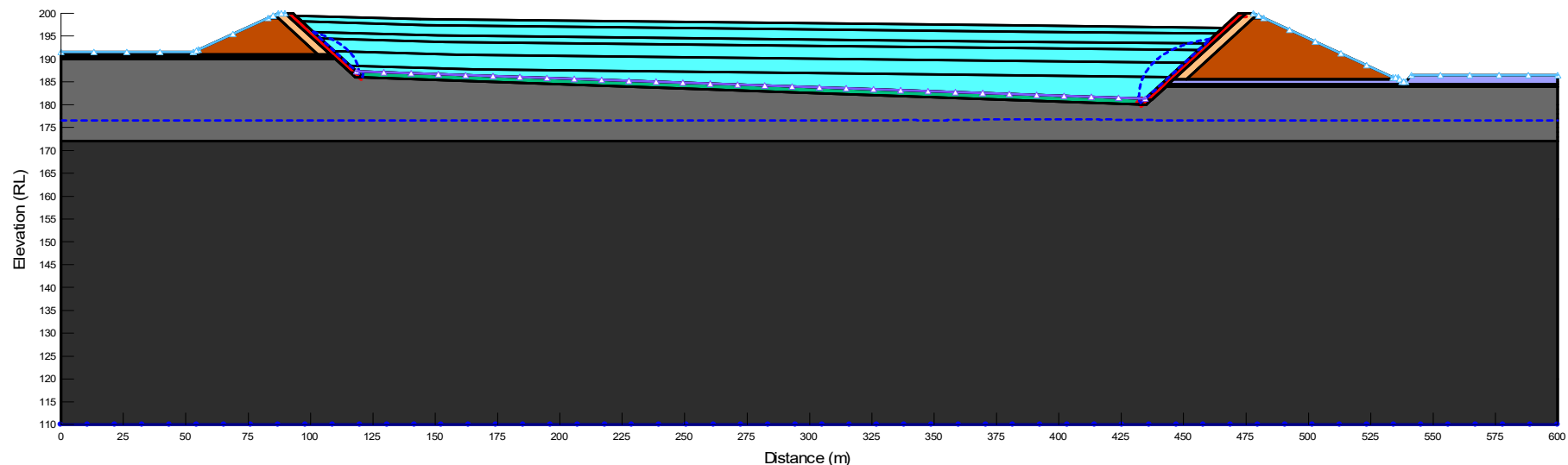
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 10

Date: 13/09/2022



| Color       | Name                               | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (1/kPa) |
|-------------|------------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|-------------------------|
| Red         | BGMLiner                           | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                       |
| Green       | Compacted Clay (Zone 1)            | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                         |
| Light Green | Compacted Clay (Zone 1A)           | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Grey        | EW Siltstone Foundation            | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                         |
| Blue        | Foundation Clay                    | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                         |
| Cyan        | Fresh Tailings                     | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                         |
| Dark Grey   | HW/MW Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                         |
| Black       | HW/MW Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone           | Siltstone (Lower)   |                | 0.1         | 0            |                          |                         |
| Orange      | Rockfill (Zone 3A)                 | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                       |
| Dark Orange | Rockfill (Zone 3B)                 | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                       |

| Color      | Name                   | Category  | Kind             | Parameters |
|------------|------------------------|-----------|------------------|------------|
| Blue       | GW RL 177m             | Hydraulic | Water Total Head | 177 m      |
| Light Blue | Potential Seepage Face | Hydraulic | Water Rate       | 0 m³/d     |
| Purple     | Underdrainage          | Hydraulic | Water Rate       | 0 m³/d     |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 10

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.9



# ADVERTISED PLAN

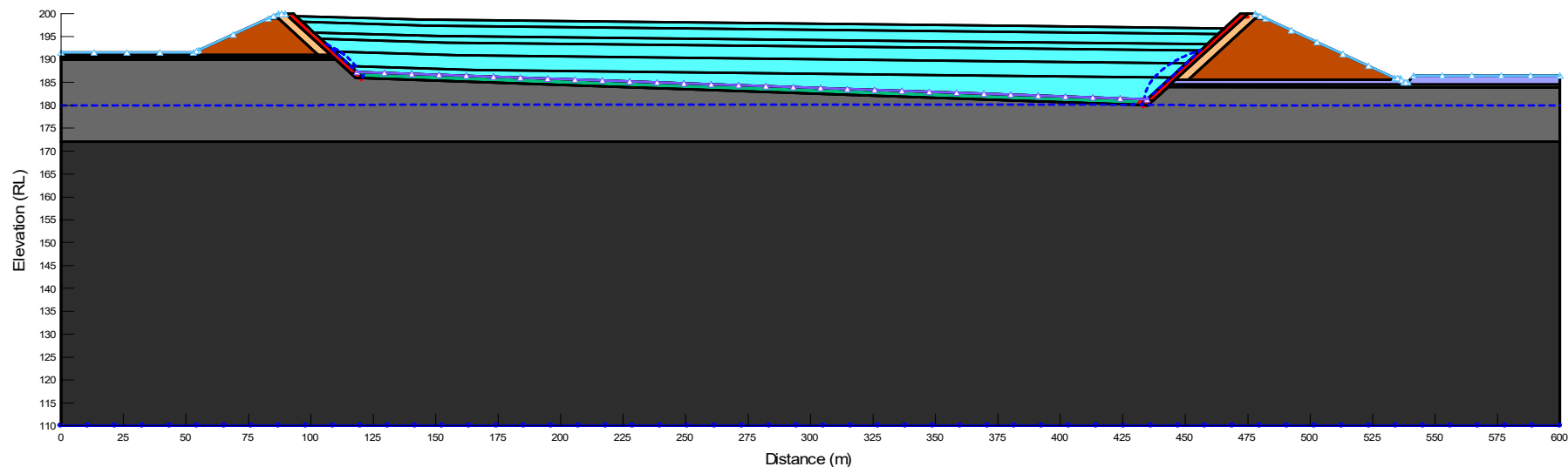
Costerfield Brunswick West TSF Design

File Name: New TSF - BGM Design (Groundwater Interaction).gsz

Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SeepW\

Name: Year 20

Date: 13/09/2022



| Color       | Name                              | Model                   | Vol. WC. Function   | K-Function          | Sat Kx (m/sec) | Ky/Kx Ratio | Rotation (°) | Volumetric Water Content | Compressibility (/kPa) |
|-------------|-----------------------------------|-------------------------|---------------------|---------------------|----------------|-------------|--------------|--------------------------|------------------------|
| Red         | BGM Liner                         | Saturated Only          |                     |                     | 1e-12          | 1           | 0            | 0                        | 0                      |
| Green       | Compacted Clay (Zone 1)           | Saturated / Unsaturated | Clay                | Clay (1e-9)         |                | 1           | 0            |                          |                        |
| Light Green | Compacted Clay (Zone 1A)          | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| Grey        | EW Siltstone Foundation           | Saturated / Unsaturated | Weathered Siltstone | Weathered Siltstone |                | 1           | 0            |                          |                        |
| Blue        | Foundation Clay                   | Saturated / Unsaturated | Clay                | Clay (5e-8)         |                | 1           | 0            |                          |                        |
| Cyan        | Fresh Tailings                    | Saturated / Unsaturated | Tailings            | Tailings            |                | 1           | 0            |                          |                        |
| Dark Grey   | HMMW Siltstone Foundation         | Saturated / Unsaturated | Siltstone           | Siltstone           |                | 1           | 0            |                          |                        |
| Black       | HMMW Siltstone Foundation (Lower) | Saturated / Unsaturated | Siltstone           | Siltstone (Lower)   |                | 0.1         | 0            |                          |                        |
| Orange      | Rockfill (Zone 3A)                | Saturated Only          |                     |                     | 1e-05          | 1           | 0            | 0                        | 0                      |
| Brown       | Rockfill (Zone 3B)                | Saturated Only          |                     |                     | 1e-06          | 1           | 0            | 0                        | 0                      |

| Color  | Name                   | Category  | Kind             | Parameters          |
|--------|------------------------|-----------|------------------|---------------------|
| Blue   | GW RL 180m             | Hydraulic | Water Total Head | 180 m               |
| Cyan   | Potential Seepage Face | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |
| Purple | Underdrainage          | Hydraulic | Water Rate       | 0 m <sup>3</sup> /d |



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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Seepage Assessment - Groundwater Impact - Transient Assessment - End Year 20

Date: 1/03/2022 Job No: 109014.15

FIGURE F2.10





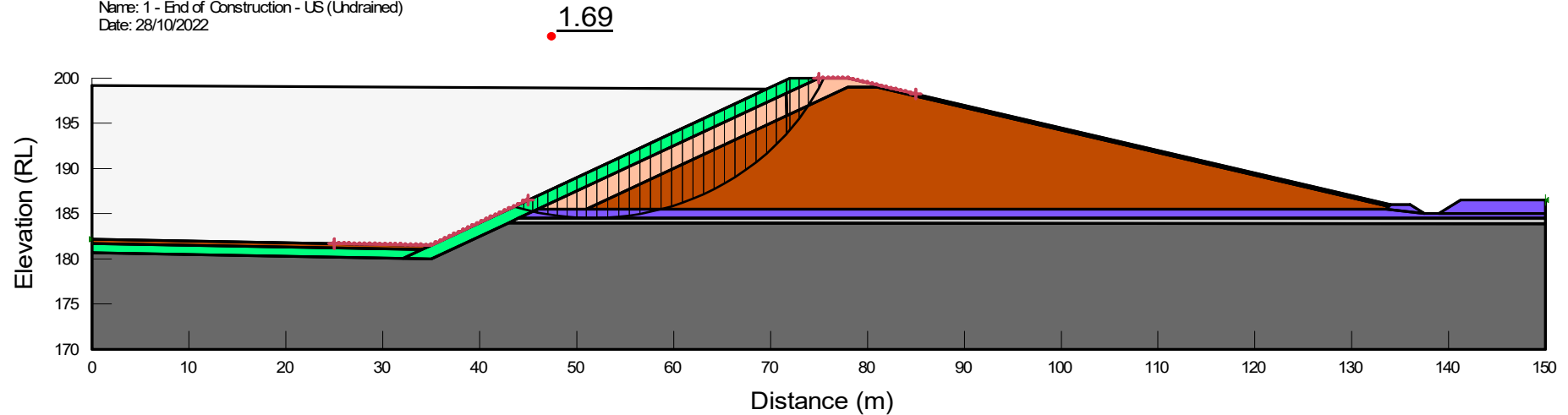
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## APPENDIX G – STABILITY ASSESSMENT RESULTS

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Costerfield Brunswick West TSF Design  
 File Name: New TSF - BGM Design (Stability).gsz  
 Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SlopeVM  
 Name: 1 - End of Construction - US (Undrained)  
 Date: 28/10/2022



| Color     | Name                                       | Model                  | Unit Weight (kN/m <sup>3</sup> ) | Strength Function | Cohesion* (kPa) | Phi* (°) | Phi-B (°) | Minimum Strength (kPa) | Tau/Sigma Ratio |
|-----------|--|------------------------|----------------------------------|-------------------|-----------------|----------|-----------|------------------------|-----------------|
| Green     | Compacted Clay (Zone 1/1B) (Undrained)     | SHANSEP                | 19                               |                   |                 |          |           | 20                     | 0.28            |
| Grey      | EW Siltstone Foundation                    | Mohr-Coulomb           | 22                               |                   | 0               | 36       | 0         |                        |                 |
| Purple    | Foundation Clay (Undrained)                | SHANSEP                | 20.5                             |                   |                 |          |           | 20                     | 0.35            |
| Dark Grey | HW Siltstone Foundation                    | Bedrock (Impenetrable) |                                  |                   |                 |          |           |                        |                 |
| Orange    | Rockfill (Zone 3A) - Unsaturated (Dr/Undr) | Mohr-Coulomb           | 20                               |                   | 30              | 28       | 0         |                        |                 |
| Brown     | Rockfill (Zone 3B) (Dr/Undr)               | Shear/Normal Fr.       | 22                               | Laps Lower Bound  |                 |          | 0         |                        |                 |

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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

Stability Assessment - Short Term Static Stability  
 End of Construction (Undrained), Upstream Failure

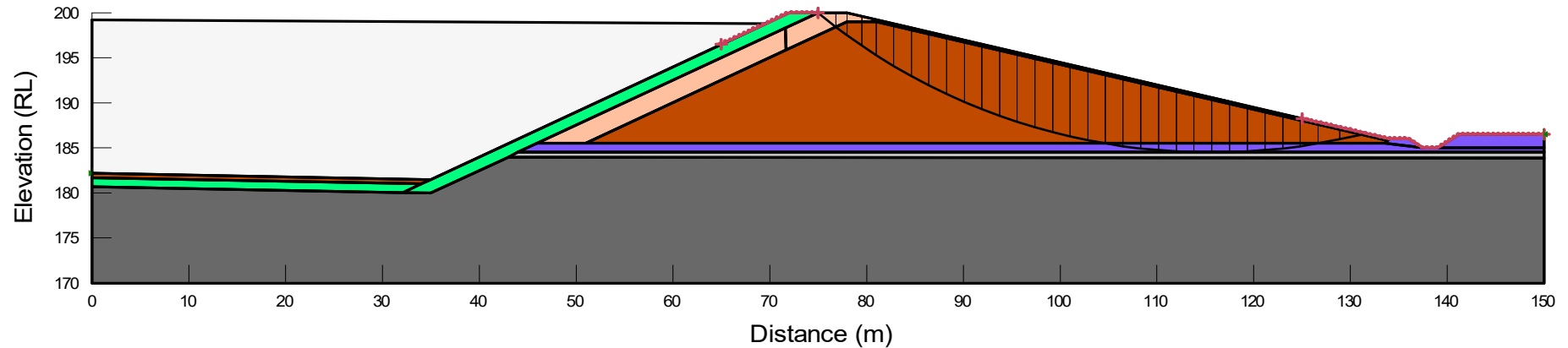
Date: 28/10/2022 Job No: 109014.15

**FIGURE G1**



Costerfield Brunswick West TSF Design  
File Name: New TSF - BGM Design (Stability).gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SlopeW  
Name: 2 - End of Construction - DS (Undrained)  
Date: 28/10/2022

2.79



| Color     | Name                                       | Model                  | Unit Weight (kN/m <sup>3</sup> ) | Strength Function | Cohesion <sup>1</sup> (kPa) | Phi <sup>1</sup> (°) | Phi-B (°) | Minimum Strength (kPa) | Tau/Sigma Ratio |
|-----------|--|------------------------|----------------------------------|-------------------|-----------------------------|----------------------|-----------|------------------------|-----------------|
| Green     | Compacted Clay (Zone 1/1B) (Undrained)     | SHANSEP                | 19                               |                   |                             |                      |           | 20                     | 0.28            |
| Grey      | EW Siltstone Foundation                    | Mohr-Coulomb           | 22                               |                   | 0                           | 36                   | 0         |                        |                 |
| Blue      | Foundation Clay (Undrained)                | SHANSEP                | 20.5                             |                   |                             |                      |           | 20                     | 0.35            |
| Dark Grey | HW Siltstone Foundation                    | Bedrock (Impenetrable) |                                  |                   |                             |                      |           |                        |                 |
| Orange    | Rockfill (Zone 3A) - Unsaturated (Dr/Undr) | Mohr-Coulomb           | 20                               |                   | 30                          | 28                   | 0         |                        |                 |
| Brown     | Rockfill (Zone 3B) (Dr/Undr)               | Shear/Normal Fr.       | 22                               | Laps Lower Bound  |                             |                      | 0         |                        |                 |

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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

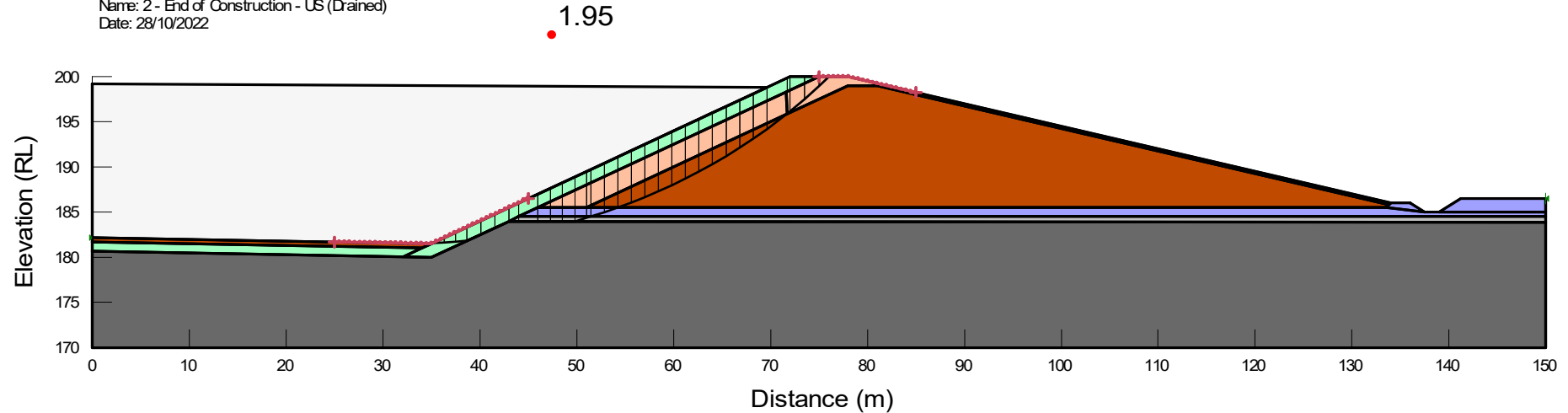
Stability Assessment - Short Term Static Stability  
End of Construction (Undrained), Downstream Failure

Date: 28/10/2022 Job No: 109014.15

**FIGURE G2**



Costerfield Brunswick West TSF Design  
File Name: New TSF - BGMDesign (Stability).gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SlopeVM  
Name: 2 - End of Construction - US (Drained)  
Date: 28/10/2022



| Color     | Name                                       | Model                  | Unit Weight (kN/m³) | Strength Function | Cohesion' (kPa) | Phi' (°) | Phi-B (°) |
|-----------|--|------------------------|---------------------|-------------------|-----------------|----------|-----------|
| Green     | Compacted Clay (Zone 1/1B) (Drained)       | Mohr-Coulomb           | 19                  |                   | 0               | 30       | 0         |
| Grey      | EWSiltstone Foundation                     | Mohr-Coulomb           | 22                  |                   | 0               | 36       | 0         |
| Blue      | Foundation Clay (Drained)                  | Mohr-Coulomb           | 20.5                |                   | 38              | 20       | 0         |
| Dark Grey | HWSiltstone Foundation                     | Bedrock (Impenetrable) |                     |                   |                 |          |           |
| Orange    | Rockfill (Zone 3A) - Unsaturated (Dr/Undr) | Mohr-Coulomb           | 20                  |                   | 30              | 28       | 0         |
| Brown     | Rockfill (Zone 3B) (Dr/Undr)               | Shear/Normal Fr.       | 22                  | Laps Lower Bound  |                 |          | 0         |

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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

Stability Assessment - Short Term Static Stability  
End of Construction (Drained), Upstream Failure

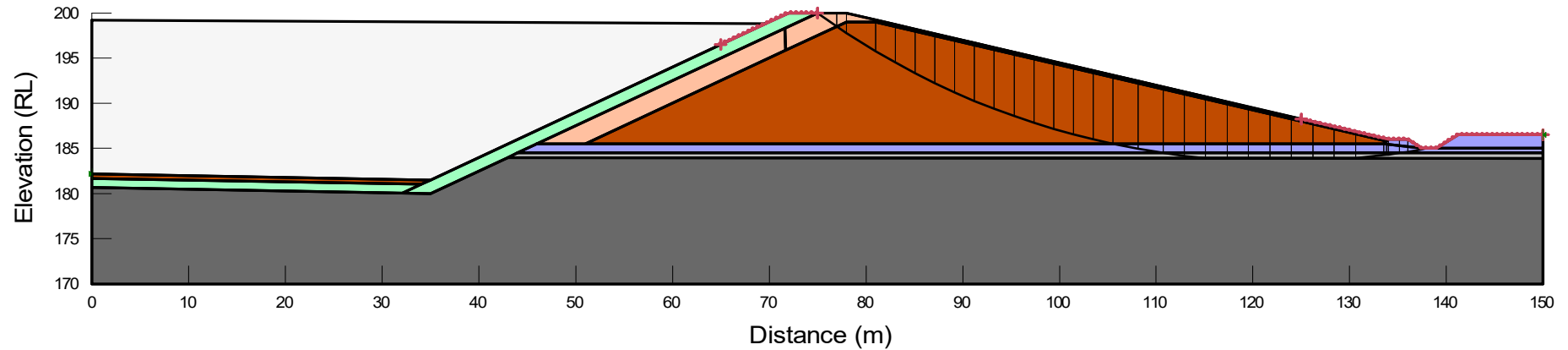
Date: 28/10/2022 Job No: 109014.15

**FIGURE G3**



Costerfield Brunswick West TSF Design  
 File Name: New TSF - BGM Design (Stability).gsz  
 Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SlopeW  
 Name: 4 - End of Construction - DS (Drained)  
 Date: 28/10/2022

3.41



| Color        | Name                                       | Model                  | Unit Weight (kN/m³) | Strength Function | Cohesion* (kPa) | Phi* (°) | Phi-B (°) |
|--------------|--|------------------------|---------------------|-------------------|-----------------|----------|-----------|
| Light Green  | Compacted Clay (Zone 1/1B) (Drained)       | Mohr-Coulomb           | 19                  |                   | 0               | 30       | 0         |
| Light Grey   | EW Siltstone Foundation                    | Mohr-Coulomb           | 22                  |                   | 0               | 36       | 0         |
| Blue         | Foundation Clay (Drained)                  | Mohr-Coulomb           | 20.5                |                   | 38              | 20       | 0         |
| Dark Grey    | HW Siltstone Foundation                    | Bedrock (Impenetrable) |                     |                   |                 |          |           |
| Light Orange | Rockfill (Zone 3A) - Unsaturated (Dr/Undr) | Mohr-Coulomb           | 20                  |                   | 30              | 28       | 0         |
| Dark Orange  | Rockfill (Zone 3B) (Dr/Undr)               | Shear/Normal Fr.       | 22                  | Laps Lower Bound  |                 |          | 0         |

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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

Stability Assessment - Short Term Static Stability  
 End of Construction (Drained), Downstream Failure

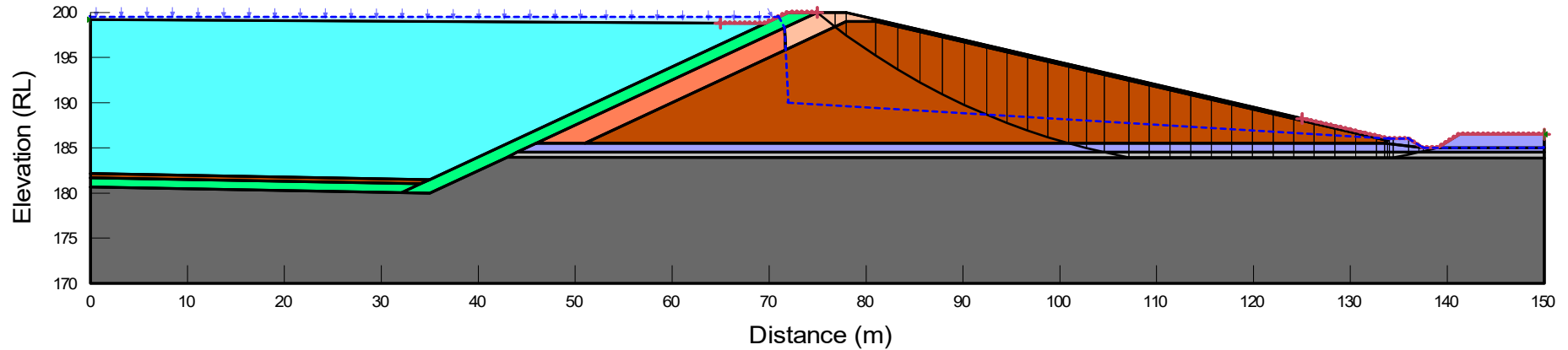
Date: 28/10/2022 Job No: 109014.15

**FIGURE G4**



Costerfield Brunswick West TSF Design  
File Name: New TSF - BGM\Design (Stability).gsz  
Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SlopeW  
Name: 5 - End of Filling - DS  
Date: 28/10/2022

2.97



| Color | Name                                       | Model                  | Unit Weight (kN/m³) | Strength Function | Cohesion (kPa) | Phi (°) | Phi-B (°) | Minimum Strength (kPa) | Tau/Sigma Ratio | Piezometric Line |
|-------|--|------------------------|---------------------|-------------------|----------------|---------|-----------|------------------------|-----------------|------------------|
| ■     | Compacted Clay (Zone 1/1B) (Undrained)     | SHANSEP                | 19                  |                   |                |         |           | 20                     | 0.28            | 1                |
| ■     | EWSiltstone Foundation                     | Mohr-Coulomb           | 22                  |                   | 0              | 36      | 0         |                        |                 | 1                |
| ■     | Foundation Clay (Drained)                  | Mohr-Coulomb           | 20.5                |                   | 38             | 20      | 0         |                        |                 | 1                |
| ■     | Fresh Tailings                             | Spatial Mohr-Coulomb   | 16                  |                   | 0              | 0       | 0         |                        |                 | 1                |
| ■     | HWsiltstone Foundation                     | Bedrock (Impenetrable) |                     |                   |                |         |           |                        |                 | 1                |
| ■     | Rockfill (Zone 3A) - Saturated (Dr/Undr)   | Mohr-Coulomb           | 22                  |                   | 15             | 23      | 0         |                        |                 | 1                |
| ■     | Rockfill (Zone 3A) - Unsaturated (Dr/Undr) | Mohr-Coulomb           | 20                  |                   | 30             | 28      | 0         |                        |                 | 1                |
| ■     | Rockfill (Zone 3B) (Dr/Undr)               | Shear/Normal Fn.       | 22                  | Laps Lower Bound  |                |         | 0         |                        |                 | 1                |

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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

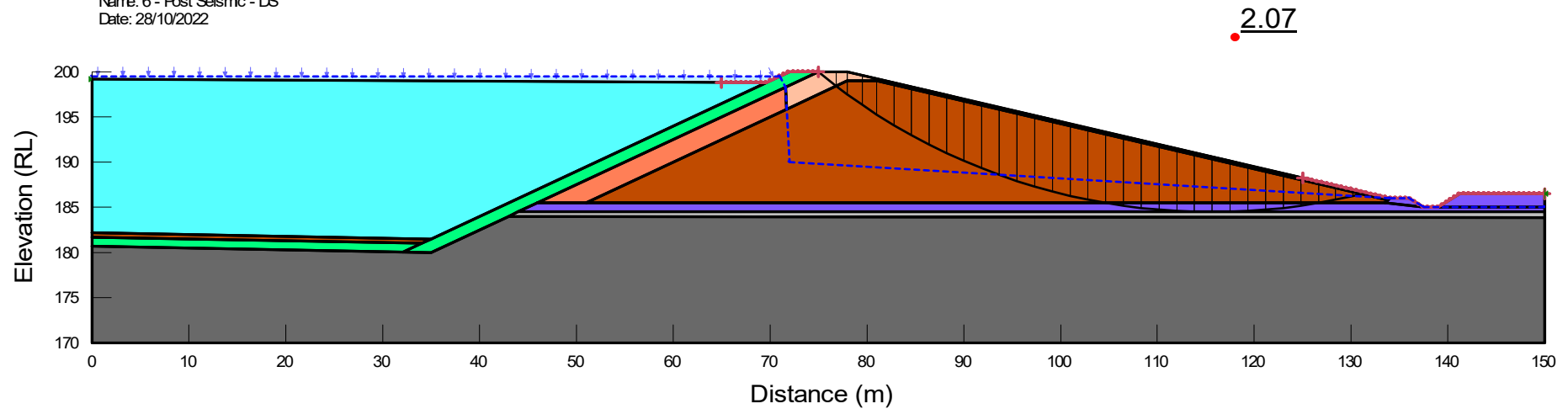
#### Stability Assessment - Long Term Static Stability End of Filling, Downstream Failure

Date: 28/10/2022 Job No: 109014.15

FIGURE G5



Costerfield Brunswick West TSF Design  
 File Name: New TSF - BGM\Design (Stability).gsz  
 Directory: K:\Projects\109\109014 Costerfield Mine, Costerfield\15 New TSF Investigation and Design\Data and Calcs\SlopeW\A  
 Name: 6 - Post Seismic - DS  
 Date: 28/10/2022



| Color        | Name   | Model                  | Unit Weight (kN/m³) | Strength Function      | Cohesion (kPa) | Phi' (°) | Phi-B (°) | Minimum Strength (kPa) | Tau/Sigma Ratio | Piezometric Line |
|--------------|--|------------------------|---------------------|------------------------|----------------|----------|-----------|------------------------|-----------------|------------------|
| Green        | Compacted Clay (Zone 1/1B) (Post Seis)           | SHANSEP                | 19                  |                        |                |          |           | 16                     | 0.224           | 1                |
| Grey         | BW Siltstone Foundation (80%)                    | Mohr-Coulomb           | 22                  |                        | 0              | 28.8     | 0         |                        |                 | 1                |
| Purple       | Foundation Clay (Post Seis)                      | SHANSEP                | 20.5                |                        |                |          |           | 16                     | 0.28            | 1                |
| Cyan         | Fresh Tailings                                   | Spatial Mohr-Coulomb   | 16                  |                        | 0              | 0        | 0         |                        |                 | 1                |
| Dark Grey    | HWS Siltstone Foundation                         | Bedrock (Impenetrable) |                     |                        |                |          |           |                        |                 | 1                |
| Orange       | Rockfill (Zone 3A) - Saturated (Dr/Undr) (80%)   | Mohr-Coulomb           | 22                  |                        | 12             | 18.4     | 0         |                        |                 | 1                |
| Light Orange | Rockfill (Zone 3A) - Unsaturated (Dr/Undr) (80%) | Mohr-Coulomb           | 20                  |                        | 24             | 22.4     | 0         |                        |                 | 1                |
| Brown        | Rockfill (Zone 3B) (Dr/Undr) (80%)               | Shear/Normal Fr.       | 22                  | Laps Lower Bound (80%) |                |          | 0         |                        |                 | 1                |

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## MANDALAY RESOURCES COSTERFIELD OPERATIONS

### Costerfield Gold Mine

#### Brunswick West Tailings Storage Facility

#### Stability Assessment - Post Seismic Stability End of Filling, Downstream Failure

Date: 28/10/2022 Job No: 109014.15

**FIGURE G6**





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## APPENDIX H – DESIGN CERTIFICATION

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## Certificate of Design Compliance

### Mandalay Resources Costerfield Operations – Brunswick West Tailings Storage Facility

---

**Name and address of Chartered Professional Engineer providing certification:**

**Craig Noske** MIEAust CPEng NER (EA ID 1124101)  
**Senior Principal Engineer, ATC Williams Pty Ltd**  
**222 Beach Road, Mordialloc, Victoria, 3195**

**Statement of relevant experience:**

I hereby state that I am a Chartered Professional Engineer, registered by Engineers Australia in the 'Civil Engineering' filed of practice, and meet the requirements of the definition of 'suitably qualified and competent person'.

**Statement of certification:**

For and on behalf of Mandalay Resources Costerfield Operations Pty Ltd, I, Craig Noske, do hereby certify and confirm that the Brunswick West Tailings Storage Facility has been designed in compliance with ANCOLD and Victorian State Government requirements, as documented in the "Mandalay Resources Costerfield Operations, Costerfield Gold Mine, Brunswick West Tailings Storage Facility Detailed Design Report", Ref. 109014.15-R04 Rev 0 October 2022.

I, Craig Noske, declare that the information provided as part of this certification is true to the best of my knowledge.

**Signed:**



**Date:** 11<sup>th</sup> October 2022

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melbourne@atcwilliams.com.au www.atcwilliams.com.au ABN 64 005 931 288

