Capricorn Copper Pty Ltd

Rehabilitation of Old TSF and HLEP2 Cover Design Report

December 2018

Executive summary

Capricorn Copper Pty Ltd (CCPL) engaged GHD Pty Ltd (GHD) to undertake a detailed cover design for the Old TSF and HLEP2 to meet CCPL's obligations under the Transitional Environmental Program MAN 17560 (TEP). CCPL's obligations under the TEP Items 5 and 16 (Old TSF) and Items 9 and 17 (HLEP2), are generally as follows:

- Evaluation of preferred rehabilitation strategy (1 March 2018).
- Completion of all capital programs for alternative strategies (if selected) (1 November 2018).
- Define and implement an appropriated landform and cover design (1 March 2019).

GHD's scope of work includes investigation for low permeability clay material and growth medium sourcing for the cover, hydrological assessments inclusive of design of diversion drains and spillways for the final landform, cover modelling, groundwater modelling and final cover detailed design inclusive of technical specifications, design drawings and bill of quantities.

This document presents the design of the cover based on information available to date with minimal update to design required to accommodate final laboratory testing results. This report is subject to, and must be read in conjunction with, the limitations set out in section 1.5 and the assumptions and qualifications contained throughout the Report.

The initial EMM (2015) cover concept design comprised a reduced permeability clay underlying a 2 m thick growth medium with clay assumed to be readily available by harvesting from the existing Old TSF cover with the balance sourced from the existing North Rock Quarry. These EMM (2015) assumptions were proven inaccurate by the GHD investigation with no evidence of clay found at the North Rock Quarry. GHD also hold concern associated with the feasibility of harvesting clay from the Old TSF through separation (screening) from underlying tailings (potentially acid forming) and overlying fill. This is considered to add additional and unnecessary risk to the project. Although sources of clay were identified in the GHD investigation, these sources are off the mining lease therefore CCPL hold concern with respect to obtaining necessary approvals to access the areas and with hauling material via public roads and through the operating mine site.

As such, GHD proposed a capping system incorporating a synthetic liner as an alternative to clay. A Bituminous Geomembrane Liner (BGM) was selected as a preferred option for the reduced permeability layer and adopted for cover modelling. BGM's are widely used within mining and heavy industry for mine waste storage, dams and landfill lining applications. Modelling and sensitivity analysis showed a minimal difference in net percolation through the BGM for either a 2 m and 1 m growth medium thickness and therefore a 1 m growth medium is proposed for the cover.

Based on the analysis of cover seepage rates over 100 years of climate data, there is no increase in environmental harm by the use of BGM as an alternate to a clay liner. The cover analysis shows the clay liner arrangement would in fact be at risk of reaching low saturation levels which could lead to shrinkage cracking resulting in liner damage (increased permeability). There is less environmental harm due to the reduction in disturbance by not developing a clay borrow offsite which would subsequently require rehabilitation. Rehabilitation objectives will still be achieved with the proposed BGM liner and the reduced 1m thick growth medium. The BGM will enable a lower risk project by offering a reduction in placement schedule over a clay liner, which will be a significant benefit particularly due to constructing the cover in the wetter months.

The intention of the closure landform on the Old TSF is to drain rainfall runoff to the existing eastern drain constructed in natural ground. The existing cover will be removed/shaped to provide a slope towards the eastern drain. The grade ranges from 0.5% to 1%, as shown on the drawings. The BGM liner will be placed onto the prepared subgrade and anchored into natural ground and the embankment at the perimeter of the Old TSF. Growth medium will be placed over the BGM in a single layer.

The existing access road will be reinstated on the final cover once complete. A 300 mm wearing course will be placed over the growth medium. Drains will be constructed on both sides of the access to direct drainage to the eastern drain. The existing culvert will be re-used at the eastern end of the access road to allow flows to pass under the road.

The existing spillway shall be widened to 5 m to safely pass the PMF event. Rip-Rap is required against the embankment or in areas where the spillway is not cut into rock, to prevent erosion.

The HLEP2 will also utilise a BGM liner overlayed by Growth Medium material. The existing surface will be shaped to a 1% grade, falling to the south, prior to placing the BGM and growth medium. A diversion drain will be constructed at the south of the HLEP2, which will direct flows to the west, reporting to an existing gully.

Glossary

Acronym	Definition
AEP	Annual Exceedance Probability
BGM	Bituminous Geomembrane
BoM	Bureau of Meteorology
CCM	Capricorn Copper Mine
CCPL	Capricorn Copper Pty Ltd
DEM	Digital Elevation Model
DES	Department of Environment and Science
GARD	Global Acid Rock Drainage
GSDM	Generalised Short Duration Method
HDPE	High Density Polyethylene
HLEP2	Heap Leach Evaporation Pad
IFD	Intensity Frequency Duration
INAP	International Network for Acid Prevention
LST / HST	Low Sulfur Tailings / High Sulfur Tailings
NAF	Non Acid Forming
NAG	Net Acid Generation
NAPP	Net Acid Production Potential
NWRD	North Waste Rock Dump
PAF	Potentially acid forming
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SWCC	Soil Water Characteristic Curve
TEP	Transitional Environmental Program
TSF	Tailings Storage Facility
VWC	Volumetric Water Content

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1. Introduction

1.1 Background information

Capricorn Copper Pty Ltd (CCPL) is subject to a Transitional Environmental Program MAN 17560 (TEP) which remains in force until 1 March 2019. CCPL previously engaged GHD Pty Ltd (GHD) to undertake a review of the technical feasibility of a range of rehabilitation strategies upon which CCPL could make a decision and progress through to implementation. The work corresponds to CCPL's obligations under TEP Items 5 and 16 (Old TSF) and Items 9 and 17 (HLEP2), generally as follows:

- Evaluation of the preferred rehabilitation strategy (1 March 2018).
- Completion of all capital programs for alternative strategies (if selected) (1 November 2018).
- Define and implement an appropriate landform and cover design (1 March 2019).

As per CCPL's submission to the Department of Environment and Science (DES) dated 31 March 2018, CCPL outlined their preference for implementation of Low Sulfur Tailings / High Sulfur Tailings (LST/HST) separation and LST capping of the Old TSF and clay based capping for the HLEP2. In CCPL's submission to DES it was noted that:

- The timing for implementation of LST/HST separation and capping of the Old TSF was tight and that clay-based capping would be substituted if necessary to meet the TEP requirements.
- CCPL would implement a risk management program to ensure conventional clay material is readily available.

CCPL has given further consideration to LST / HST separation and LST capping option for the Old TSF. It has been subsequently determined technically unfeasible to be implemented within the required timeframes for capital programs (1 November 2018) and execution (1 March 2019).

CCPL engaged GHD to progress site investigation works for clay material sourcing to mitigate this risk. Although sources of clay have been identified in the area, these sources are off lease therefore CCPL hold concern with respect to obtaining necessary approvals to access the areas and with hauling material via public roads / through the operating mine site.

As such, CCPL have also engaged GHD to undertake design of a capping system incorporating a synthetic liner as an alternative to clay. GHD's scope of works includes hydrological assessments inclusive of design of diversion drains and spillways for the final landform, cover modelling, groundwater modelling and final cover detailed design inclusive of technical specifications, design drawings and bill of quantities.

1.2 Purpose of this report

The purpose of this report is to outline the findings of the hydraulic assessment, liner options analysis and cover modelling and present the design for Old TSF and HLEP2 capping works.

1.3 Scope of works

The following outlines GHD's scope of works in development of this report:

- Review of liner options including Bituminous Geomembrane Liner (BGM) and High Density Polyethylene (HDPE) liner.
- Review of hydrology and hydraulics for Old TSF and HLEP2 including:
  - Assessment of the internal drainage infrastructure sizing for both facilities to the one percent Annual Exceedance Probability (1 % AEP).

  - Sizing the spillway of the Old TSF for the Probable Maximum Flood (PMF) event.
- Model two (2) scenarios for liner cover inclusive of one (1) and two (2) metre thick growth mediums.
- Develop design drawings as follows:
  - General Arrangement Plan.
  - Geotechnical Investigation Plan.
  - Old TSF Cover Layout.
  - Old TSF Spillway Plan.
  - HLEP2 Cover Layout.
  - Typical Sections and Details.
  - Old TSF Sump 6 Plan.
  - Old TSF Sump 6 Typical Section.
- GHD also completed a site inspection and geotechnical / geochemical investigation for potential cover growth medium sources. Results of this investigation are still pending some final laboratory testing and will be outlined within a separate report 4220321-REP-Geotechnical Investigation Report.

1.4 Assumptions

Technical assumptions made in liner assessments, hydrology and hydraulics review and cover modelling are outlined within respective sections of this report.

1.5 Statement of limitations

This report has been prepared by GHD for Capricorn Copper Pty Ltd and may only be used and relied on by Capricorn Copper Pty Ltd for the purpose agreed between GHD and the Capricorn Copper Pty Ltd as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Capricorn Copper Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.4 and throughout this report where specifically noted). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Capricorn Copper Pty Ltd and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the preliminary cost estimate/prices set out in section 6 of this report using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD and quotes provided by third party suppliers. The Cost

Estimate has been prepared for the purpose of options analysis and must not be used for any other purpose. The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the project can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. Current site arrangements

2.1 HLEP2

GHD (2018a) provides a summary of the geotechnical and geochemical conditions of the HLEP2. Key findings are summarised as follows:

- HLEP2 materials are currently above the water table (unsaturated). HLEP2 material is overlain by a HDPE liner (albeit requiring minor repair) which is likely to limit infiltration to the underlying material.
- HLEP2 materials may be considered an appropriate material for use as closure materials elsewhere given that they have already been leached, and contains relatively low sulfur and metals compared with other site materials (e.g. potential use as growth medium for Old TSF cover). Given the leaching that has already occurred, the HLEP2 poses a relatively low risk of further oxidation in their current state. If left insitu, the HDPE liner could be repaired and maintained to prevent infiltration until the HLEP2 is rehabilitated.

2.2 Old TSF

GHD (2018a) provides a summary of the geotechnical and geochemical conditions of the Old TSF. Key findings are summarised as follows:

- Old TSF tailings are geochemically classified as potentially acid forming (PAF) and not considered an appropriate material for use as closure materials elsewhere.
- Given the chemistry of Sump 6 is significantly elevated with respect to sulfate and metals, it is likely to be the result of oxidation (and potentially hydrolysis) of tailings within the Old TSF. That it is elevated even higher than observed elsewhere (including within the bores in the tailings), could suggest that:
  - Water quality is deteriorating along the flow path (i.e. not just shallow oxidation is occurring, but iron hydrolysis at low pH is occurring without the need for oxygen); and / or
  - Water reporting to the sump now still reflects quality associated with previous practices within and on the Old TSF (i.e. other contaminated catchment influences as discussed in GHD 2018a), due to travel times through the Old TSF which are anticipated to be in the order of years to decades.
- Ongoing management of Sump 6 is recommended as a priority for management of the seepage from the Old TSF as previously identified which is being undertaken by CCM. Surface water management should be maintained to prevent pooling and infiltration.
- Investigations undertaken in the current cover of the Old TSF indicate that the existing cover is variable and follows two distinct arrangements:
  - Gravelly Silt (~0.7m) growth medium overlying gravel with sand (~0.3m), or
  - Silty Gravel (~0.5m) growth medium overlying clay (~0.5m).

  The current arrangement of the cover system does not limit infiltration, this is most likely in the areas with the gravel layer. The areas which are clay lined do not have a capillary break layer which is not in line with modern cover design, a capillary break layer is required to limit infiltration through to the underlying tailings by forming an air entry value break.
- A more modern cover design with increased thickness of growth medium with a reduced permeability layer and capillary break e.g. EMM (2015) or alternatives is likely to decrease the net mass loading of contaminants to Sump 6 in the long term as a result of reduced rainfall infiltration. Given the chemistry of the Old TSF groundwater and tailings material and likely travel times within

the Old TSF, an inert cover system (non-acid forming) is not likely to result in significantly improved conditions within the Old TSF in the short to medium term (years to decades) or address potential seepage generated from other contaminated catchment influences. However, placement of the proposed cover will have a long term impact of reduction in contaminated outflow to Sump 6 due to reduced net percolation through the cover.

3. Regulatory requirements and guidance

3.1 Regulatory requirements

CCPL is subject to a TEP which remains in force until 1 March 2019. Key items relevant to this design report are as follows:

- Items 5 and 16 (Old TSF).
- Items 9 and 17 (HLEP2).

These are generally summarised as follows:

- Evaluation of preferred rehabilitation strategy (1 March 2018).
- Completion of all capital programs for alternative strategies (if selected) (1 November 2018).
- Define and implement an appropriated landform and cover design (1 March 2019).

3.2 DES project update meeting

A meeting was held with DES to provide an update on the progress of the Old TSF and HLEP2 rehabilitation works on 10th October 2018. A draft copy of this report was provided to DES for review prior to the meeting. Key outcomes relevant to the development of this report are identified in Table 1. Corresponding sections of this report where DES comments are addressed are also identified.

Table 1 DES commentary and where addressed

DES comment	Where addressed
Modelling should compare synthetic liner and clay system with respect to cover performance	Section 8
Risks with respect to synthetic liner and clay system should be identified and addressed inclusive of: erosion / underdrainage; surface erosion; vegetation coverage; long term landform erosion; material sources (i.e. clay source, haulage distances and routes including public safety), inclement weather, desiccation cracking, internal erosion, settlement, metals capillary rise, construction defects, root penetration, etc.)	Risk Assessment at Appendix B
Provide examples of synthetic liner usage.	Section 9

In summary, the proposed BGM liner provides the following advantages over the clay capping system:

- BGM liner performance is comparable to the clay system and provides significant constructability advantages.
- Rehabilitation objectives (i.e. reduced low permeability layer to limit cover seepage to underlying tailings/waste rock) are achievable through implementation of the BGM liner and reduced growth medium.
- There is a reduced risk to the program (approvals required for off lease clay source), public safety (significant haul distances via public road for clay source) and environment (new disturbance areas for clay source).

3.3 Design guidelines

The following standards and guidelines were referenced in the development of this report:

- ANCOLD; *Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure*, May 2012.
- The International Network for Acid Prevention (INAP), *Global Acid Rock Drainage (GARD) Guide*, 2009.

- Department of Environment and Science (DES), *Rehabilitation requirements for mining resource activities*.
- *Environmental Protection Act 1994*.

4. Design opportunities & constraints

4.1 Constraints

Various design constraints are applicable to the rehabilitation of the Old TSF and HLEP2. These include, but are not limited to:

- Sufficient volume of suitable (clay) material for capping:
  - Capping works require 78,300 m3 of low permeability clay to construct the EMM (2015) cover design on the Old TSF and HLEP2.
- Availability of suitable (clay) material for capping onsite (refer section 5):
  - EMM (2015) assumed clay would be sourced by harvesting from the existing Old TSF cover with the balance from the North Rock Quarry.
  - GHD drilling and test pitting investigations (January 2018 and August 2018) identified sufficient sources of clay in the area (i.e. airport borrow) however, these are off lease and do not align with EMM (2015) assumptions.
  - Existing Old TSF clay thickness is variable in depth / properties and not present in some areas. The required cut depth to reach the proposed design subgrade for the liner varies. Based on existing clay variability and subgrade cut depths, this raises issues associated with harvesting existing clay through separation (screening) from underlying tailings (potentially acid forming) and overlying fill which will significantly impact constructability and program.
  - Existing North Rock Quarry showed gravel over shallow bedrock and was considered unlikely to provide any significant volume of suitable cover material in particular the balance of clay per EMM (2015) assumptions.
  - No land holder agreements or approvals are in place for GHD identified clay sources (i.e. airport borrow). Matters of State Interest identified in the area include Waterways for Waterway Barrier Works and Regulated Vegetation (Category B) whereby there will be significant impacts to the program.
- NWRD (cover growth medium source) access road suitability:
  - Existing road to the north of the NWRD is steep and the current width would necessitate a single lane, with no vehicle passing.
  - High traffic flow if redirected via alternative routes (i.e. mine haul roads) poses additional transport risks.

4.2 Opportunities

The following opportunities are currently evident for the rehabilitation works:

- Use of bituminous geosynthetic liner (BGM) from Coletanche (or equivalent):
  - Material type offers benefits in terms of constructability and performance, i.e. not severely impacted by inclement weather.
  - Availability of stock (Brisbane) could result in shorter lead times, beneficial to project program.
  - Adopting BGM opposed to clay does not require offsite disturbance and subsequent rehabilitation of clay borrow.
- Growth medium alternate sources: Gilberts Quarry (HLEP2), Sump 6 Ridge (Old TSF) and Magazine Road Quarry (Old TSF). The locations are within the mining lease.

5. Summary of geotechnical investigation

A geotechnical site investigation was undertaken by GHD at the Capricorn Copper Mine Site between 20th and 23rd August 2018. A total of 39 test pits were excavated using a 20t excavator. The intention of the investigation was to identify suitable materials for construction of the EMM (2015) cover including bridging layer, clay layer and growth medium and to confirm EMM (2015) assumptions with respect to the availability of clay material within the existing Old TSF cover and North Rock Quarry.

The following on mine lease areas were investigated:

- Sump 6: 4 Test Pits to investigate existing sub-surface conditions.
- Old TSF: 2 Test Pits to further investigate sub-surface conditions and collect samples for laboratory analysis. This supplemented the previous drilling and test pitting program completed by GHD in January 2018.
- North Rock Quarry: 2 Test Pits to identify suitable materials for construction of the cover and confirm EMM (2015) assumptions with respect to sourcing clay material.
- North Waste Rock Dump (NWRD): 6 Test Pits to determine if suitable material is available for growth medium.

The following off mine lease areas were investigated:

- Airport Borrow Area: 25 Test pits to identify potential clay borrow areas subsequent to EMM (2015) assumption of North Rock Quarry being clay source being proven inaccurate.

5.1 EMM (2015) cover assumptions and clay availability

As outlined within section 4 of this report, EMM (2015) assumptions with respect to the availability of sourcing the required balance of clay material from the North Rock Quarry were proven inaccurate by the GHD investigation. There are also significant concerns associated with the feasibility of harvesting clay from the Old TSF through separation (screening) from underlying tailings (potentially acid forming) and overlying fill. This is considered to result in additional and unnecessary constructability and environmental risks.

GHD's investigation identified a large area of clay off the mine lease near the airport borrow area to the east of Gunpowder road. Clay was typically found to be 1m deep overlying Dolerite. Based on the area investigated, it is estimated that approximately 200,000 m^3 would be available from this area. Geotechnical testing would be required to confirm the suitability of this material. The source of this material is off lease and therefore CCPL have concern in respect to obtaining necessary approvals to access the areas and hauling material via public roads in excess of 10 km away from the Old TSF and through the operating mine site.

These concerns prompted a need to review of the reduced permeability layer material selection and adoption of an alternate as discussed in section 6.

5.2 Growth medium

The test pits undertaken by GHD in the NWRD identified a suitable resource for the growth medium. Geotechnical and geochemical testing was undertaken to determine suitability. Geochemical results indicated that the material would be suitable as a cover growth medium. Based on the test pit investigation it is estimated that there is at least 350,000 m^3 of material available which is well in excess of estimated quantity required.

CCPL completed further test pit investigations on the 2nd October 2018. A total of 2 test pits were excavated using a 20t excavator with additional 4 locations sampled from the face of existing on mine lease borrow areas summarised as follows:

- Sump 6 Ridge: 2 by surface samples from existing borrow face to determine if suitable material is available for growth medium
- Gilberts Quarry: 2 by surface samples from existing borrow face to determine if suitable material is available for growth medium
- Old Magazine Road Quarry: 2 by Test Pits to investigate sub-surface conditions and collect samples to determine if suitable material is available for growth medium.

The purpose of this additional investigation was to identify alternative sources of growth medium and to address NWRD constraints (i.e. access road suitability and interfaces with operational mine vehicles).

Initial geochemical results indicated that samples from both Gilberts Quarry and Old Magazine Road Quarry would be suitable as a cover growth medium, with both areas reporting as non-acid forming and having the majority of total elements within range of average crustal abundance. Sump 6 Ridge was found to be unsuitable as a cover growth medium and reported as potentially acid forming. Further analysis is being completed on samples that are potentially suitable growth medium to determine the potential leachability, the acid neutralising capacity and the reactivity and estimated reaction time. These results are required to confirm the initial findings and will be outlined within the associated Geotechnical Investigation Report.

Based on this information, there are a number of on mine lease sources of growth medium available to CCPL which are considered geochemically and geotechnical suitable.

6. Liner options

6.1 Overview

Following assessment of the cover system design, GHD have proposed employing a Bituminous Geomembrane Liner (BGM) to limit infiltration at both the Old TSF and HLEP2. Such liners are used broadly across the industry for lining mine waste storages, particularly where there is a lack of readily available low permeability clay. GHD have obtained quotes for the supply of a suitable BGM for the capping system (refer GHD letter *Comparison of BGM Options*, 2018). In response, CCPL have obtained independent quotes for supply and install of High Density Polyethylene (HDPE) liner.

This section compares both liner types and suppliers, with recommendations provided on preferred option.

6.2 Comparison of liner types

BGM's have been recommended by two suppliers, Coletanche and Geotas Pty Ltd (Geotas). The BGM's specification are generally similar and will meet the design requirements for the capping system. Application of a HDPE liner has also been considered but would necessitate installation of a Bidim A74 Geotextile overlay to meet design requirements, and carries additional installation complexity. The HDPE and BGM are detailed in the following sub-sections.

6.2.1 HDPE

A cover option utilising a HDPE liner was investigated by CCPL. While a HDPE liner would be suitable for the proposed, there are a number of advantages of using a BGM over HDPE including cost. These advantages were detailed in the letter *"Justification of Liner – BGM vs HDPE"* (GHD, 2018d), and are presented in Table 2.

Table 2 Comparison of geomembranes

Parameter	BGM*	HDPE & Bidim A74 Geotextile overlay	Comment
Design life	300-1,000 yrs	No studies for long term design life	
Liner thickness	4 mm	2 mm	BGM less likely to be damaged during installation; more appropriate for rougher subgrades.
Permeability	6x10^{-14} m/s	Assumed to be impermeable, leakage governed by defects	Based on manufacturers testing.
Required no. layers	1	2 (1 x HDPE, 1 x Bidim)	Only 1 layer for BGM; less complex install & less time-consuming. HDPE may need a geotextile layer above and below to provide adequate protection,

Parameter	BGM*	HDPE & Bidim A74 Geotextile overlay	Comment
			increasing the cost and timeframe for install.
Joining methodology	Heating and Rolling	Electrowelding	Joining of BGM is simpler process using less equipment. A simple gas torch is used to melt the bitumen and the joint is rolled to seal the join.
Environmental for install	Easy to peg down/fill over in high wind. Less affecting in hot conditions.	Progressive covering may be required. HDPE can expand/shrink in hot/cold conditions.	BGM has less subgrade preparation, and more accommodating to weather events / Mount Isa climate.

***BGM is based on Coletanche ES2*

Based on the information in Table 2, it was recommended that a BGM was adopted for the cover design.

6.2.2 Bituminous geomembranes

The technical specifications of the BGM's are presented in Table 3.

The major difference between the two products is the size of the rolls. The Coletanche ES2 is produced on a wider roll, which results in less seaming required overall, providing a reduction in installation time.

Table 3 BGM characteristics

BGM	Coletanche ES2	Teranap 431 TP
Thickness	4	4.1
Length (m, per roll)	80	80
Width (m, per roll)	5.1	4
Area (per roll)	408	320
Resistance to Tearing (N)	825 x 700	940 x 750
Max Tensile Strength (kN/m)	27 x 24	29 x 21
Elongation (%)	60 x 60	55 x 60
Static Puncture (N)	530	550
Permeability (m/s)	$6x10^{-14}$	$2x10^{-14}$

6.3 Suppliers

6.3.1 Geotas

Geotas are a Tasmanian based wholesaler of civil products. Geotas are the national distributor of Siplast products (manufacturer of Teranap). Geotas have provided a quote for supply of 116,640 m^2 (103,800 m^2 + 13% wastage). This would be sufficient for the Old TSF, additional product would be required for the HLEP2.

Geotas have provided an estimated lead time of 11 weeks, due to the product being manufactured in France.

6.3.2 Coletanche

Coletanche manufacture BGM products in France and distribute the products within the Australia. Coletanche have provided a quote for supply of 108,120 m2 of Coletanche ES2 (103,800 m2 + 4.2% wastage). This is sufficient for the Old TSF only. Coletanche have quoted a lower wastage rate as they have approximately 50,000 m2 of various BGM grades in stock in Brisbane which could be dispatched at short notice if required to meet additional requirements. The additional material could be increased if required.

The lead time for the Coletanche is 11 weeks. However Coletanche stock in Brisbane could be utilised to commence construction prior to the complete order arriving at site.

Coletanche have an estimated installation rate of 10,000 m2 per day. This higher than the installation rate provided by Geotas for two reasons:

- Wider Rolls, requiring less seaming.
- Use of a hydraulic deployment beam designed for Coletanche products.

The hydraulic beam is stated to double the rate of installation and is expected that suitable installation contractors would have these beams for installation, alternatively the beam could likely be on sold to recover some costs post installation.

6.4 Recommendation

The products are relatively comparable in terms of technical specification. It is recommended that CCPL procure the BGM from Coletanche for the following reasons:

- Higher installation rate, will reduce construction timeframes. This assuming the installation contractor uses the Coletanche hydraulic deployment beam at no additional cost to CCM.
- If the installation of the two products was tendered to installation contractors, it is expected that the total cost of Coletanche installation would be lower due to the shorter installation timeframe.
- Wider rolls resulting in less seaming, this will minimise the potential for delays due to seaming issues or the need to re-seam if defects are found during QA processes.
- Available stock in Brisbane reduces the risk of being short of material and could also be used to get the installation underway earlier.

7. Hydrology and hydraulics

7.1 Overview

This section outlines the specific methodology applied and results of the hydrology and hydraulic assessment of the Old TSF and the HLEP2 cover landforms. The purpose of this assessment was to determine the internal drainage sizing for both facilities to the one percent Annual Exceedance Probability (1 % AEP), as well as sizing the spillway of the Old TSF for the Probable Maximum Flood (PMF) event. The section of the PMF event for the closure spillway is consistent with ANCOLD 2012.

7.2 Methodology

Rainfall data for all AEPs down to the 1 % event was obtained from the Bureau of Meteorology (BoM) as per the Australian Rainfall and Runoff (ARR, 2016) guidelines, i.e. the latest Intensity: Frequency Duration (IFD) data and the associated ten temporal patterns for the site were obtained from the BoM website. To determine the PMF, the Probable Maximum Precipitation (PMP) was derived using the Generalised Short Duration Method (GSDM), as per the ARR (2016) guidelines. The following parameters were determined in the derivation of the PMF:

- Smooth Factor = 1
- Rough Factor = 0
- Elevation Adjustment = 0
- EAF Factor = 1
- GSDM MAF Factor = 1

The design rainfall used in this study is presented in Table 4.

Table 4 Design rainfall data (mm) – Capricorn Copper Mine

Duration	Annual Exceedance Probability							PMP
	63.2%	50%	20%	10%	5%	2%	1%	GSDM
5 min	8.32	9.58	13.3	15.7	17.9	20.5	22.5	
10 min	13.9	16.0	22.2	26.2	30.0	34.9	38.5	
15 min	18.0	20.6	28.6	33.8	38.8	45.1	49.9	250
20 min	21.1	24.2	33.7	39.8	45.6	53.0	58.5	
25 min	23.7	27.2	37.8	44.6	51.1	59.3	65.3	
30 min	25.8	29.6	41.2	48.6	55.6	64.5	70.9	360
45 min	30.5	35.1	48.9	57.7	65.9	76.1	83.5	400
1 hour	33.8	39.0	54.4	64.2	73.3	84.5	92.5	570
1.5 hour	38.4	44.3	62.0	73.2	83.6	96.4	106	640
2 hour	41.5	48.0	67.4	79.7	91.1	105	115	710
3 hour	45.8	53.1	74.9	88.9	102	118	131	810
4 hour								900
5 hour								960
6 hour	53.4	62.0	88.6	106	123	146	163	1,000

7.2.1 Old TSF

The design flood hydrology and the sizing of the internal stormwater channels were simulated using the DRAINS software package. This software made use of the latest Australian Rainfall and Runoff (ARR, 2016) guidelines on climate, losses, temporal patterns, etc. Two open channel drains were identified to control stormwater within the site, namely the Cover Drain (which is proposed to drain the landform cover on either side of the access road) and the Diversion Drain, which collects flow from various contributing locations (including the landform) within the Old TSF site and conveys the stormwater to the spillway. The internal drainage area contributing to the Cover Drain was 103,168 m^2, whilst the entire site area contributing to the Diversion Drain and the spillway was 172,245 m^2. The Cover Drain runs from west to east across the landform cover collecting flows draining to this low point. The landform cover is graded at a one percent slope into the Cover Drain, this slope is intended to promote surface drainage but limit potential for cover erosion. The Cover Drain meets the Diversion Drain, which flows in a south to north direction near to the eastern boundary of the site. This drain exits the site via the spillway in the north-east corner. Figure 1 provides a layout of the drainage structures, for reference purposes only.

Figure 1 Old TSF drainage structure's layout (Google Earth, 2018)

The XP-RAFTS (RAFTS) software was used to simulate the PMF for the impounded area and, thus, sized the spillway capacity for the PMF event to pass without overtopping the surrounding embankment. The Initial Loss: Continuing Loss approach was used in the design flood simulation, with these values being selected as 0 mm and 1 mm, respectively. In order to estimate the flood routing component of the spillway and landform, a Depth: Storage curve (see Figure 2) was generated from the proposed cover profile.

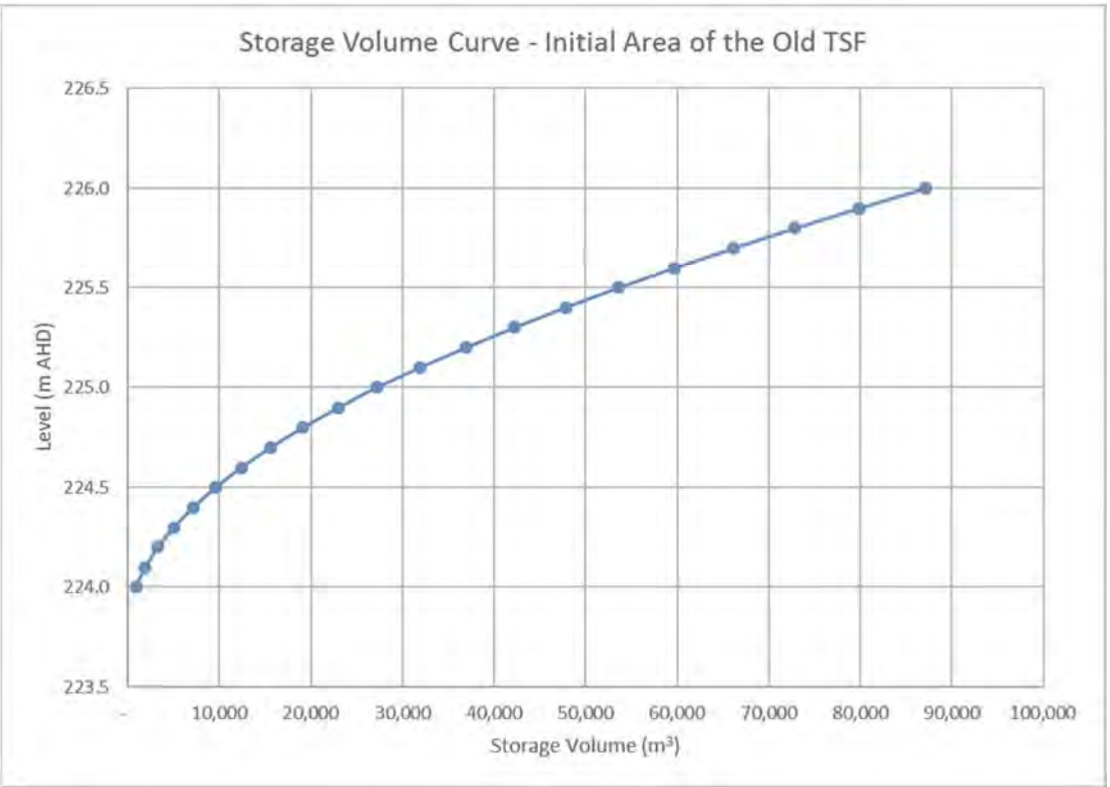

Figure 2 Area of the Old TSF storage: volume curve

Table 5 provides typical site information used in the hydraulic assessment of the site in this study.

Table 5 Input values used in the hydraulic assessment

Parameter	Value
Total Old TSF Area	172,245 m^2
Landform Cover Area	103,168 m^2
Initial Area Lowest Embankment Level	226 m AHD
Spillway Crest Level	219 m AHD
Spillway Area Lowest Embankment Level	222 m AHD
Cover Drain Slope	1 %
Diversion Drain Slope	1.50 %

7.2.2 HLEP2

Similarly to the process followed for the Old TSF, the internal drainage for the HLEP2 site included the simulation of the on-site stormwater in DRAINS to determine the stormwater channel capacity to convey flows up to the 1 % AEP event off site in a controlled manner. As the site is relatively uniform in its dimensions, the landform is proposed to be graded to drain towards the southern side of the facility at a 1% slope with flows removed to the existing drainage line in natural ground towards Mill Creek.

7.3 Results

7.3.1 Old TSF internal drainage

Based on the modelling undertaken in DRAINS, using the BoM design rainfall data, Figure 3 provides the design peak discharge results for the Cover Drain, whilst Figure 4 provides the corresponding results for the Diversion Drain. Figure 3 shows that the peak design flood for the 1 % AEP for the

Cover Drain was simulated to be 1.91 m^3/s, which was derived from Storm 2 in the 30 min critical duration event. Figure 4 shows that the peak design flood for the 1 % AEP for the Diversion Drain was simulated to be 2.92 m^3/s, which was derived from Storm 7 in the 30 min critical duration event. Using these values, the drains as shown on the drawings within Appendix A were sized to include a minimum 300 mm freeboard allowance.

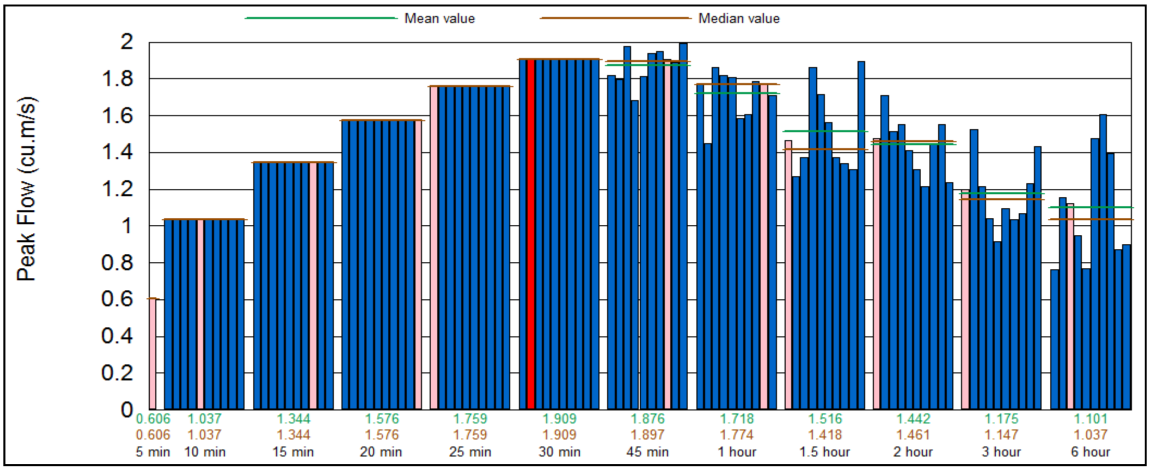

Figure 3 Design flood estimation for the cover drain

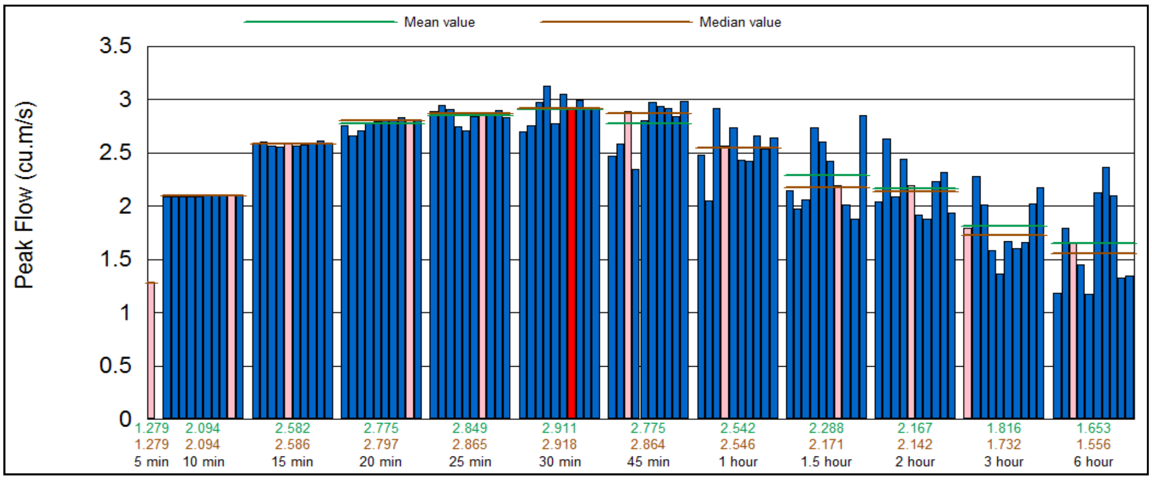

Figure 4 Design flood estimation for the diversion drain

The channel velocities for the two drains were calculated to be 1.0 m/s for the Cover Drain and 1.4 m/s for the Diversion Drain. As these velocities are below 1.5 m/s, a dense short grass/vegetation cover would be sufficient to prevent scour of the channels, however establishment of cover vegetation will take some time coarser gravels will be used in the cover along these drains. A formal rock lined section of the Cover Drain will be adopted to prevent erosion where it drops at a steeper grade of 1:10 to the Diversion Drain. In the case of the Diversion Drain, the majority of this channel is on rock and, as such, won't require any form of lining.

7.3.2 Old TSF spillway

The total peak flow for the PMF event was 36.1 m^3/s, for the 1 hour critical event shown in Figure 5. Routing simulated with the Diversion Drain and basin characteristics, with the resultant water levels from the simulations presented in Figure 6. In order for the system to be fully functional under PMF conditions (i.e. not overtop the adjacent embankment), the existing spillway base width needs to be increased to five metres (5 m).

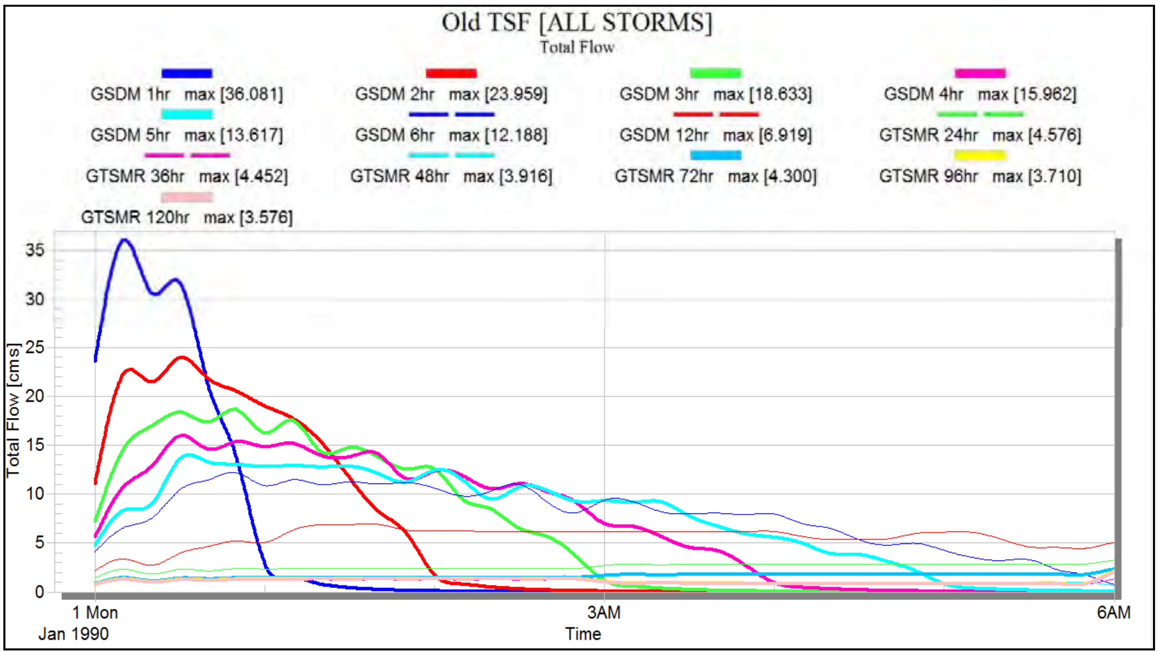

Figure 5 Total PMF flow rate for the Old TSF site

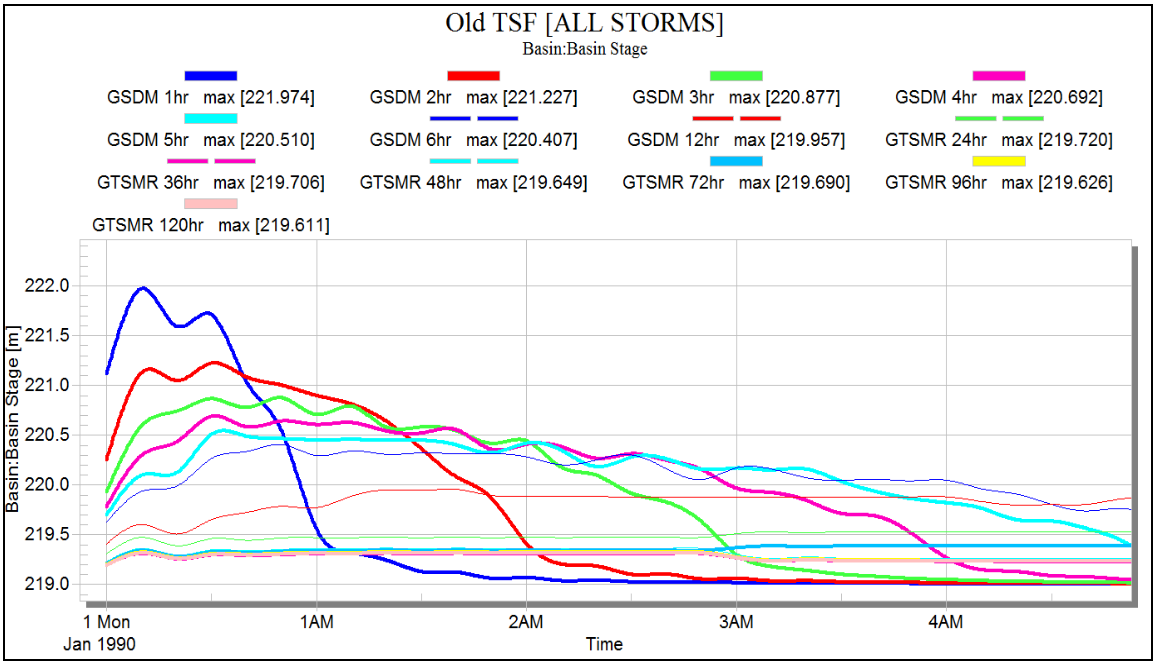

Figure 6 Spillway area water levels under the PMF event conditions

7.3.3 HLEP2 internal drainage

Based on the modelling undertaken in DRAINS, using the BoM design rainfall data, Figure 7 provides the design peak discharge results for the HLEP2 Drain. Figure 7 shows that the peak design flood for the 1 % AEP for the Cover Drain was simulated to be 0.4 m^3/s, which was derived from Storm 5 in the 20 min critical duration event.

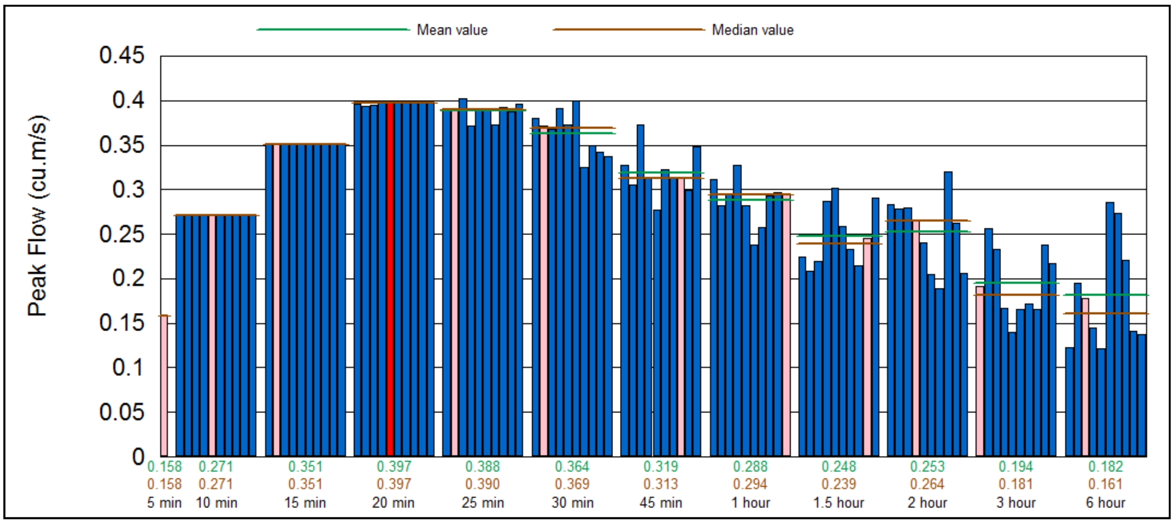

Figure 7 Design flood estimation for the HLEP2 drain

The channel velocities for the drain were simulated to be 1.2 m/s for the HLEP2 Drain. As these velocities are below 1.5 m/s, which is suitable for a dense short grass/vegetation cover to prevent scour of the channel, however the granular cover material will be sufficient to prevent erosion in the short term.

8. Cover design and modelling

8.1 Overview

The proposed cover design comprises using a BGM overlying the tailings to significantly minimize infiltration to the tailings. A growth medium layer will be constructed above the BGM to promote revegetation of the area and provide protection to the BGM.

One dimensional models were developed in *SVFlux*, a finite element software package produced by SoilVision to model unsaturated soils. Two models were developed for the BGM cover and an additional model using the EMM (2015) design utilising a reduced permeability layer to limit infiltration.

8.2 Model parameters

8.2.1 BGM model parameters

The model parameters adopted for the BGM are presented in Table 6, including the source of the data. There are two main material parameters adopted in each model, the growth medium and tailings. It is expected that the actual saturated permeability of the growth medium may be lower than adopted and will be updated once results are available.

Table 6 BGM cover material parameters

Parameter	Tailings	Source	Growth Medium	Source
Saturated VWC	0.491	70th Percentile - GHD, 2018	0.3	Average of EMM (2015) results
Specific Gravity (t/m3)	2.76	75th Percentile - GHD, 2018	2.8	Assumed (TBC)
Saturated Permeability	1 x 10 $^{-8}$ m/s	GHD, 2018	1 x 10 $^{-5}$ m/s	Assumed (TBC)

The Soil Water Characteristic Curve (SWCC) for each of the materials in the model are a critical parameter for unsaturated soil modelling. The SWCC represents the relationship between pore water and matric suction.

The SWCC for the tailings has been determined based on laboratory testing undertaken in January 2018 by GHD (2018). The adopted SWCC for the model is a best fit between the five samples, and represents approximately the 70th Percentile SWCC, shown in Figure 8. The five SWCC curves from laboratory testing are presented in Figure 9, with the average and 70th percentile curves.

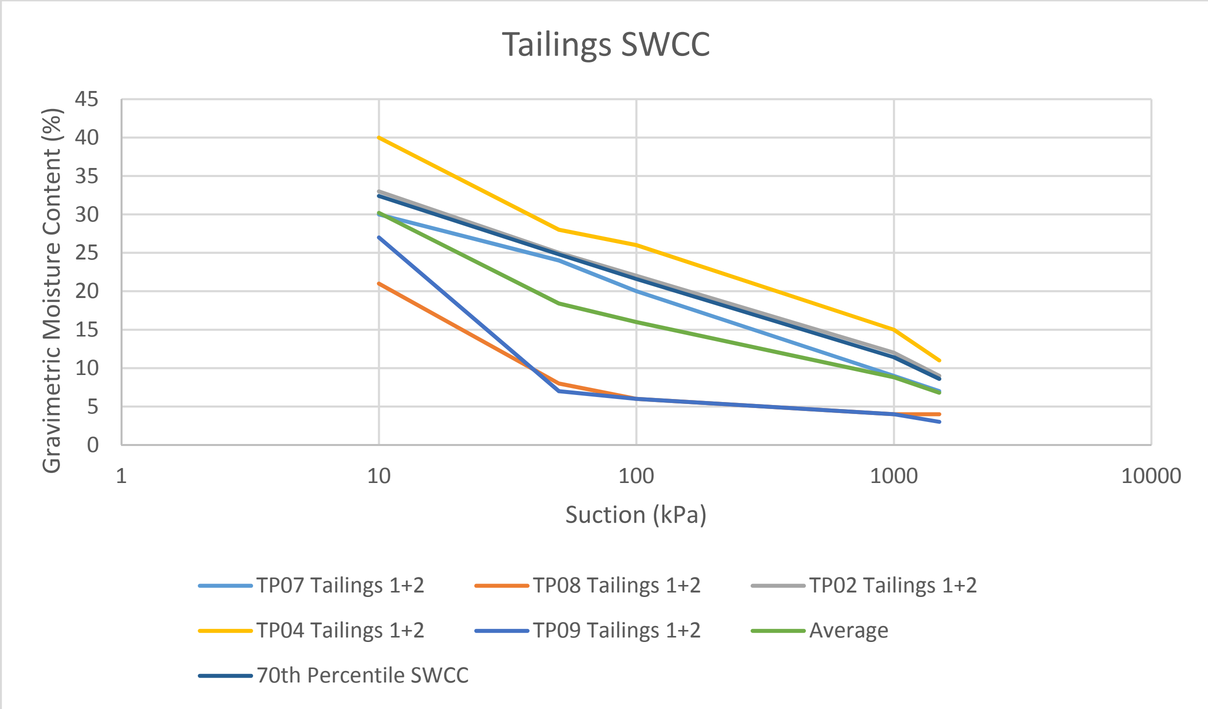

Figure 8 Tailings SWCC results

The SWCC for the growth medium has been adopted from the SWCC's presented in the EMM (2015) report, for various growth mediums. An average SWCC has been adopted, and will be updated when laboratory data for the proposed material is available.

The adopted SWCC curves are presented in Figure 9.

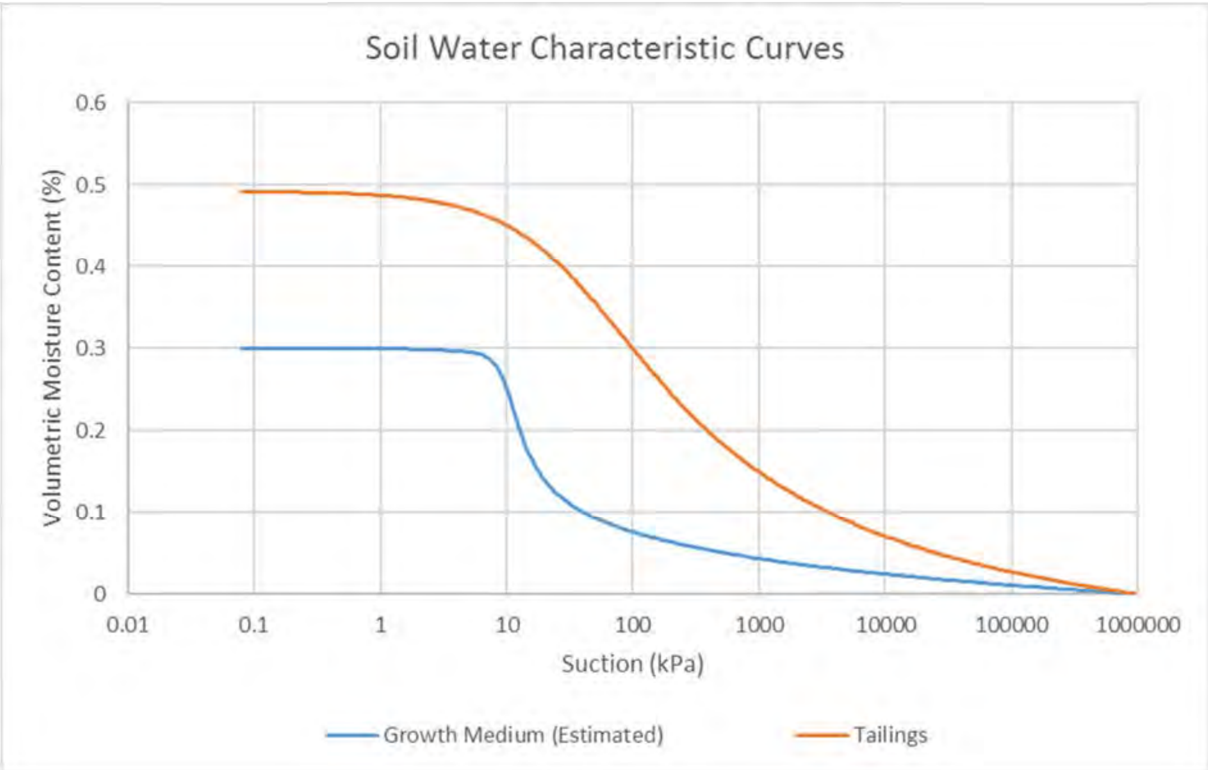

Figure 9 SWCC properties

The unsaturated permeability of the material is the relationship between permeability and suction as the saturation (VWC) of a material changes. SoilVision software has been used to determine the unsaturated permeability curves of the material using a Modified Campbell Estimation, the resultant curves are shown in Figure 10.

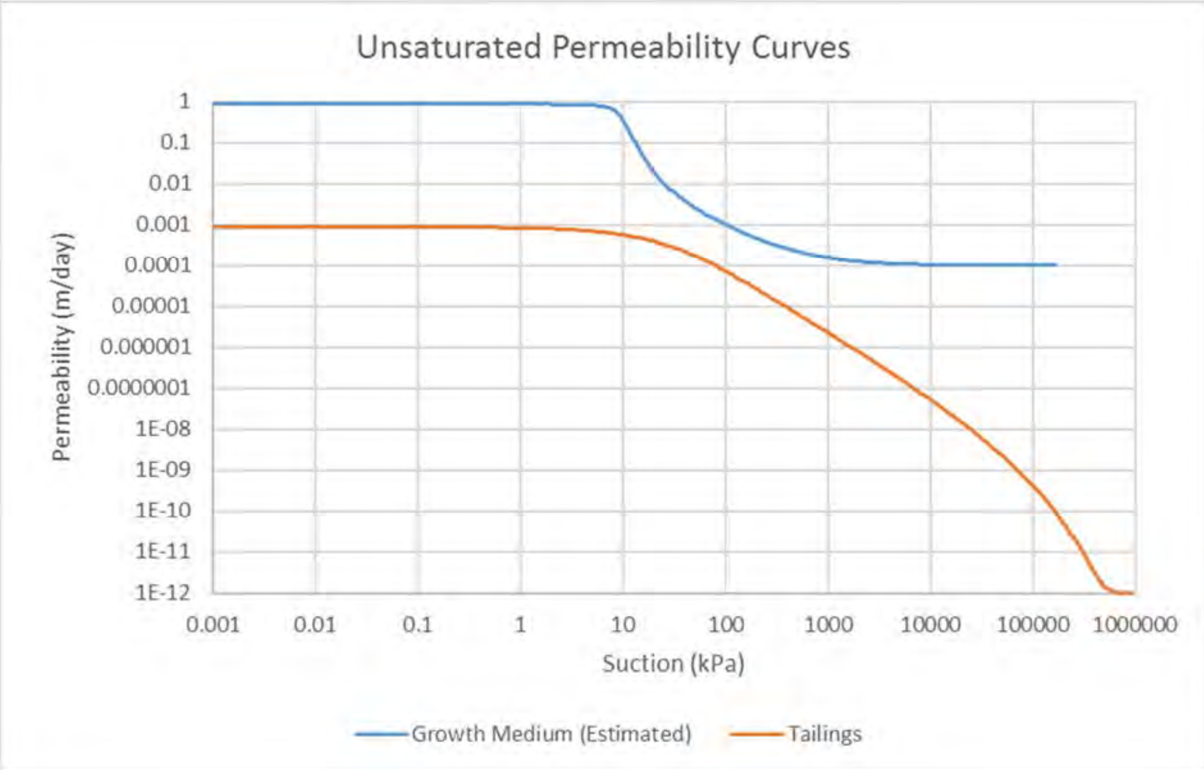

Figure 10 Unsaturated permeability curves.

8.2.2 Reduced permeability layer cover

In addition to the material properties adopted for the BGM, two additional materials were required for the model of the EMM (2015) design:

- Clay for the reduced permeability layer.
- Capillary Break.

The parameters for these materials were detailed in the EMM (2015) report and have been adopted for the cover modelling.

Parameter	RPL	Capillary Break	Source
Saturated VWC	0.345	0.37	EMM (2015)
Specific Gravity (t/m^3)	2.96	2.8	EMM (2015)
Saturated Permeability	2×10^{-9} m/s	1×10^{-3} m/s	EMM (2015)

The Soil Water Characteristic Curves and Unsaturated Permeability Curves for the RPL and Capillary Break material have been calculated from data available within the EMM (2015) report and are presented in Figure 11 and Figure 12

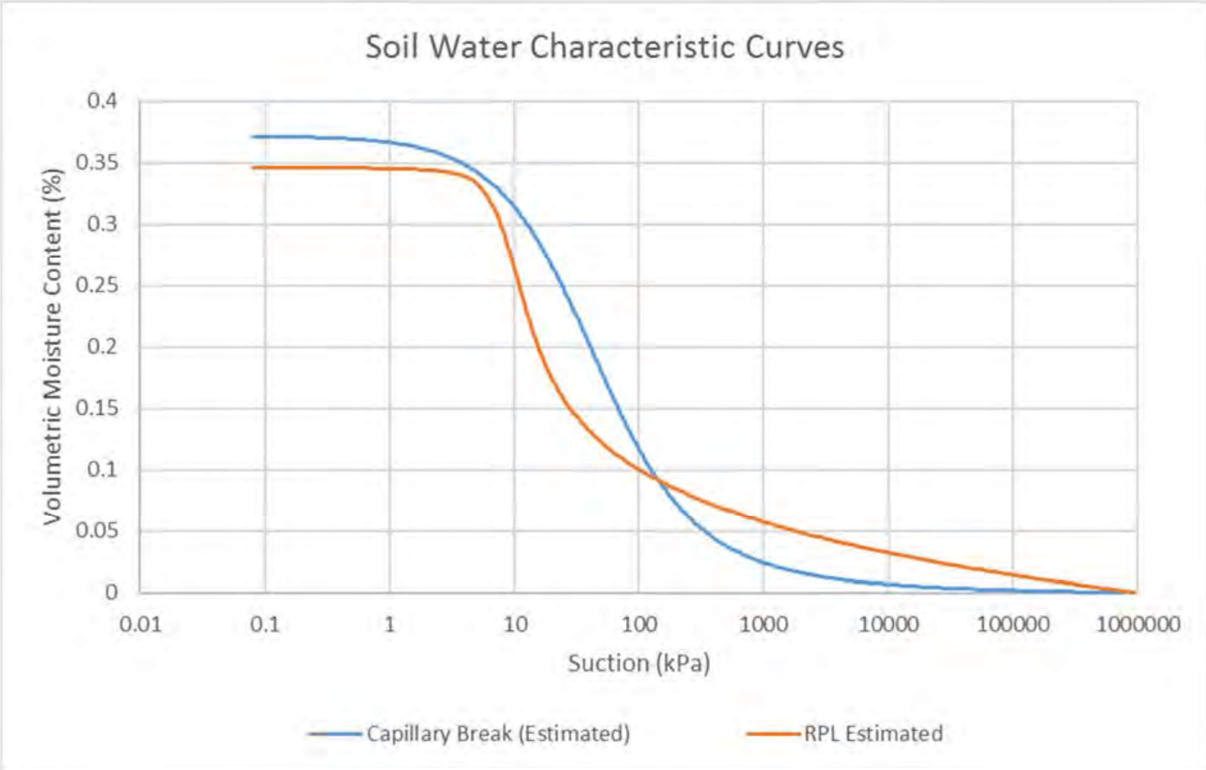

Figure 11 RPL and capillary break SWCC

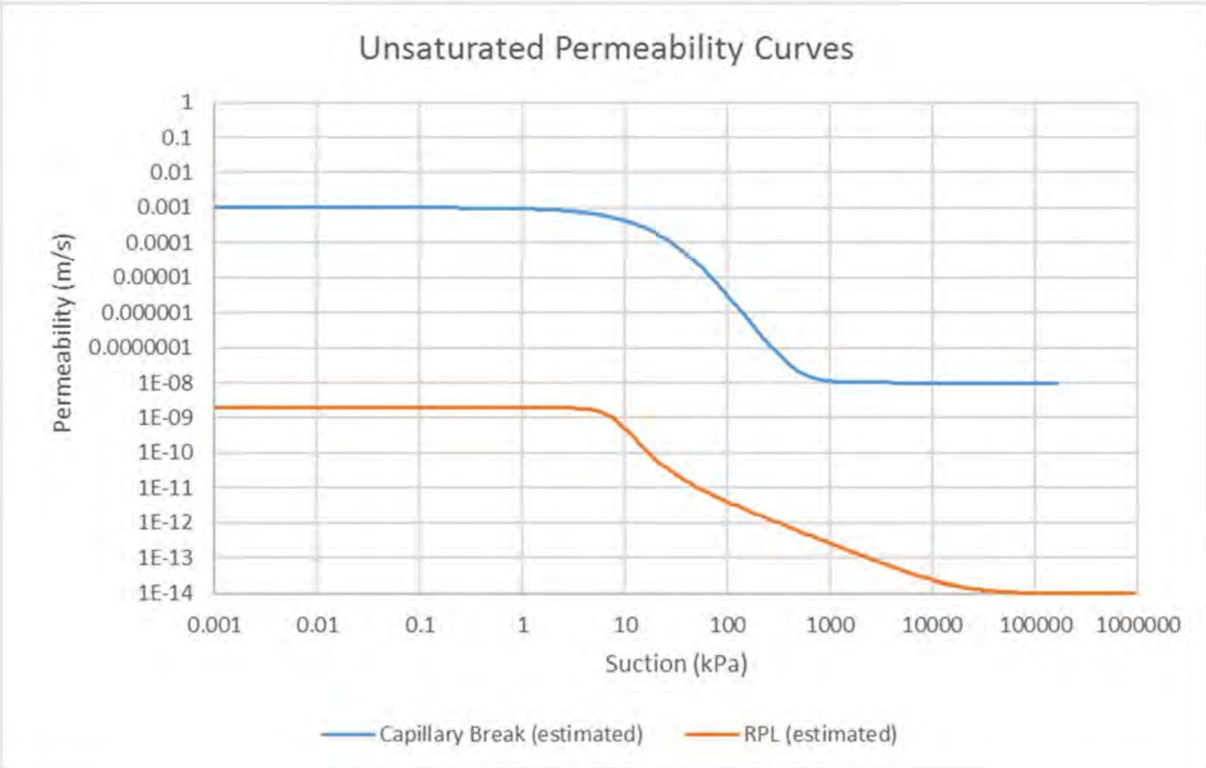

Figure 12 RPL and capillary break unsaturated permeability curve

8.3 Model set-up

8.3.1 Model geometry

Three 1D models have been set up to compare two cover arrangements using the arrangement proposed by EMM (2015) with RPL and a bituminous geomembrane liner, with varying Growth Medium Thicknesses. The geometry is detailed in Table 7 for the BGM liner model. The geometry for the clay cover is presented in Table 8.

Table 7 BGM liner model geometry

Material	2 m Cover	1 m Cover
Tailings	RL183-RL223 m	RL183-RL223 m
Liner	RL223m	RL223 m
Growth Medium	RL223-RL225 m	RL223-RL224 m

Table 8 RPL model geometry

Material	RPL Cover
Tailings	RL183-RL223 m
Capillary Break	RL223 – RL223.6m
RPL	RL223.6-RL224.1 m
Growth Medium	RL224.1-RL226.1m

8.3.2 Boundary conditions

The following boundary conditions have been applied to each of the models:

- Climate Boundary at the surface of the growth medium, detailed in section 8.3.4.
- Geomembrane at the boundary between the growth medium and tailings (RL223m), note not included in the RPL cover model.
- The following properties were adopted for the Geomembrane based on the selected liner manufacturers test data:
  - Thickness = 4 mm;
  - Hydraulic Conductivity = 2 x 10^{-14} m/s
- Unit gradient boundary applied at the base of the model – this allows flow out of the model where there is positive pore pressure.

8.3.3 Initial conditions

An initial condition has been applied to the model to simulate the current groundwater levels. The level has been based on the average level in the groundwater monitoring bores. The adopted initial groundwater level is RL212.1 m.

8.3.4 Climate

Model of the Climate Conditions has been developed for the Capricorn Copper Mine site based on the Bureau of Meteorology SILO data (https://legacy.longpaddock.qld.gov.au/silo/). A 100 year data set was obtained, from January 1918 to January 2018. The following data was obtained and imported into SVFlux:

- Daily Rainfall (Assumed to start at 6 am and finish at 6 pm when raining)
- Potential Evaporation
- Average Daily Temperature
- Minimum and Maximum Relative Humidity.

Daily Rainfall is plotted in Figure 13. SVFlux calculates runoff based on the rainfall and permeability of materials.

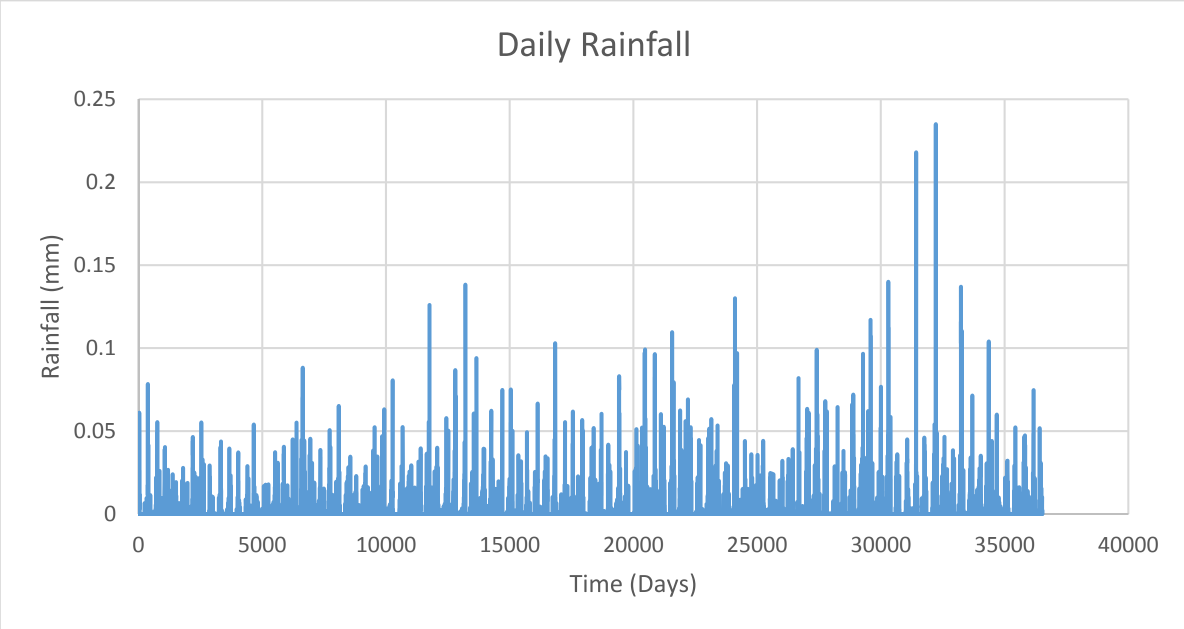

Figure 13 Daily rainfall

SVFlux calculates actual evaporation using the Modified Wilson Limiting Equation (1997) using the Potential Evaporation, Temperature and Relative Humidity.

Transpiration from vegetation is calculated within SVFlux, based on the following information:

- Leaf Area Index of "Good" (Ranges from "Poor" to "Excellent").
- Growing Season from October to April.
- Root Depth of 0.4 m.
- Transpiration applied from start of model (in reality this may take 5 yrs post seeding to develop to full parameters, however noted this will have minimal impact in the cover thickness comparison).

8.3.5 Model outputs

The following outputs have been incorporated into the model:

Climate

An output of the results from the Climate Boundary Condition is provided with cumulative totals for each climate parameter with time.

Flux sections

The flux sections have been applied to the models to determine the cumulative volume of flux at each location. Flux sections were applied at the following sections/boundaries in the BGM models:

- Surface of the Growth Medium RL224 & 225 m.
- Boundary of the Liner and Tailings (BGM) RL223 m (i.e. represents flux through liner).
- Initial Groundwater level RL212.1 m.

The following flux sections were used in the RPL cover:

- Surface of the Growth Medium.
- Top of the RPL.

- Bottom of the RPL.
- Bottom of the Capillary Break Layer.
- Initial Groundwater Level.

Saturation

Saturation is reported from two points in each of the models:

- Centre of the Growth Medium Layer.
- In the tailings, 1 m below the BGM or Capillary Break.

The following points are included in the RPL model:

- RPL Saturation.
- Capillary Break Saturation.

8.4 Model results

The model results for all models are detailed in this section.

2 m growth medium cover

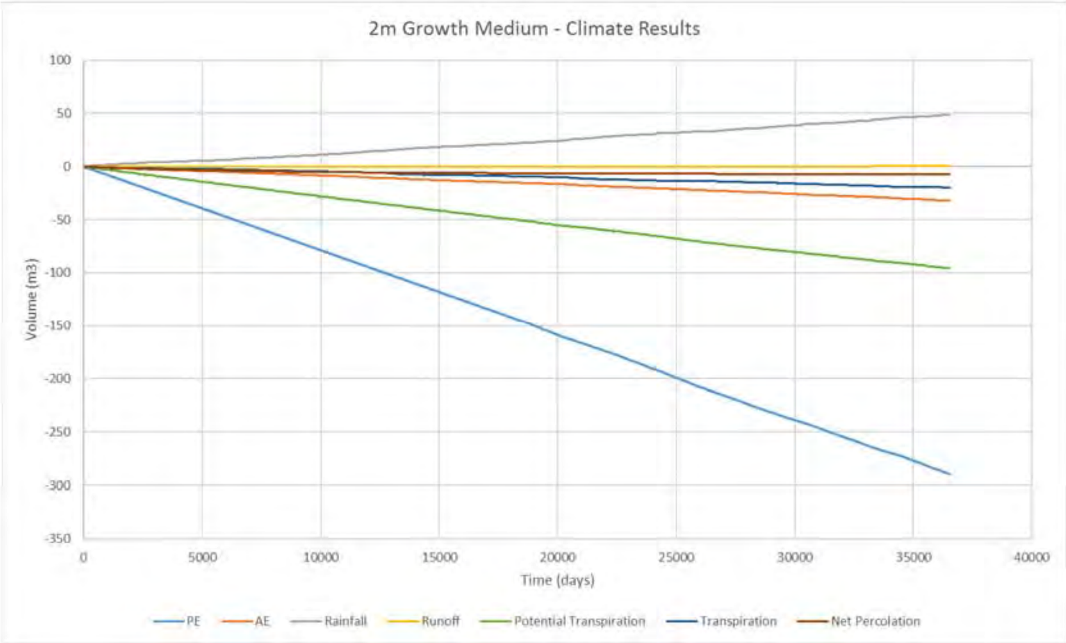

Figure 14 Climate results

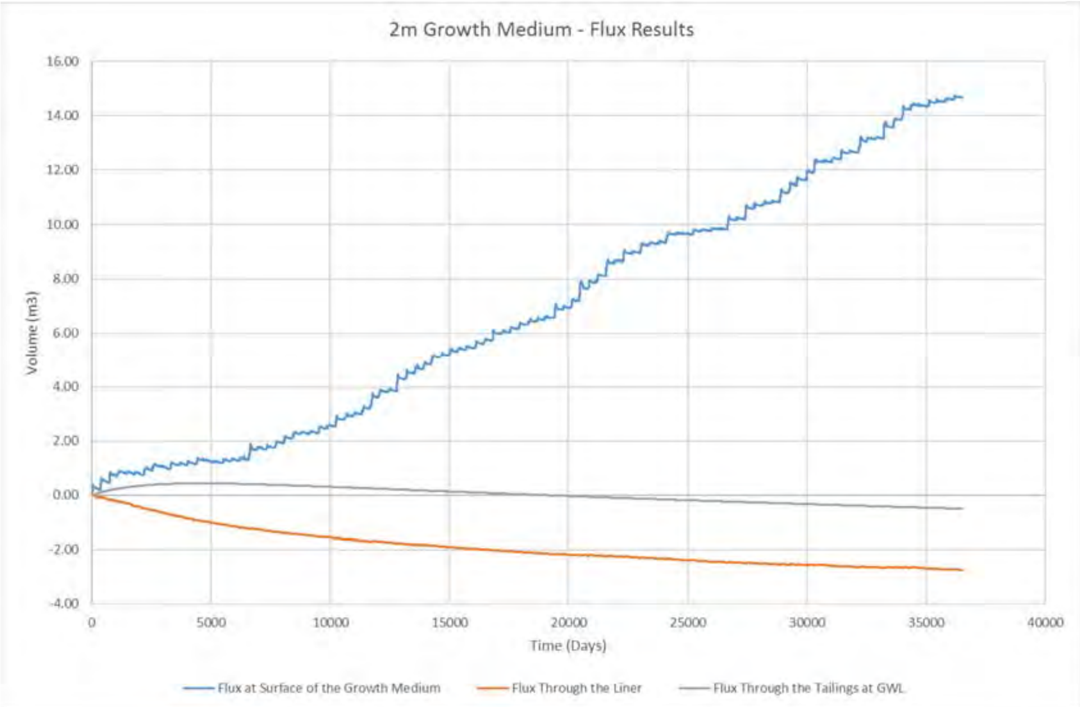

Figure 15 Flux results

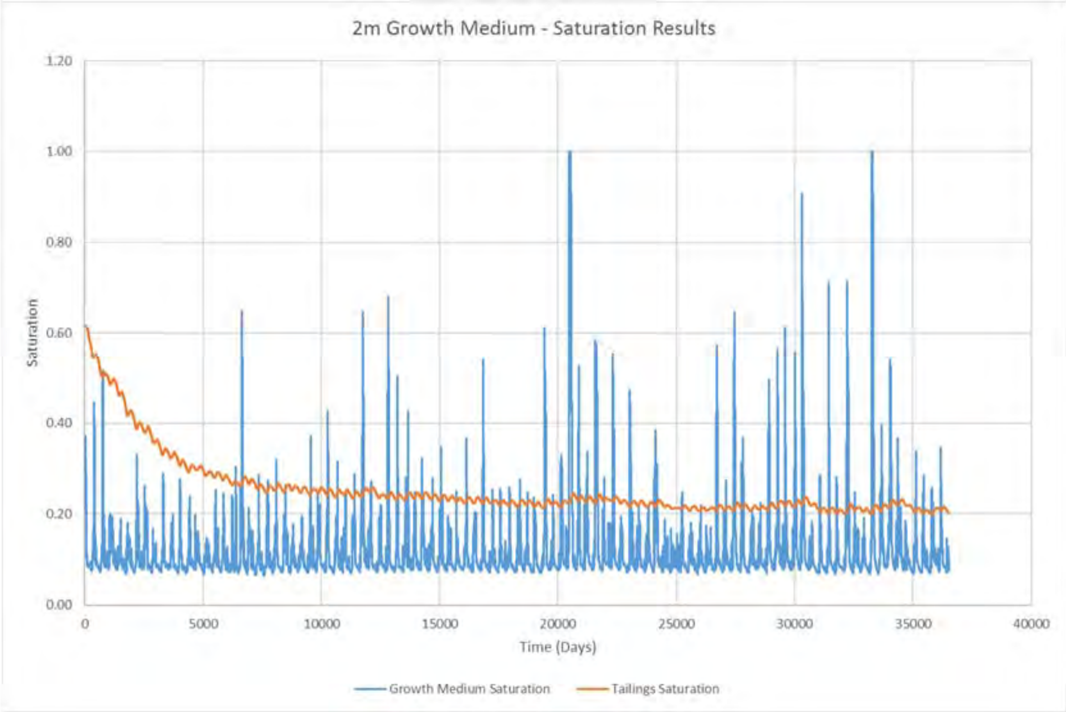

Figure 16 Saturation results

1 m growth medium results

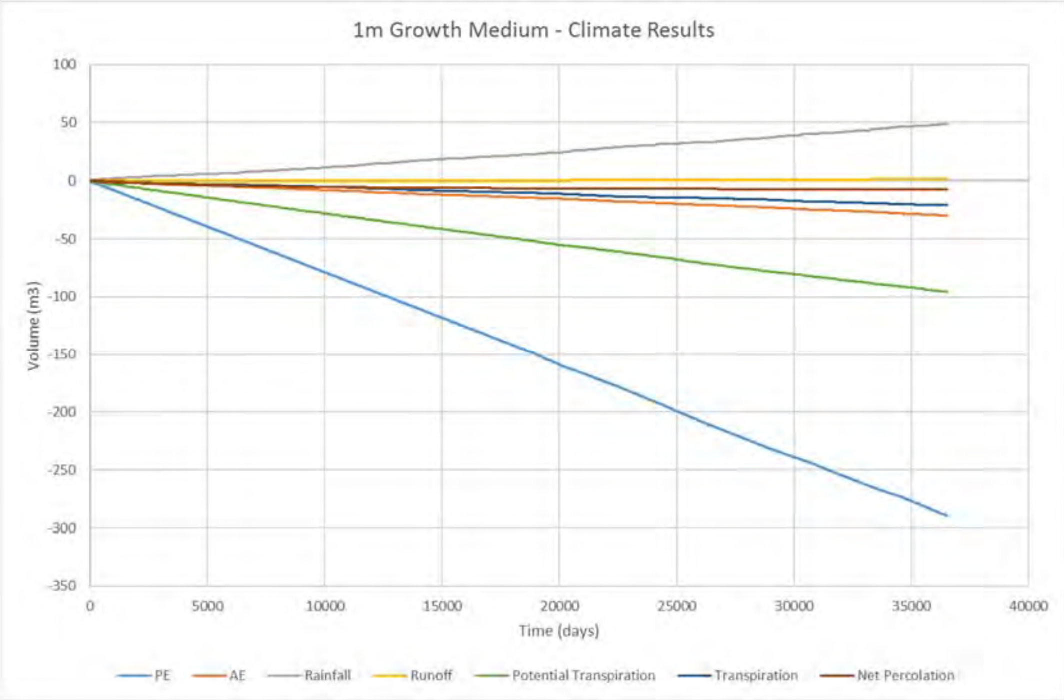

Figure 17 Climate results

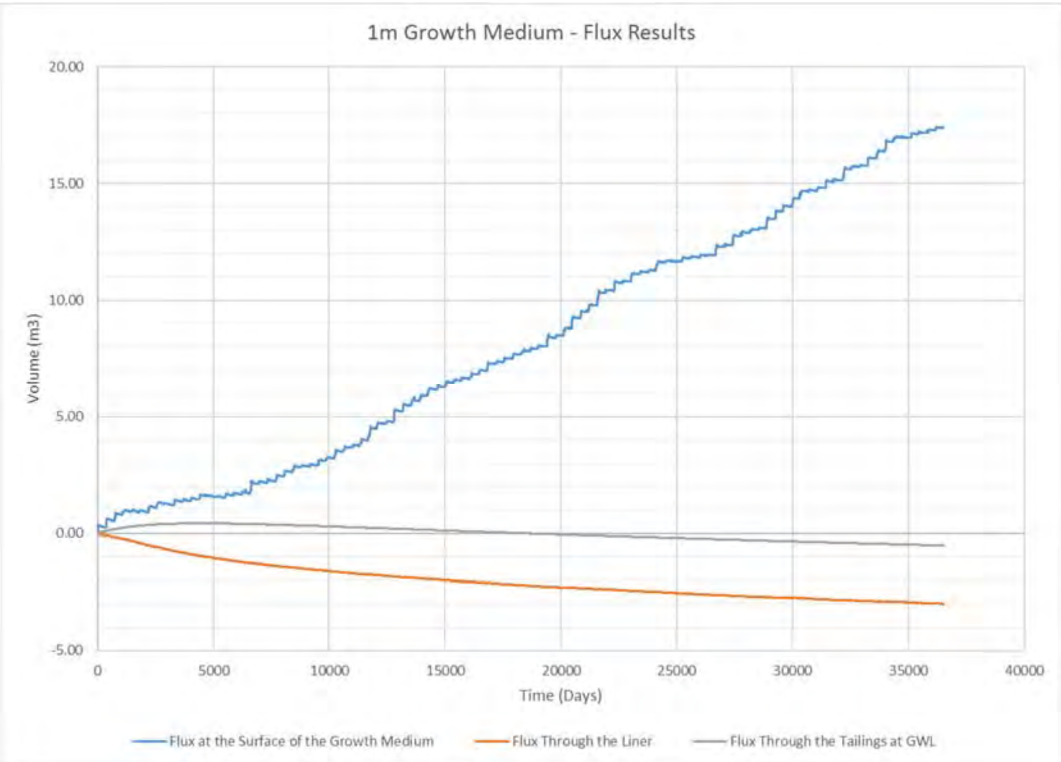

Figure 18 Flux results

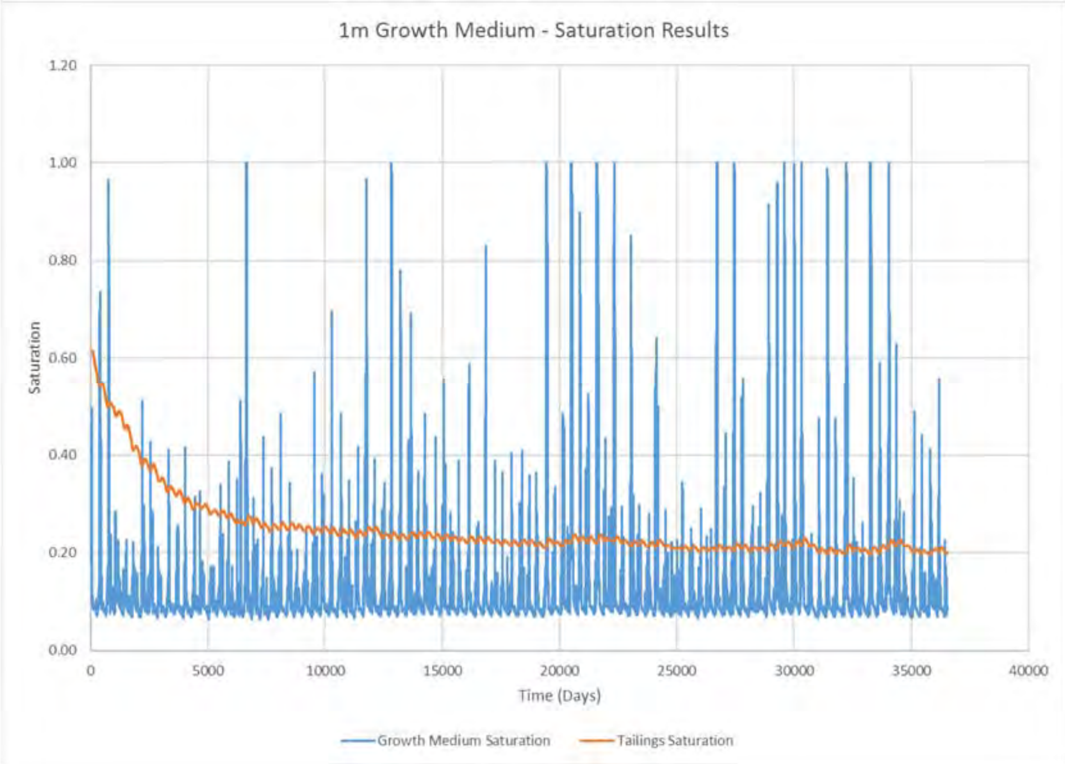

Figure 19 Saturation results

RPL/EMM (2015) cover design

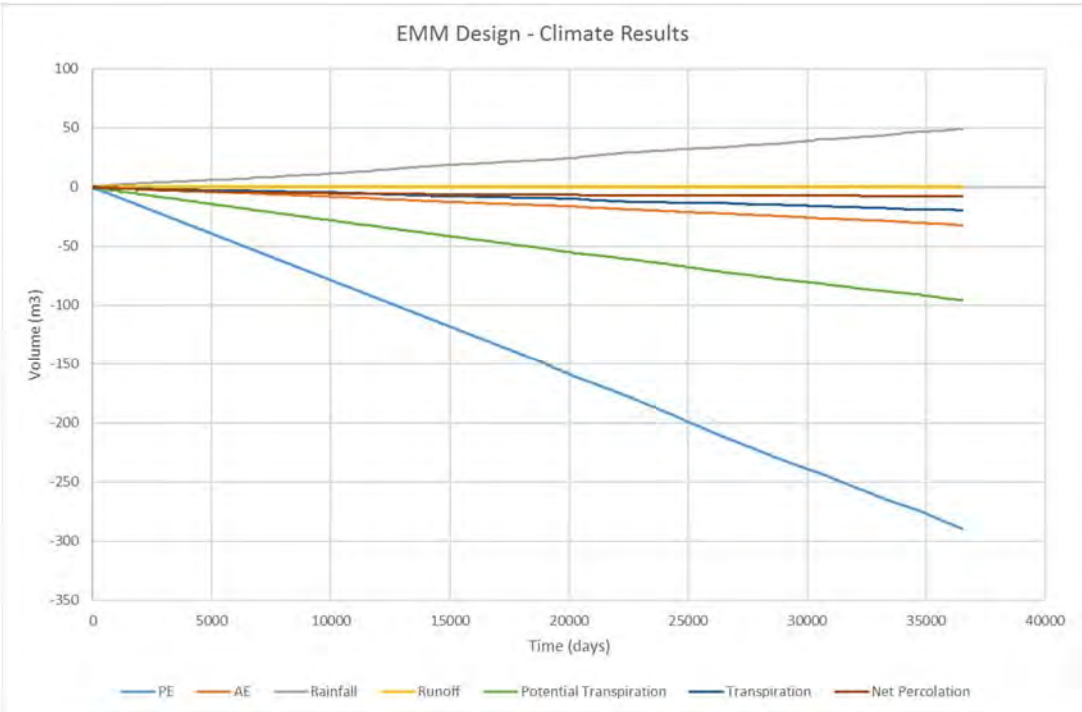

Figure 20 Climate results

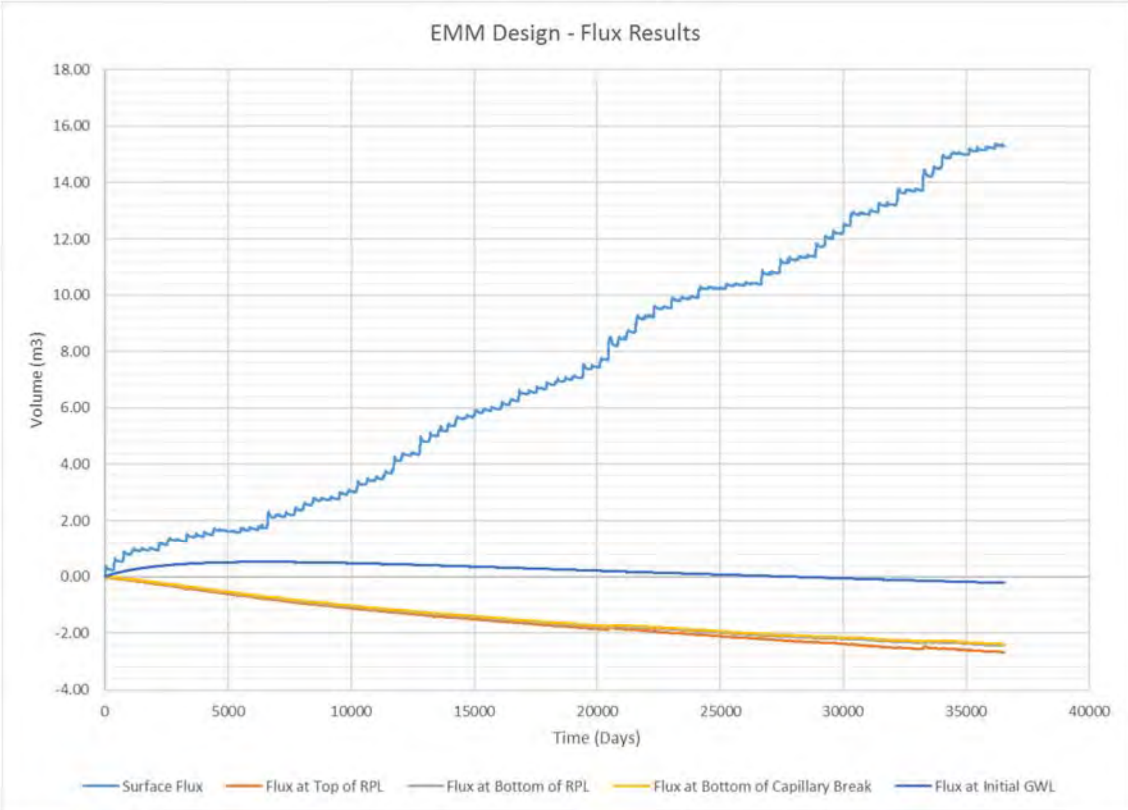

Figure 21 Flux results

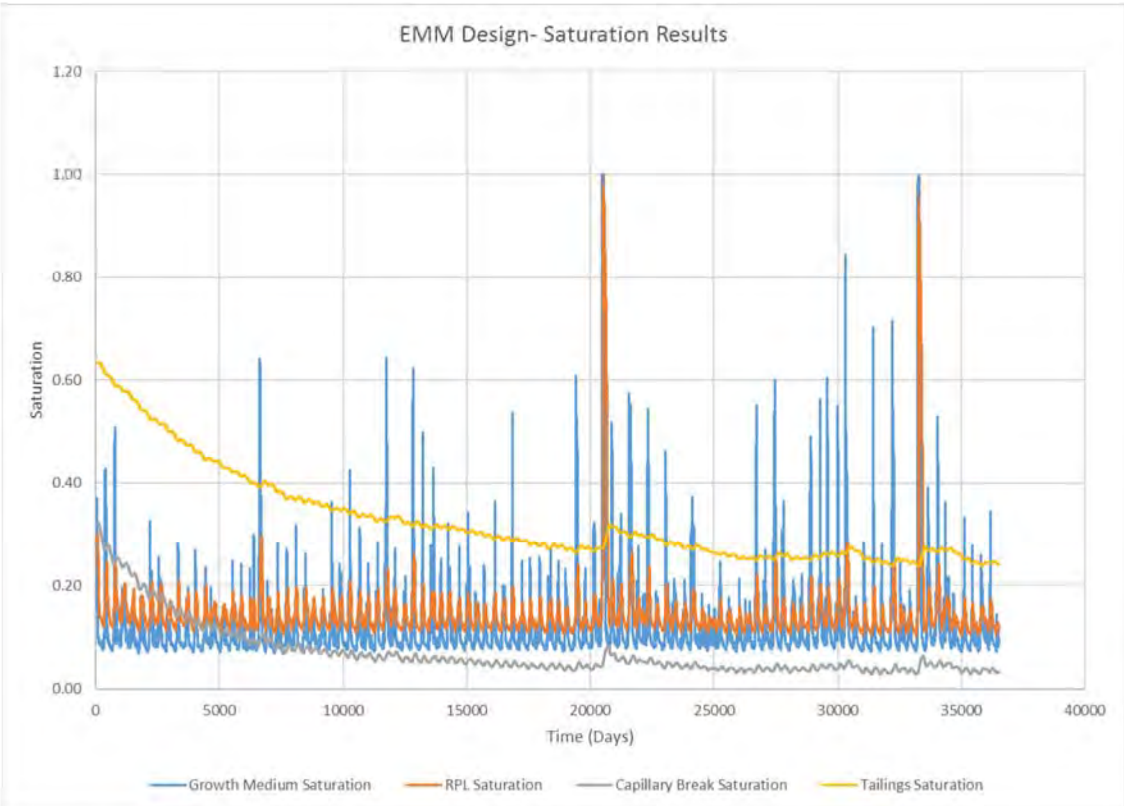

Figure 22 Saturation results

8.5 Comparison of results

A summary of results for the three cover options is presented in Table 9;

Table 9 Climate total comparison over 100 year transient model

	2 m Growth Medium	1 m Growth Medium	RPL EMM (2015) Design	Unit
Climate Totals				
Potential Evaporation	-289.87	-289.82	-289.82	m^3
Actual Evaporation	-32.25	-29.91	-32.16	m^3
Rainfall	48.69	48.69	48.69	m^3
Runoff	0.35	1.37	0.17	m^3
Potential Transpiration	-95.82	-95.79	-95.79	m^3
Actual Transpiration	-19.59	-20.62	-19.26	m^3
Flux Totals				
Surface	14.67	17.38	15.30	m^3
BGM	-2.74	-3.00		m^3
Top of RPL			-2.68	m^3
Bottom of RPL			-2.45	m^3
Bottom of Capillary Break			-2.40	m^3
Groundwater (RL212.1m)	-0.50	-0.53	-0.22	m^3
Average Saturation Values				
Growth Medium	12%	12%	11%	
RPL			14%	
Capillary Break			5%	
Tailings	24%	22%	27%	

The results presented in section 8.4 and Table 9, show similar results for both cover thicknesses. The model shows that once the cover is placed the tailings dry out gradually as the groundwater level lowers due to the significant reduction in infiltration through the cover system. The 1 m cover shows larger variation in the saturation than the 2 m cover.

The volume of flux movement gets significantly lower with depth into the tailings profile. The flux totals presented in Table 9, show that the difference in total flux between the 1 m and 2 m covers is minimal. It should be noted that the flux sections at the surface do not account for transpiration.

The average saturation results are similar between the two BGM covers, with the average saturation of the tailings being slightly lower for the 1 m cover.

The design proposed by EMM (2015) was also modelled as a comparison to the BGM option. The results presented in Table 9 show that the BGM and RPL covers show comparable reduction in infiltration, with the RPL resulting in -2.45 m^3 verses a lower -3.00 m^3 for the BGM. It is important to note that the average saturation of the RPL is quite low which is expected to be problematic as this could led to shrinkage cracking during dry periods, cracking would then increase infiltration through the cover.

The BGM manufacturers permeability adopted in the model assumes the cover is installed with no defects, therefore a sensitivity analysis was undertaken to determine the impact of two defects per hectare in the installed BGM, this approach is similar to that used to estimate liner leakage when used in dam embankment lining. This was performed by increasing the permeability of the geomembrane in the model to account for 2 defects per hectare, 2 mm in diameter, with a nominal head of 100 mm used to calculate leakage rates. The updated liner permeability was 5.3×10^{-10} m/s compared to the 2×10^{-14} m/s manufacturers permeability laboratory testing. The modelled difference was found to be marginal in terms of the flux through the BGM. A minimal decrease in flux (-0.08 m^3) was recorded for the 2 m cover over 100 years, with the cover and tailings to be slightly lower in saturation. The 1 m cover showed an increase in infiltration through the BGM of 0.39 m^3 over 100 years, however in both cover thicknesses the flux is still negative representing essentially no net percolation through the BGM.

An additional sensitivity check was undertaken to determine the effect of having a lower permeability growth medium layer, should the laboratory testing show the assumed permeability of 1 x 10^{-5} m/s to be lower. A growth medium permeability of 1 x 10^{-7} m/s was assumed for sensitivity analysis. The results showed that the volume of runoff increased as expected. The flux through the BGM reduced to -1.41 m^3 over 100 years indicating less overall flux through the growth medium (but still essentially no net percolation through the BGM). The underlying tailings retain a higher average level of saturation.

Based on the results of the sensitivity analysis the models should be updated with the results of constant head permeability testing of the cover growth medium, noting a range of permeability's between 1 x 10^{-5} to 10^{-7}m/s may be acceptable.

Based on the similar results, a 1 m cover would be suitable for rehabilitation of the Old TSF and HLEP2.

9. Project examples

Bituminous Geomembranes are used in a number of applications around the world as an impermeable barrier. BGM's are commonly used in waste confinement, embankment dams, drains and transportation projects.

Various grades of BGM have been recently used to cover tailings storage facilities and waste rock dumps in Australia. These projects include:

- 70,000 m^2 of Coletanche SC1 installed at Geraldton, Western Australia – Figure 23
- 20,000 m^2 trial of Coletanche ES4 scheduled to be installed at McArthur River Mine, Northern Territory – This project underwent an intensive review during the design process and found that the BGM lined option was favoured for its long life compared to other options.
- 370,000 m^2 Silplast TERANAP 531 TP, BGM (equivalent to Coletanche ES3) installed to cover an old tailings dam at Rosebery Mine, Tasmania.
- 65,000 m^2 of Coletanche ES4HFA (High Friction Angle) installed on a steep tailings dam raise in the Pilbarra.
- Covering a steep tailings dam at the Dugald River Mine, Queensland.

Coletanche BGM products have a minimum design life of 300 years, with a design life of 1,000 years selected by the Nuclear Safety Agency in the USA.

BGM's have a high level of dimensional stability and are not impacted by high temperatures, an example is presented in Figure 24.

Figure 23 Coletanche SC1 installed in WA

Figure 24 Coletanche Installed in Hot Climate with no wrinkling evident

10. Summary of design

A drawing set for the capping design of the Old TSF and HLEP2 is attached as Appendix A. These drawings have been developed based on the information provided above in this report (hydraulic parameters, etc.). Drawings will be updated to reflect the liner and cap surface specifications when these parameters have been finalised.

The drawing set consists of the following items:

- General arrangement plan
- Geotechnical investigation plan
- Old TSF cover layout
- Old TSF spillway plan
- HLEP2 cover layout
- Typical sections and details
- Sump 6 plan existing conditions
- Sump 6 typical section existing conditions

A summary of the design is detailed in the following sub-sections.

10.1 Old TSF

The intention of the closure landform on the Old TSF is to drain rainfall runoff to the existing eastern drain constructed in natural ground. The existing cover will be removed/shaped to provide a slope towards the eastern drain. The grade ranges from 0.5% to 1%, as shown on the drawings, this grade will facilitate excess surface water drainage off the cover whilst minimising the risk for surface erosion.

The BGM liner will be placed onto the prepared subgrade and anchored into natural ground and the embankment at the perimeter of the Old TSF. Growth medium will be placed over the BGM in a single layer.

The existing access road will be reinstated on the final cover once complete. A 300 mm wearing course will be placed over the growth medium. Drains will be constructed on both sides of the access to direct drainage to the eastern drain. The existing culvert will be re used at the eastern end of the access road to allow flows to pass under the road.

Rip-rap will be required in the drains where the drains fall into the eastern drain, due to a steeper gradient of 1V:10H resulting in higher velocities at this location.

The existing spillway shall be widened to 5m to safely pass the PMF event. Rip-Rap is required against the embankment or in areas where the spillway is not cut into rock, to prevent erosion.

10.2 HLEP2

The HLEP2 will also utilise a BGM liner overlayed by Growth Medium material. The existing surface will be shaped to a 1% grade, falling to the south, prior to placing the BGM and growth medium. A diversion drain will be constructed at the south of the HLEP2, which will direct flows to the west, reporting to an existing gully.

10.3 Instrumentation

It is recommended that the following instrumentation is installed in the final cover to monitor performance:

- Oxygen and VWC sensors in the growth medium and underlying tailings to monitor oxygen content and changes in Volumetric Water Content with time.
- V-Notch weirs in drains to monitor runoff from the cover, this could be compared to a water balance of the site to indicate performance of the cover.

11. Risk register

A risk register for this project has been prepared for this design and is presented in Appendix B.

12. References

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Appendices

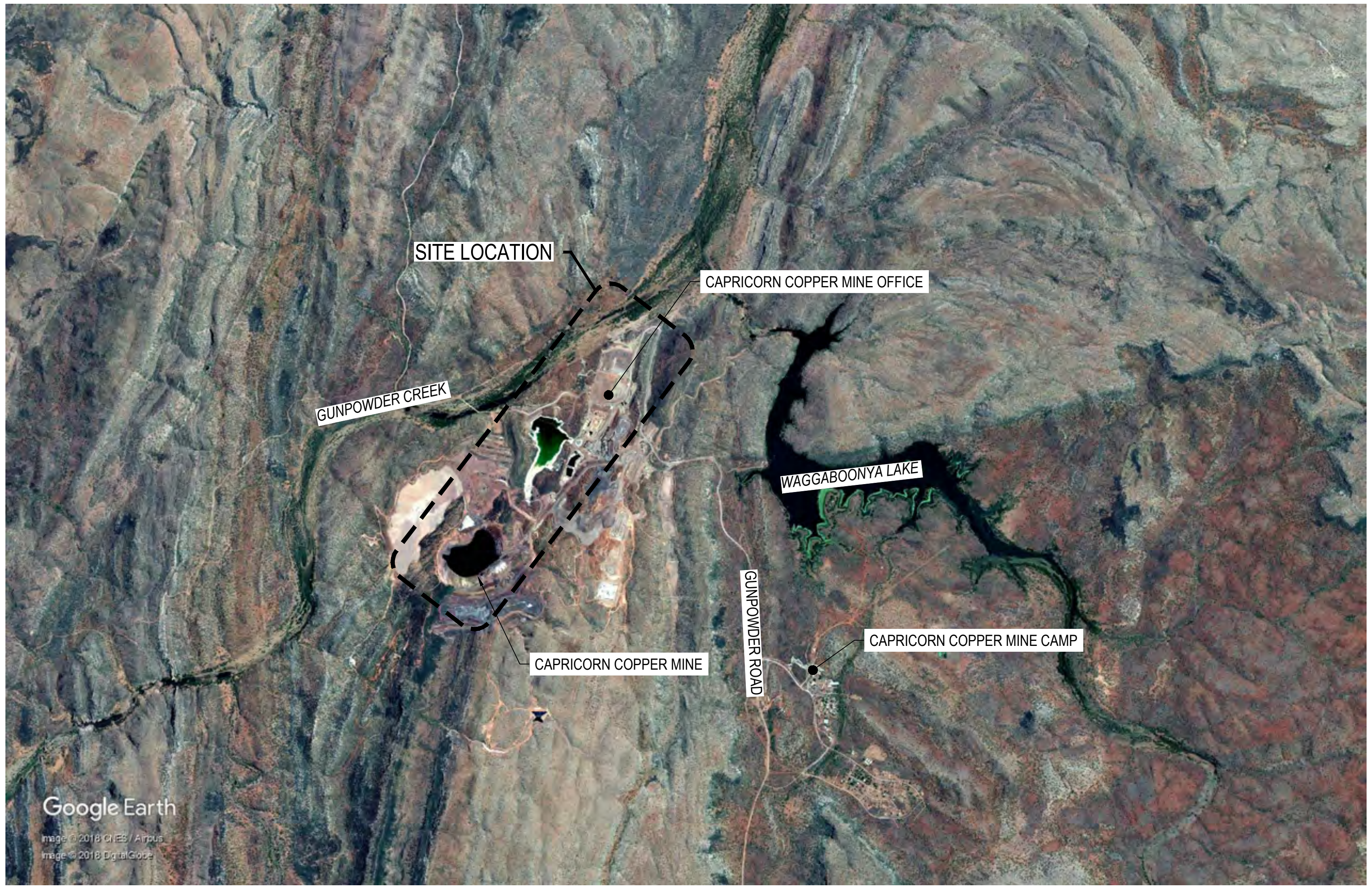
Appendix A - Drawings

Content:

- 42-20321-C001: Cover sheet and drawing list
- 42-20321-C002: General arrangement plan
- 42-20321-C003: Geotechnical investigation plan
- 42-20321-C004: Old TSF cover layout
- 42-20321-C005: Old TSF spillway plan
- 42-20321-C006: HLEP2 cover layout
- 42-20321-C007: Typical sections and details – sheet 1
- 42-20321-C008: Typical sections and details – sheet 2
- 42-20321-C009: Typical sections and details – sheet 3
- 42-20321-C010: Sump 6 plan existing conditions
- 42-20321-C011: Sump 6 typical section existing conditions

CAPRICORN COPPER PTY LTD
REHABILITATION PLAN &
FINANCIAL ASSURANCE REVIEW
42-20321

N



LOCALITY PLAN

NOT TO SCALE

DRAWING LIST

DRAWING No.	TITLE
42-20321-C001	COVER SHEET AND DRAWING LIST
42-20321-C002	GENERAL ARRANGEMENT PLAN
42-20321-C003	GEOTECHNICAL INVESTIGATION PLAN
42-20321-C004	OLD TSF COVER LAYOUT
42-20321-C005	OLD TSF SPILLWAY PLAN
42-20321-C006	HLEP2 COVER LAYOUT
42-20321-C007	TYPICAL SECTIONS AND DETAILS – SHEET 1
42-20321-C008	TYPICAL SECTIONS AND DETAILS – SHEET 2
42-20321-C009	TYPICAL SECTIONS AND DETAILS – SHEET 3
42-20321-C010	SUMP 6 PLAN
42-20321-C011	SUMP 6 TYPICAL SECTION

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No	Revision	Drawn	Job Manager	Project Director	Date
A	PRELIMINARY DRAFT - ISSUE FOR CLIENT COMMENT	JE	KK*	MB*	02.10.18

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Drafting Check	Design Check
Approved (Project Director) Date	
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Client **CAPRICORN COPPER PTY LTD**

Project **REHABILITATION PLANS**

Title **COVER SHEET AND DRAWING LIST**

Original Size **A1** **Drawing No: 42-20321-C001** **Rev: A**

Plot Date: 20 November 2018 - 8:25 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C001.dwg

LEGEND:

- EXISTING CONTOUR MAJOR
- HAUL ROUTES
- BORROW AREAS
- SURFACE WATER MONITORING SITES
- TEST PITS GHD 2018

DRAFT - NOT FOR CONSTRUCTION

No	Revision	Drawn	Job Manager	Project Director	Date
B	AMENDED BORROW AREA AND HAUL ROUTE	JE	KK*	AA*	20.11.18
A	PRELIMINARY DRAFT - ISSUE FOR CLIENT COMMENT	JE	KK*	MB*	02.10.18

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0 50 100 150 200 250m
SCALE 1:5000 AT ORIGINAL SIZE

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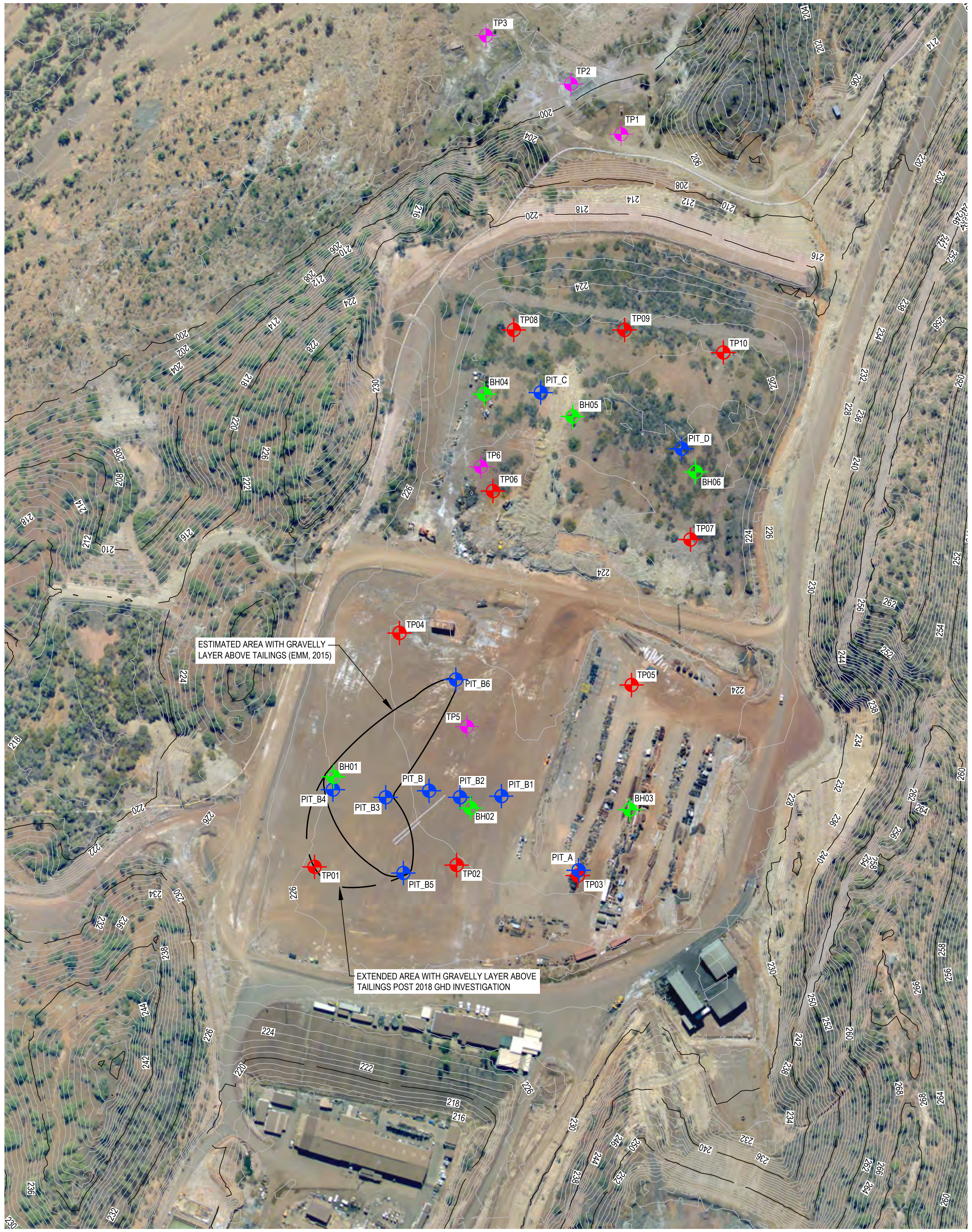
Project **REHABILITATION PLANS**
Title **GENERAL ARRANGEMENT PLAN**

Original Size **A1** **Drawing No: 42-20321-C002** **Rev: B**

Plot Date: 21 November 2018 - 5:05 PM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C002.dwg



OLD TSF LAYOUT PLAN

SCALE 1:1500

HLEP 2 LAYOUT PLAN

SCALE 1:1000

LEGEND:

- EXISTING CONTOUR MINOR
- 200 EXISTING CONTOUR MAJOR
- JANUARY 2018 TEST PITS (GHD)
- 2018 BOREHOLES (GHD)
- 2015 TEST PITS (EMM)
- AUGUST 2018 TEST PITS (GHD)

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A	PRELIMINARY DRAFT - ISSUE FOR CLIENT COMMENT	JE	KK*	MB*	02.10.18

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0 10 20 30 40 50m
SCALE 1:1000 AT ORIGINAL SIZE

0 15 30 45 60 75m
SCALE 1:1500 AT ORIGINAL SIZE

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Client **CAPRICORN COPPER PTY LTD**
Project **REHABILITATION PLANS**
Title **GEOTECHNICAL INVESTIGATION PLAN**

Original Size **A1** Drawing No: **42-20321-C003** Rev: **A**

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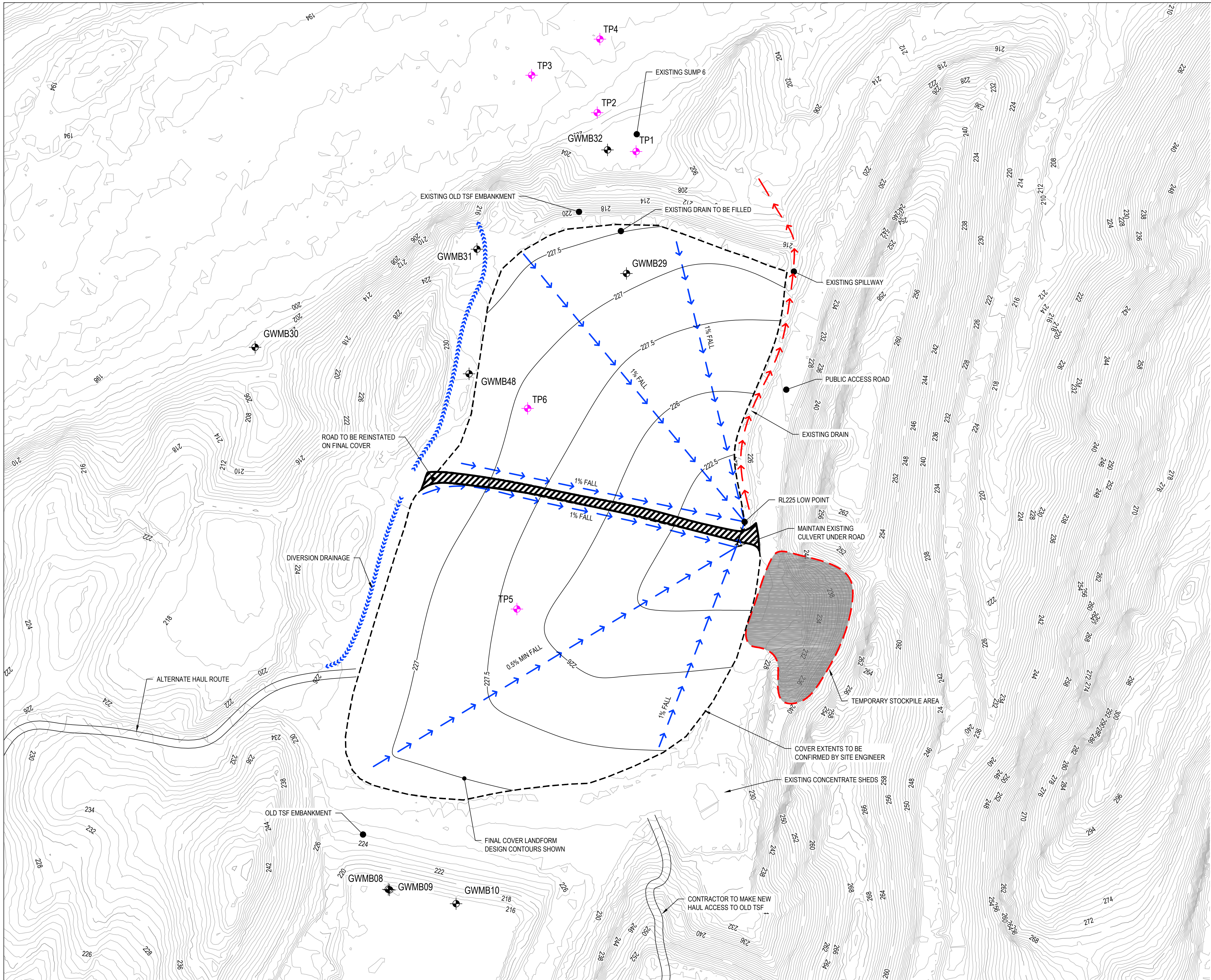

NOTE:

1. CONTOURS HAVE BEEN SMOOTHED AND INTERPOLATED

LEGEND:

- EXISTING CONTOUR MINOR
- 200 EXISTING CONTOUR MAJOR
- 200 DESIGN CONTOUR
- OLD TSF COVER EXTENTS
- HAUL ROUTES
- FALL TO LOW POINT
- EXISTING DRAIN
- DIVERSION DRAIN
- TEST PITS
- GROUNDWATER BORES

LAYOUT PLAN

SCALE 1:1500

DRAFT - NOT FOR CONSTRUCTION

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A	PRELIMINARY DRAFT - ISSUE FOR CLIENT COMMENT	JE	KK*	MB*	02.10.18

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0 15 30 45 60 75m

SCALE 1:1500 AT ORIGINAL SIZE

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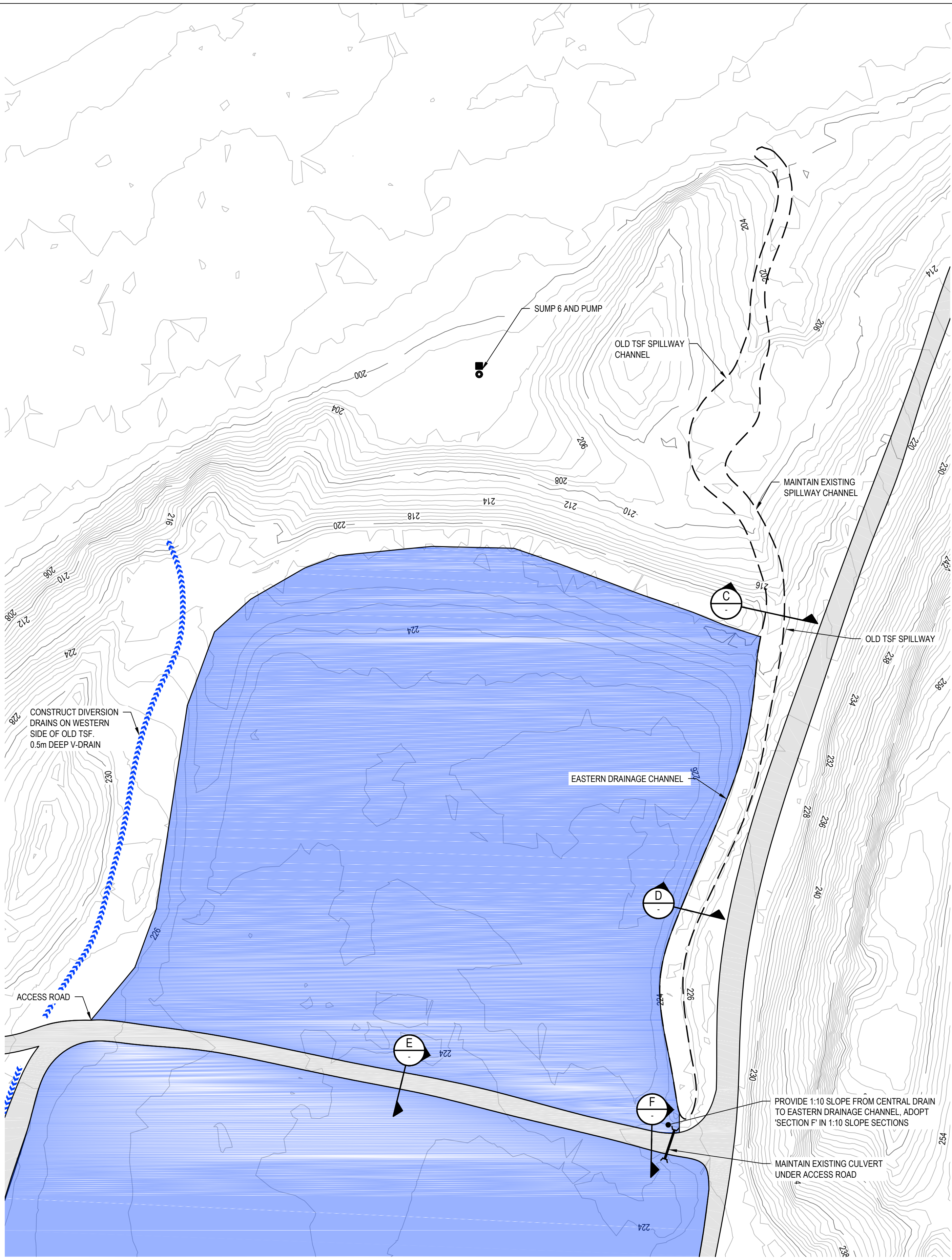
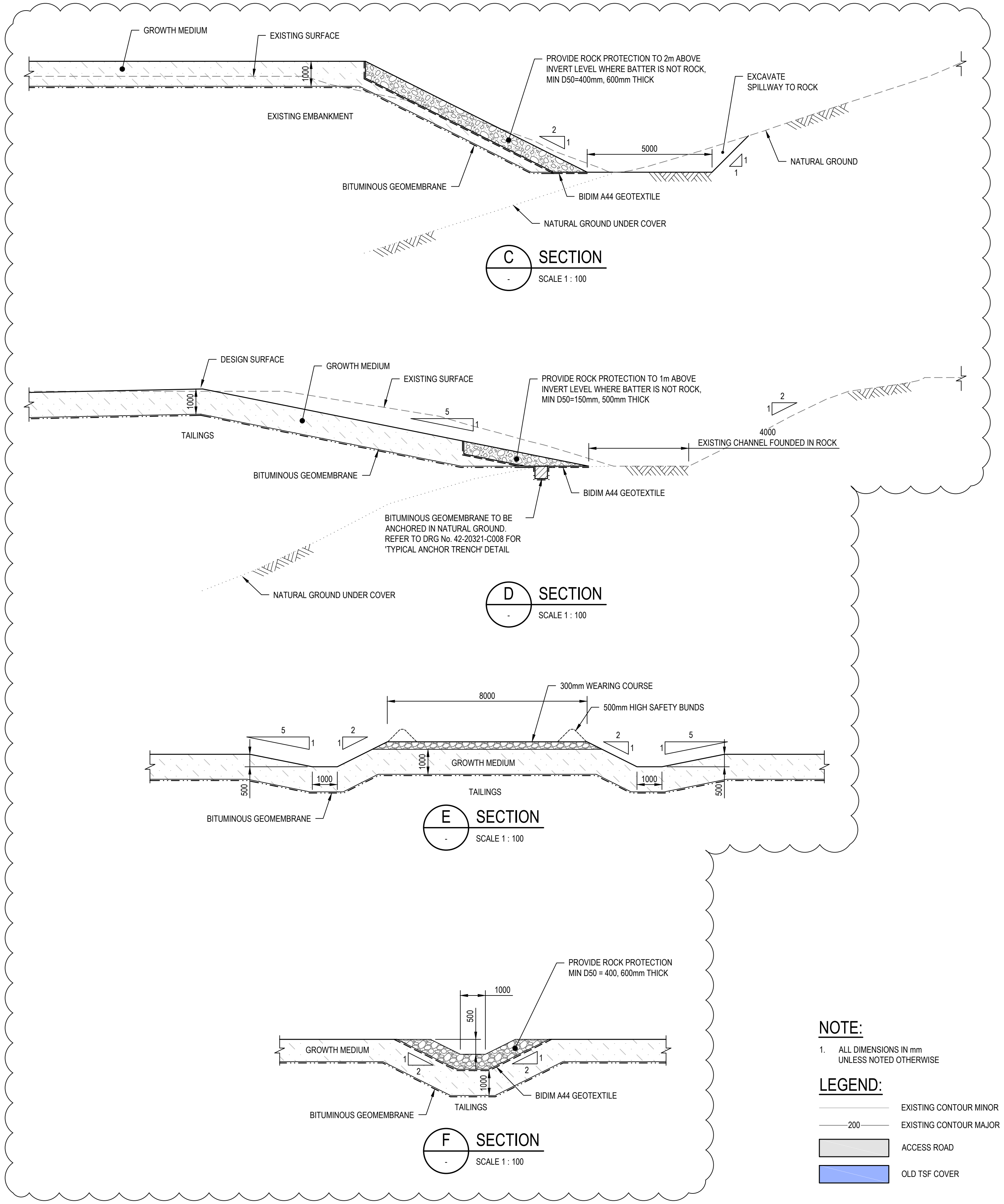
Project **REHABILITATION PLANS**
Title **OLD TSF COVER LAYOUT**

Original Size A1 Drawing No: **42-20321-C004** Rev: A

Plot Date: 20 November 2018 - 8:21 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C004.dwg



OLD TSF SPILLWAY
SCALE 1:1000



NOTE:

1. ALL DIMENSIONS IN mm UNLESS NOTED OTHERWISE

LEGEND:

- EXISTING CONTOUR MINOR
- 200 EXISTING CONTOUR MAJOR
- ACCESS ROAD
- OLD TSF COVER

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No	Revision	Drawn	Job Manager	Project Director	Date
B	GROWTH MEDIUM REDUCED TO 1M	JE	KK*	AA*	20.11.18
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0 1 2 3 4 5m
SCALE 1:100 AT ORIGINAL SIZE

0 10 20 30 40 50m
SCALE 1:1000 AT ORIGINAL SIZE

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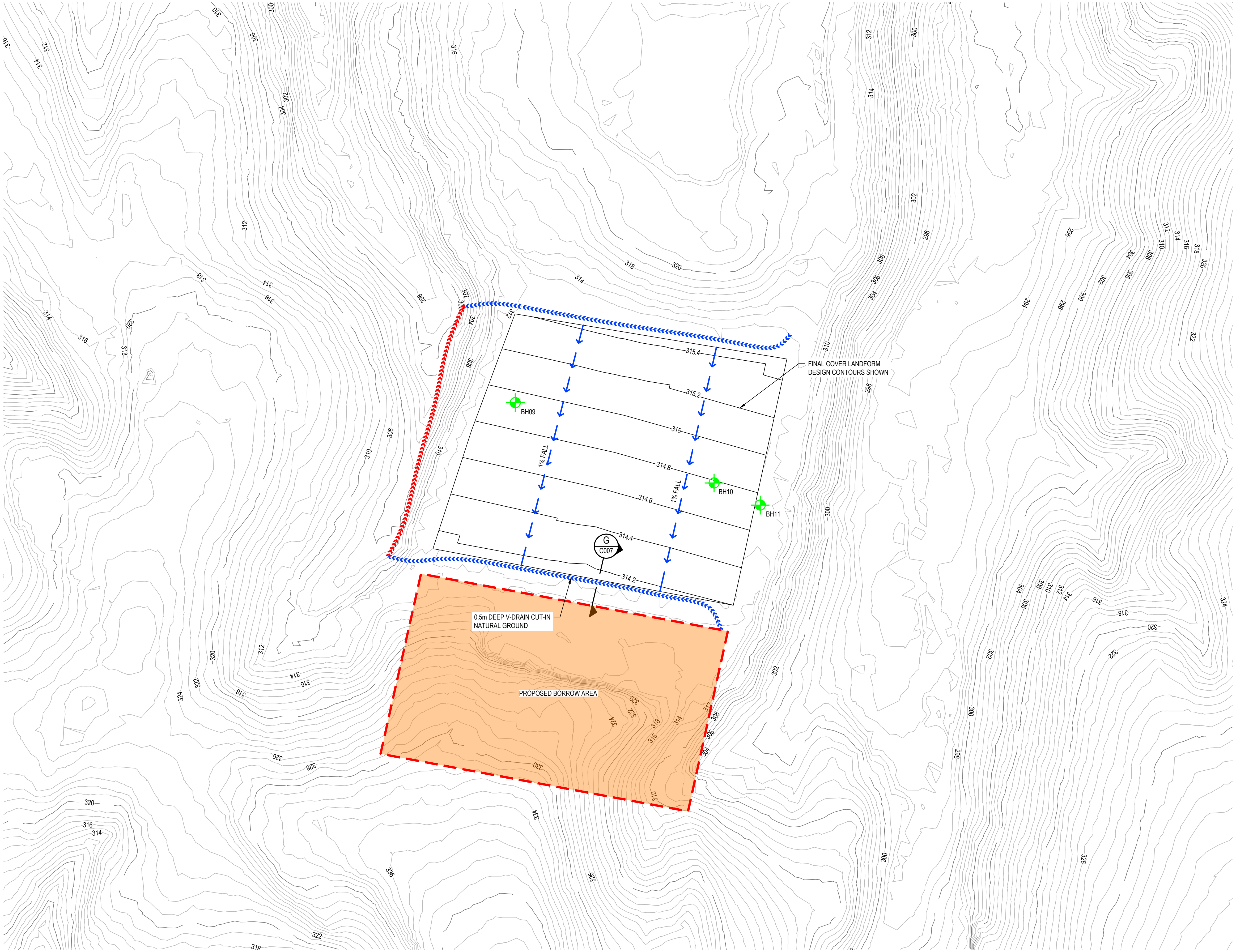
Client CAPRICORN COPPER PTY LTD
Project REHABILITATION PLANS
Title OLD TSF SPILLWAY PLAN

Original Size A1 | Drawing No: 42-20321-C005 | Rev: B

Plot Date: 20 November 2018 - 8:21 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C005.dwg



LEGEND:

- EXISTING CONTOUR MINOR
- 200 EXISTING CONTOUR MAJOR
- 200 DESIGN CONTOUR
- EXISTING DRAIN
- DIVERSION DRAIN
- FALL TO LOW POINT
- 2018 BOREHOLES (GHD)

LAYOUT PLAN

SCALE 1:1000

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A	PRELIMINARY DRAFT - ISSUE FOR CLIENT COMMENT	JE	KK*	MB*	02.10.18

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0 10 20 30 40 50m
SCALE 1:1000 AT ORIGINAL SIZE

0 15 30 45 60 75m
SCALE 1:1500 AT ORIGINAL SIZE

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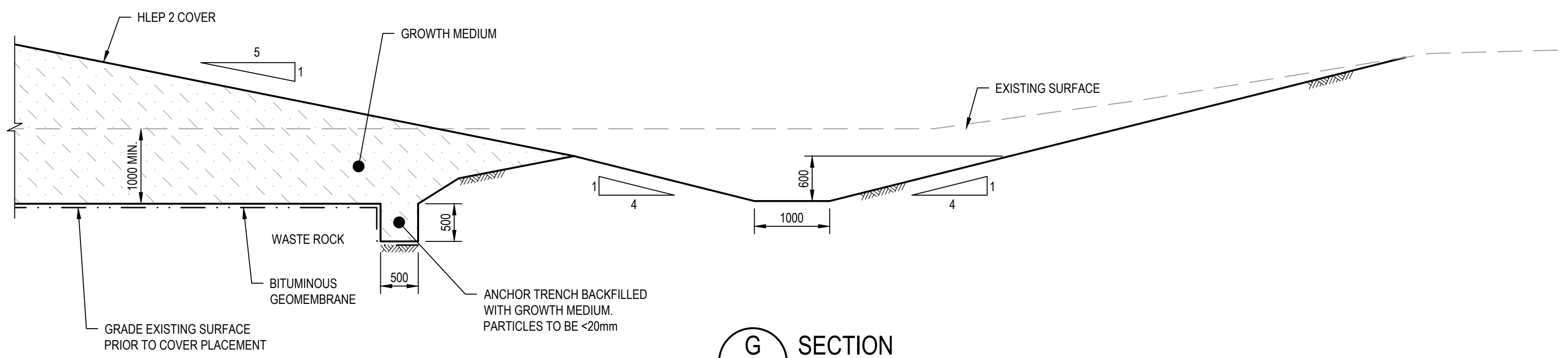
Client **CAPRICORN COPPER PTY LTD**
Project **REHABILITATION PLANS**
Title **HLEP2 COVER LAYOUT**

Original Size **A1**
Drawing No: **42-20321-C006**
Rev: **A**

Plot Date: 20 November 2018 - 8:22 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C006.dwg



G SECTION
C006 SCALE 1 : 50

TYPICAL HLEP 2 DIVERSION DRAIN

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B	GROWTH MEDIUM REDUCED TO 1M	JE	KK*	AA*	20.11.18
A	PRELIMINARY DRAFT - ISSUE FOR CLIENT COMMENT	JE	KK*	MB*	02.10.18

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0 0.5 1.0 1.5 2.0 2.5m
SCALE 1:50 AT ORIGINAL SIZE

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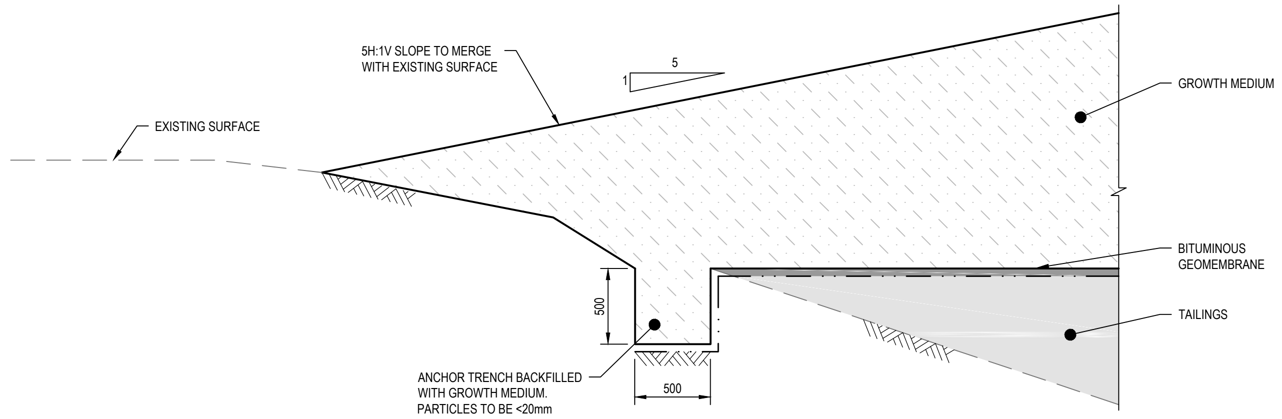
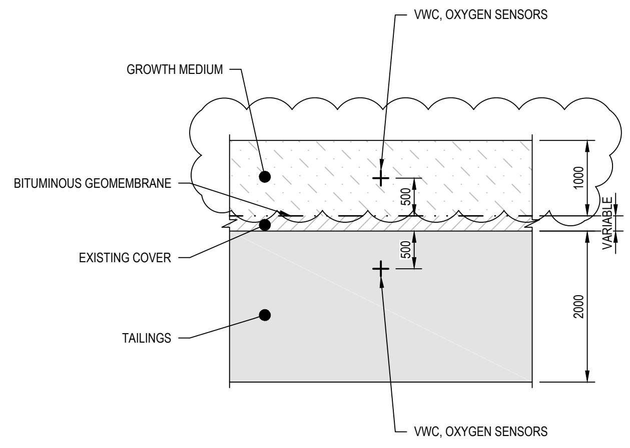
Client **CAPRICORN COPPER PTY LTD**
Project **REHABILITATION PLANS**
Title **TYPICAL SECTIONS AND DETAILS – SHEET 1**
Original Size **A1**
Drawing No: **42-20321-C007**
Rev: **B**

Plot Date: 20 November 2018 - 8:22 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C007.dwg



TYPICAL ANCHOR TRENCH

SCALE 1:25



TYPICAL COVER SECTION

SCALE 1:50

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No	Revision	Drawn	Job Manager	Project Director	Date
B	GROWTH MEDIUM REDUCED TO 1M	JE	KK*	AA*	20.11.18
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0 0.25 0.5 0.75 1.0 1.25m
SCALE 1:25 AT ORIGINAL SIZE

0 0.5 1.0 1.5 2.0 2.5m
SCALE 1:50 AT ORIGINAL SIZE

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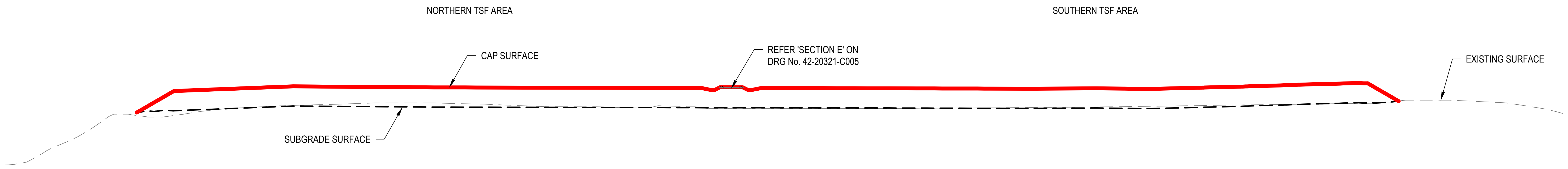
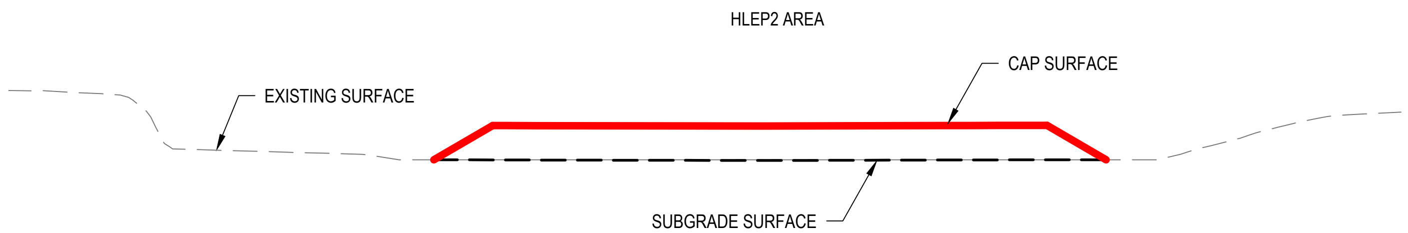
Client **CAPRICORN COPPER PTY LTD**
Project **REHABILITATION PLANS**
Title **TYPICAL SECTIONS AND DETAILS – SHEET 2**
Original Size **A1** Drawing No: **42-20321-C008** Rev: **B**



A SECTION
C002 NOT TO SCALE



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Approved (Project Director)
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Client **CAPRICORN COPPER PTY LTD**
Project **REHABILITATION PLANS**
Title **TYPICAL SECTIONS AND DETAILS – SHEET 3**
Original Size **A1**
Drawing No: **42-20321-C009**
Rev: **A**

Plot Date: 20 November 2018 - 8:22 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C009.dwg

LAYOUT PLAN

SCALE 1:1500

0 5 10 15 20 25m

SCALE 1:500 AT ORIGINAL SIZE

N

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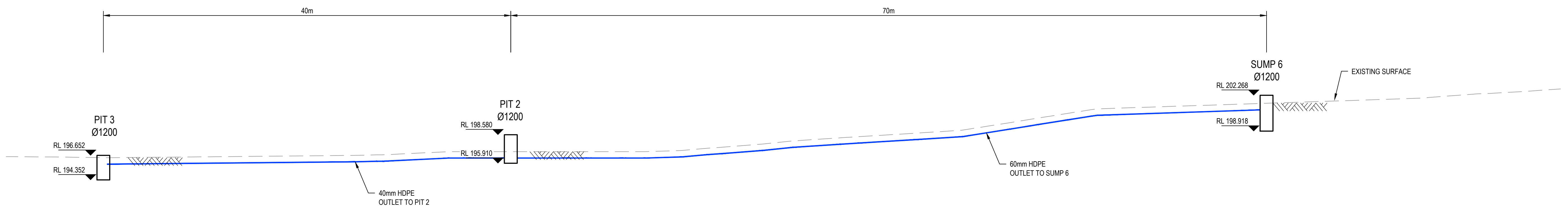
Client **CAPRICORN COPPER PTY LTD**
Project **REHABILITATION PLANS**
Title **SUMP 6 PLAN EXISTING CONDITIONS**

Original Size A1 Drawing No: **42-20321-C010** Rev: **A**

Plot Date: 20 November 2018 - 8:22 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C010.dwg



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DRAFT - NOT FOR CONSTRUCTION

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A	PRELIMINARY DRAFT - ISSUE FOR CLIENT COMMENT	JE	KK*	MB*	02.10.18

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0 2 4 6 8 10m
SCALE 1:200 AT ORIGINAL SIZE

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Design Check
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Date
Scale 1:200m
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Client CAPRICORN COPPER PTY LTD
Project REHABILITATION PLANS
Title SUMP 6 TYPICAL SECTION EXISTING CONDITIONS

Original Size A1
Drawing No: 42-20321-C011
Rev: A

Plot Date: 20 November 2018 - 8:22 AM Plotted by: James Edwards Cad File No: G:\42\20321\CADD\Drawings\42-20321-C011.dwg

Appendix B – Risk Register

HSE040 Safety in Design Risk Assessment

Notes: *Designs with significant quantities of dangerous goods may require detailed risk assessments under Dangerous Goods or Major Hazard legislation
* Most industrial processes will require an industry specific assessment, e.g. HAZOP and/or Quantitative Risk Assessment for facilities that have chemical or high-pressure processes under Dangerous Goods or Major Hazard legislation.

Design Life Cycle:	Investigation and Design	Setup, Construction and Commissioning	Operation	Maintenance	Disposal		**Date:**	**Revision No:**	A
Job Name:	Old TSF & HELP#2 Rehabilitation		**Job No:**	42-20321	**Client**	Capricorn Copper	**Design:**	OLD TSF and HELP#2 Cover Design
People involved in Risk Assessment:		C. Cahill						

Design Ref	Design Life Cycle Stage (Select from Drop Down Box)	Hazards What could cause injury or ill health, damage to property or damage to the environment	Risk What could go wrong and what might happen as a result	Existing Control Measures	Initial Risk Rating C	Initial Risk Rating L	Initial Risk Rating RR	Potential Control Measures (Consider Hierarchy of Control - Elimination, Substitution, Isolation, Engineering Controls, Administrative Controls, PPE)	Responsibility	Residual Risk Rating C	Residual Risk Rating L	Residual Risk Rating RR	Comments
1	Investigation and Design	Erosion of Cover	Erosion of Cover resulting in a significant reduction in cover thickness over the long term	Cover designed with a maximum fall of 1% to limit overland flow velocity. Growth medium material specified to have a percentage of gravel to be less susceptible to erosion.	C- Severe	1 - Very Unlikely	Low	Monitoring of the cover after heavy rainfall events to determine if erosion has occurred and repair if erosion has taken place.	Capricorn Copper	B - Major	1 - Very Unlikely	Negligible	
2	Investigation and Design	Drainage	Flooding of Cover Surface	Internal drains have been designed to pass 1:100 year AEP storm events. Old TSF spillway has been designed to pass a probable maximum flood.	C- Severe	1 - Very Unlikely	Low	Nil	Capricorn Copper	C- Severe	1 - Very Unlikely	Low	
3	Investigation and Design	Infiltration	Infiltration through cover not meeting design intent for closure (i.e. multiple liner failures)	Cover has been designed using an impermeable geomembrane to limit infiltration to the underlying tailings. Growth medium grading specified to significantly reduce the likelihood of damage during placement of the growth medium.	E- Catastrophic	2 - Unlikely	Significant	Strict QA/QC to be adopted during placement of the liner to identify any defects during construction and rectify prior to covering with Growth Medium.	Capricorn Copper	E- Catastrophic	1 - Very Unlikely	Moderate	
4	Investigation and Design	Erosion of Drains	Erosion of internal drains and spillways	Rip-Rap has been designed and specified in areas where flows are concentrated and have higher velocity to prevent erosion.	C- Severe	1 - Very Unlikely	Low	Monitoring of drains after heavy rainfall events to determine if erosion has occurred and repair if erosion has taken place.	Capricorn Copper	C- Severe	1 - Very Unlikely	Low	
5	Investigation and Design	Internal erosion of the growth medium	Internal erosion of the growth medium due to groundwater movement within the growth medium above the BGM Liner	Growth medium shall be constructed from well graded materials which are expected to be relatively resistant to internal erosion. The permeability of the growth medium and maximum slope of 1% will limit the velocity of any seepage significantly. Any seepage would exit the growth medium at the eastern drain, geofabric is placed between the growth medium and rip-rap which would prevent any movement of particles from the growth medium.	C- Severe	1 - Very Unlikely	Low	Monitor any seepage, record flow rates and test turbidity.	Capricorn Copper	C- Severe	1 - Very Unlikely	Low	
6	Setup, Construction and Commissioning	Availability of cover materials	Lack of suitable / available low permeability clay quantity. Design not able to be constructed	BGM Synthetic liner adopted opposed to clay to address this risk. This negates the need to disturb offsite clay resources and reduce traffic impact on public road.	C- Severe	2 - Unlikely	Low	Multiple sources of growth medium tested to ensure volumes sufficient to place over BGM.	Capricorn Copper	C- Severe	2 - Very Unlikely	Low	
7	Setup, Construction and Commissioning	Long term settlement of tailings/cover	Settlement leads to damage of liner	BGM Synthetic liner adopted opposed to clay. BGM has ability to accommodate relatively high settlement due to elongation properties. Given age of Old TSF majority of settlement has occurred already.	B - Major	3 - Unlikely	Low	Inspections post construction.	Capricorn Copper	B - Major	3 - Very Unlikely	Low	

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