

MRM ZINC PROJECT EXPANSION (McARTHUR RIVER MINE)

CONCEPT DESIGN AND FEASIBILITY STUDY FOR PHASE 3 LIFE OF MINE TAILINGS STORAGE FACILITY



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McArthur River Mines

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The McArthur River Mine concept design feasibility study for phase 3 life of mine tailings storage facility (TSF) has been carried out to provide feasibility concept for tailings management for the project and provide input to regulatory approvals for the proposed extension of the TSF. The study has been prepared based on existing conditions at the TSF and a proposed total life of mine tailings production of 89Mt from 2012, with the following breakdown of current approval status provided to delineate currently approved development and proposed extension/expansion of the TSF, as follows:

- Phase 2 (Current TSF Approvals)
 - Cell 2 – the existing operating cell is currently at a crest RL 49.0m and is proposed to be raised by upstream construction techniques to an ultimate crest RL68.0m. The ultimate capacity of Cell 2 will be some 24,600ML, containing some 44.3Mt of tailings.
 - Cell 3 – a proposed cell to the south of Cell 2 and within the western portion of the Water Management Dam area, Cell 3 to comprise a starter embankment to RL55.0m and then upstream lifting to an ultimate approved crest RL68.0m. The Capacity of Cell 3 is some 21,400ML, containing some 37.3Mt of tailings.

- Phase 3 (Proposed TSF Extension)

The proposed Phase 3 TSF concept will comprise the construction of Cell 4 to the west of existing Cell 2 and proposed Cell 3 area. Details of the Cell 4 proposal comprise:

- Starter Embankment to a crest RL 55.0m, constructed from earth and rock fill materials with a storage liner.
- A minimum buffer of some 250m would be provided between Surprise Creek and Cell 4.
- The Cell 4 would be constructed in the 2012 dry season and would be lined using a engineered low permeability polyethylene (PE) liner, the purpose of which is to minimise seepage, and also permits usage of the cell within the site water management system to evaporate excess water from the TSF and mine dewatering activities. Details of the site water management phase of the cell are provided under a separate cover.
- Tailings deposition into cell 4 would commence post 2030.
- Two upstream raises of the cell to a final embankment crest height of RL61.0m.
- The proposed capacity of Cell 4 is some 8,500ML, containing some 11.7Mt

Based on the above, significant outcomes to the Phase 3 ultimate TSF development study are summarized as follows:

- The proposed development configuration of starter embankments and upstream raising for Cells 2, 3 and 4 is considered generally feasible and in accordance with proposed engineering philosophy and design criteria.
- TSF footprint increases by some 65ha (Cell 4 footprint) to a total TSF area of 405ha.

EXECUTIVE SUMMARY

- The ultimate height of the TSF remains as per the Phase 2 approvals, at RL 68.0m for Cells 2 and 3.
- The ultimate height of the proposed Cell 4 will be RL 61.0m.
- Seepage analysis of the proposed lined Cells 3 and 4 indicates seepage rate likely to be of the order of 2% of the modelled seepage rates of Cell 2.
- Surface water management works for the TSF will comprise an extension of the existing perimeter drain to extend around the proposed Cell 4.
- The engineering design of the storages shall be in accordance with the relevant ANCOLD and ICOLD guidelines as detailed or otherwise considered best practice tailings management, including
 - Embankment stability to ANCOLD standards
 - Managed freeboard to accommodate an extreme wet season (greater than 200 year annual recurrence interval)
 - Emergency spillway sizing to discharge events up to 100,000 year peak flood events

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SECTION 1.0 - INTRODUCTION

1.1 BACKGROUND

McArthur River Mining Limited (MRM) proposes to expand its McArthur River Mine to a 5.5 million tonnes per annum (Mtpa) open pit operation producing a mixed concentrate of lead, zinc and silver with the concentrate refined off-site. The projected life of the expanded project is some 25 years, with closure in 2036. As part of the Phase 3 Development Project, an increase in tailings production from a current rate of approximately 2.0 Mtpa to 4.5 Mtpa would occur.

As part of the feasibility assessment for the proposed expansion, a concept design and capital-costing basis for expansion of the tailings storage facility (TSF) is required. To this end MRM has commissioned Allan Watson Associates Pty Limited (AWA) to undertake a concept design and associated feasibility study for the TSF expansion.

1.2 SCOPE AND REPORT STRUCTURE

The scope of the feasibility study for the TSF expansion is as follows:

- Develop an understanding of MRM's current TSF, including tailings deposition/water recovery practices and current operational and environmental performance;
- Compile relevant data on tailings characteristics to be produced;
- Develop a concept for long-term TSF development to support the project expansion, with this development to comprise an expansion to the existing TSF;
- Compile and review available geological/hydrogeological and geotechnical data for the area allocated for TSF expansion, forming the basis for TSF feasibility design works;
- Undertake preliminary engineering design analyses for capital work items related to the first stage of the expanded TSF;
- Prepare a schedule of capital works associated with the conceptual development.

This report has been prepared to address the above scope, with report structure as follows:

Section 2: Provides a brief description of the project, including a review of the existing TSF.

Section 3: Defines criteria/constraints relevant to the design of the TSF expansion.

Section 4: Describes the physical characteristics including geotechnical conditions within the proposed TSF development site and also the physical/geotechnical characteristics of tailings to be produced.

- Section 5:** Outlines the concept for the TSF expansion, including concepts for long-term, staged development of the facility.
- Section 6:** Describes engineering analyses, including seepage and embankment stability modelling for the development.
- Section 7:** Outlines relevant operational and closure aspects of the expanded TSF, consistent with the design/performance expectations.

A series of figures are attached that indicate the siting and layout of the proposed expanded TSF. Appendix A presents results of tailings physical characterisation test work and Appendix B provides a bill of quantities for the proposed works.

SECTION 2.0 - PROJECT DESCRIPTION

2.1 LOCALITY AND EXISTING LAYOUT

McArthur River Mine (MRM) is located 45km southwest of Borroloola in the gulf region of the Northern Territory (refer **Figure 1**). MRM was initially an underground operation, accessing an extensive stratiform zinc-lead-silver deposit at a mining rate of some 1.3Mtpa, with the open cut development and process expansion commencing in 2005, increasing throughput to the current 2.5Mtpa. The process concentrate is trucked to a port facility at Bing Bong, where it is transferred by purpose-built barge to ships in the gulf.

Significant components of the current project layout include:

- Former underground portal and workings
- Open cut pit.
- Diversion of the McArthur River to the south, and Barney Creek to the north, all of which previously traversed the proposed open cut footprint.
- An overburden embankment facility (waste dump), located to the north of the open cut.
- Plant site
- Camp and air strip
- Tailings storage facility, incorporating closed and operating tailings cells, potential expansion area and Water Management Dam (WMD).
- A borefield, located remotely from the mine area.

2.2 PROPOSED PROJECT LAYOUT

The major components of the proposed MRM Phase 3 Development Project are:

- Expansion of the TSF, with the allocated area for expansion to the west of the existing TSF.
- Plant expansion, including additional crushing and grinding circuits.
- Expansion of the waste rock dump facility.
- Additional site water management infrastructure, including a temporary evaporation cell located at the TSF. The evaporation cell will be ultimately reverted to the TSF cell 4 as described in this document.

A layout concept for the TSF expansion is presented as **Figure 4**.

2.3 DESCRIPTION OF EXISTING TAILINGS STORAGE FACILITY

2.3.1 INITIAL DEVELOPMENT (PHASE 1 - 1995 TO 2006)

The initial tailings impoundment area (containing the TSF and water storage), developed as part of the MRM underground operation (based on Fluor Daniel, 1994), with the initial operational concept being for discharge of thickened tailings from an elevated, central location to form a conical shaped stack. The profile of the stack was expected to reach 1%.

The initial impoundment comprised two tailings deposition cells (Cells 1 and 2), forming the northern and central portions of the TSF area, and a Water Management Dam (WMD) cell forming the southern portion. A central radial ramp separated Cell 1 from Cell 2. Cell 1 was used for tailings deposition and Cell 2 for containment of tailings liquor and excess storm water. The WMD was maintained as a contingency storage to accommodate extreme events.

The area encompassing Cells 1, 2 and WMD was formed by a perimeter bund. The bund on the western and southern edges of the area is used for diversion of stormwater. The bund/embankment on the eastern perimeter of WMD is used for impoundment of water. The bund ranges approximately 2 to 3m high with batter slopes of 2(H):1(V) and formed with sandy silty clays.

During 2000, following the filling of Cell 1 to the initial development extent, a centerline-type lift to Cell 1 was constructed, with the completed composite embankment comprising a clay fill upstream core and select fill buttressing. Shallow clay cut-off keys were constructed at the upstream toes of the Cell 1 embankment lift with the cut-off key depth typically between 1.0m and 3.0m. An internal wick and strip drain system was also incorporated into the lift section with this system discharging at the downstream batter of the embankment via a series of 80mm PE outlet pipes.

The embankment configuration for Cell 1 and WMD construction as part of the initial development, is as follows:

Cell 1

- Embankment Crest Level
 - External RL48m to RL 53.5m
 - Internal (Cell1/2) RL 48m to RL54.5m
- Embankment Length
 - External 2,000m
 - Internal 1,700m
- Spillway/overflow level
 - Western overflow RL49.5m
 - Eastern overflow RL47.5m

- Total Cell 1 Surface Area 78ha
- Cell 2
- Embankment Crest Level
 - Western Cell RL46.5m
 - Eastern Cell RL45.5m
 - Embankment Length
 - External 1,600m
 - Internal 1,500m
 - Spillway/overflow level
 - Western spillway RL46.0m
 - Eastern overflow RL45.0m
 - Total Cell 2 Surface Area 112ha

WMD

- Embankment Crest Level RL43.0m
- Spillway Level RL42.5m
- Total WMD Cell Surface Area 124ha

Embankment fill materials were sourced from within the storage areas.

2.3.2 UPGRADED DEVELOPMENT (PHASE 2 - 2006 TO CURRENT)

GENERAL DESCRIPTION

As outlined above, the existing TSF comprises 2 cells and the WMD (situated in Cell 3). As part of upgraded development for the TSF, completed during 2006, the layout and operation of the system was modified as follows:

- Cell 1: Cell 1 operated up to 2007, and comprised a central point/s discharge from the common embankment between Cell 1 and 2, with the discharge points stepped in approximately 100m from the embankment. The completed Cell 1 beach generally slopes towards the north where the external perimeter embankment contains the tailings and directs storm water runoff to spillway/overflow structures at both the east or west corners of the TSF. Liquor reporting to these locations discharges into Cell 2.

The completed Cell 1 tailings beach was capped using clay/earth fill materials during the 2009 and 2010 dry seasons, with materials sourced from within Cell 2 and to the west of Cell 1/2.

- Cells 2: Cell 2 is the current operating cell, used for tailings deposition. The starter embankment for Cell 2 was constructed in 2006. The area is formed along the northern extent by the existing common embankment with Cell 1, with the starter embankment forming the eastern, southern and western edges of the storage, replacing the previous perimeter bund. The southern embankment separates Cell 2 from the WMD.

An emergency spillway for Cell 2 is formed over the southern embankment, with discharge into the WMD.

A decant structure, comprising a rock fill causeway is located centrally on the southern embankment.

- WMD: The WMD was designed under the initial development to contain runoff from the TSF cells, however during the operations, Cell 2 was the primary storage for tailings liquor from Cell 1, and thus the WMD was subject predominantly to rainfall inputs. It is understood that the quality of water contained in WMD was generally low-impacted. Under current operating conditions, the WMD is used similarly, with Cell 2 providing its own wet season containment capacity. The WMD therefore remains largely as a contingency storage.

CELL 2 DEVELOPMENT (OPERATING CELL)

The configuration of the Cell 2 embankment, constructed as part of the upgraded development completed in 2006, is as follows:

- Embankment Crest Level RL49.0m
- Embankment Lengths
 - Eastern Embankment 850m
 - Western Embankment 800m
 - Northern Embankment (Internal Cell 1/2) 1,600m
 - Southern Embankment (Internal Cell 2/WMD) 1,550m
- Spillway Level RL47.5m
- Total Cell 2 Surface Area 112ha

The existing layout of the TSF is shown on **Figure 3**.

2.3.3 ASSOCIATED SYSTEM COMPONENTS

TSF SPILLWAY/OVERFLOW STRUCTURES

The configuration of the TSF is such that runoff within Cell 1 will overflow via rock armoured overflows at the eastern and western corners into Cell 2. Cell 2 subsequently spills via a rock and concrete armoured spillway into the WMD area.

Release to the environment from the TSF occurs via an emergency spillway excavated into the southern abutment of WMD and founded within surface soils/extremely weathered bedrock. The spillway discharges into the clean water diversion drain. The layout of the TSF spillway and overflow structures is shown on **Figure 3**.

MRM has indicated that spill of tailings liquor from Cells 1 and 2 to the WMD has not occurred over the period of operation, either the initial development or upgrade development. Spill has occurred from the WMD, although this spill has been unaffected from the tailings disposal area.

SEEPAGE MANAGEMENT SYSTEM

A seepage collection drain and sump has been installed along the eastern and western perimeters of Cell 2 to intercept shallow seepage flows. These systems are referred to as the Eastern and Western Water Management Drains respectively. These drains comprises an open trench approximately 1.0m deep, 2m wide, which discharges to a sump located at the southern drain extents of Cell 2. Seepage water reporting to the sumps is returned to Cell 2 by a float operated electric pump. The location of this seepage collection systems are shown on **Figure 3**.

Seepage collection system for Cell 1 currently comprises a number of dewatering bores located between the TSF and Surprise Creek as well as an open sump located within a former drainage path to Surprise Creek as shown on **Figure 3**, with this system implemented during the 2009 dry season. Seepage from the internal wick and strip drain system contained within the lift embankment (refer Section 2.2.1) discharges to the downstream toe of Cell 1 via a number of outlet pipes. Seepage cut-off for Cell 1 was installed as part of the 2006 upgrade works program for the TSF with the injection of a geo-polymer cut-off wall downstream from the northern and eastern embankment perimeter

CLEAN WATER DIVERSION DRAIN

A clean water diversion drain/bund is located on the western and southern perimeters of the TSF. The alignment of this drain is adjacent to the western perimeter bund of Cell 2 grading to the south then east, running adjacent to the TSF perimeter bund, with the outlet discharging into Little Barney Creek adjacent to the WMD main embankment. The purpose of the drain is to divert clean water around the TSF area. The drain has been formed by excavation within natural sequences, forming a trapezoidal channel some 3.0m wide, with depth varying from 0.5 to 2.5m. The longitudinal grade of the drain is approximately 0.05%, with the final 100m (outlet area) increasing to a grade of approximately 5%.

2.3.4 OPERATION AND OBSERVED PERFORMANCE OF TAILINGS STORAGE FACILITY

The operation of the TSF is undertaken in accordance with TSF Operating Guidelines (MRM 2010), with a brief description of the operations described below.

TAILINGS DEPOSITION

The tailings delivery pipeline (350mm steel/355mm PE) extends from the process plant to the eastern embankment of Cell 2 and then along the internal Cell 1/2 embankment, western embankment and the eastern embankment. Tailings deposition within Cell 2 has occurred from spigots located along the eastern, southern and western embankments, with a spigot spacing of typically 100m. In addition, single point discharge has occurred along the eastern half of the Cell 1/2

embankment. Manually operated valves are provided at each spigot tee to control discharge.

Basic deposition principles for the TSF as adopted by MRM (as advised verbally) are as follows:

- to develop a beach profile such that the decant pond will be formed centrally along the southern embankment at the decant structure/causeway.
- to direct tailings flow to develop a steady rate of tailings surface rise.
- to minimize dusting of the tailings beach surface.

TAILINGS WATER MANAGEMENT

The limits of the TSF catchment are defined by the surface area within the perimeter bund. The total diverted catchment area of the TSF is some 320ha.

Water occurring within the TSF is derived from the following sources:

- direct rainfall over the TSF area;
- water liberated from deposited tailings.
- The decant for the tailings cells (Cell 1 and 2) is located within the southern portion of Cell 2 and is formed as a rock fill causeway. The tailings surfaces within Cells 1 and 2 are largely formed to direct surface runoff to the decant area, with runoff from Cell 1 discharging into Cell 2 via the eastern and western discharge channels. A skid mounted pump is currently located adjacent to the decant area to return excess water to the process plant.

Basic principles for management of tailings water within the TSF, as adopted by MRM (as advised verbally) are as follows:

- Direct run off from Cell 1 and 2 to the decant area for recovery/reuse in the process.
- Contain “contaminated” waters within Cell 2, thereby maintaining WMD for storage of clean rainfall runoff.
- Provision for release of waters within WMD, subject to achieving required water quality guidelines.
- At the time of the visit, due to limited recovery of water from the decant during the 2009/2010 wet season as dewatering of the mine working provided the required makeup water for the plant, as well as a wet 2010/2011 wet season, a significant volume of water has accumulated within the Cell 2 area, with the volume surveyed by MRM on the 23 August 2011 calculated to be some 800ML.

2.3.5 GEOTECHNICAL INTEGRITY OF TAILINGS SURFACE

Investigation of the exposed tailings beach surface within the existing TSF was undertaken as part of AWA (2003) with additional test work completed in 2010, as provided in **Appendix A**. An interpretation of these results is summarised below:

- Exposed tailings beaches within the existing TSF area are variable in terms of strength/geotechnical integrity depending on the age of the beach surface. It is considered that access (by foot or plant) is not available on a tailings surface less than 6 weeks old. The anticipated (minimum) beach strength beyond 6 weeks is inferred to be as follows:
 - 3 months 10 to 25kPa
 - 6 months 25 to 50kPa
 - 12 months Greater than 50kPa
- Based on these conditions, access to and construction on a dried tailings surface beyond an age of 3 months is considered feasible. It is understood that such conditions enabled upstream lifting of the pipeline embankment associated with the Maunsell McIntyre (2001) works as well as the capping of Cell 1 which utilized conventional earthmoving equipment.

SECTION 3.0 - CRITERIA FOR TSF EXPANSION

Criteria for design and operation of the TSF expansion is summarised below:

3.1 PHILOSOPHY

The general design philosophy with respect to TSF expansion is as follows:

- (i) provide for the efficient storage of tailings, forming an operational and post-closure landform that is geotechnically competent/stable and not subject to excessive or uncontrolled emissions to the environment;
- (ii) provide an integral component of the total site water management system, such that releases from the system to the environment are eliminated for all but extreme conditions.

General operational philosophy is based on the use of subaerial techniques for tailings deposition. Such techniques involve discharge of tailings from multiple locations on the perimeter of the tailings storage area. At each discharge location, the tailings slurry produces near laminar flow over the gently sloping tailings beach to enable segregation and deposition of tailings solids. Subsequent evaporation from the exposed beach surface consolidates the tailings as a means of increasing insitu deposited densities and beach strengths. Water liberated from the tailings through the deposition phase accumulates within a water pond at the toe of the beach. From this pond, water can be decanted and is available for reuse.

3.2 DESIGN CRITERIA

3.2.1 TAILINGS STORAGE CAPACITY (PROCESS INPUTS)

A mine production rate for the project of up to 5.5 Mtpa for a projected mine life of 25 years is adopted with the detailed production schedule provided in **Table 1**. Total tailings production is of the order of 89 million tonnes. The design slurry density for tailings is to be within the range of 55% to 60% wt/wt.

Table 1 - Mine and Tailings Production Schedule

Year	Process Ore (t)	Concentrate Recovered (t)	Tailings (t)
2012	2,675,338	422,627	2,252,711
2013	2,813,055	440,147	2,372,908
2014	4,992,641	791,175	4,201,466
2015	4,770,796	800,370	3,970,426
2016	4,905,679	790,283	4,115,396
2017	4,802,394	794,165	4,008,229
2018	4,683,832	789,847	3,893,984
2019	4,267,093	793,264	3,473,830
2020	4,422,969	796,423	3,626,545
2021	4,562,112	792,173	3,769,939
2022	4,556,960	800,617	3,756,344
2023	4,419,696	800,257	3,619,440
2024	4,396,016	802,055	3,593,961
2025	4,679,759	800,625	3,879,134
2026	4,547,391	800,509	3,746,882
2027	4,506,581	798,201	3,708,380
2028	4,679,393	798,995	3,880,398
2029	4,603,847	797,260	3,806,586
2030	4,558,539	804,247	3,754,292
2031	4,514,089	801,547	3,712,542
2032	4,384,557	794,699	3,589,858
2033	4,206,425	798,074	3,408,351
2034	4,010,393	785,653	3,224,740
2035	3,931,965	780,895	3,151,070
2036	2,770,477	564,226	2,206,252

3.2.2 HYDROLOGY AND HYDRAULICS

(i) Stormwater Containment Capacity

Containment capacity can be quantified in either or both of two ways, as follows:

- Storage Allowance - based on the storage inputs resulting from a defined wet season period.
- Spill Risk - based on the minimum risk of spill from the storage subject to a long term rainfall record, under conservative operating conditions.

(a) *Storage Allowance*

For the purpose of concept design, the Storage Allowance concept adopted for the TSF was based on Queensland guidelines (DME, 1995) which are currently applied for the existing MRM TSF. A review of Australian tailings guidelines indicated that the Queensland guidelines are considered the preferred criteria based on providing the greatest “freeboard” for the TSF and the site climatic conditions. By definition, the storage allowance is equivalent to a storage volume that will be filled by process inputs plus stormwater derived from the critical wet period, with this allowance to be available within the system at the onset of the wet season during each year of operation.

Based on the *Guidelines on Tailings Dam Design, Construction and Operation* (ANCOLD, 1999), the hazard rating for the MRM tailings storage is HIGH, given the potential effect on human life or the environment subject to either uncontrolled release or embankment failure. By extrapolation from DME (1995), for a high hazard category, the storage allowance will be based on a 1 in 200-year, 2-month duration wet season event using decile data as obtained from the Bureau of Meteorology.

(b) *Spill Risk*

For assessing the operating performance of the system, typically in conjunction with the detailed design and pre-operational phases of the project, a Spill Risk approach would apply. This approach would define the containment capacity required for excess water/liquor to achieve a risk of spill of less than 1%, being representative of a high hazard category system.

(ii) Emergency Spillway Design

ANCOLD (1999) indicates that the emergency spillway design for a high hazard category system would be based on the worst of the following:

- (a) Probable Maximum Flood (PMF) on highest pond level in normal year; or
- (b) Worst wet season on record less water returned to plant, plus 100 year ARI storm plus waves.

A flow freeboard through the spillway of 0.0m for Condition (i) or 0.3m for Condition (ii) would apply

3.2.3 EMBANKMENT STABILITY

(i) Design of Embankment Configuration

On the basis of limit equilibrium conditions, the following typical minimum factors of safety for embankment stability would apply:

Condition	Minimum Factor of Safety
Steady State Seepage (at maximum storage level)	1.5
Seismic Condition: (i) at maximum storage level for downstream slope, or intermediate level for upstream slope. (ii) subject to maximum anticipated seismic loading for the Maximum Design Earthquake (MDE).	1.1 (pseudo-static analysis)
End of Construction	1.3

(ii) Embankment Serviceability

The serviceability criteria to be adopted for the embankment, subject to flooding conditions is for batter surfaces to be erosionally stable, requiring external batter armouring as required to at least the 1 in 500 year flood level.

3.2.4 SEEPAGE MANAGEMENT

No quantifiable criteria with respect to seepage management would generally apply, other than inference against the following:

- (i) excessive surface expression of seepage discharge downstream from the embankment should not occur;
- (ii) a significant impact on the environmental status of receiving waters should not result from the TSF; and
- (iii) the potential beneficial uses of surface and groundwater downgradient from the site should not be compromised.

Notwithstanding, there is a requirement to minimise seepage from the TSF into adjacent drainage lines.

3.2.5 CONSTRUCTION MATERIALS

It is desirable from a constructability and economics viewpoint that embankment construction materials be sourced locally (i.e. within the TSF development area), with the open cut mining operation being a secondary construction fill source for rock fill materials. Target properties of the materials proposed in construction of the embankment are outlined below:

- (i) Earth Fill
 - Clay dominant material (clay/silt fraction greater than 20% and Liquid Limits ranging from 25% to 60%).
 - Undrained shear strength in excess of 50kPa after compaction.
 - Achievable compacted permeability of less than 10^{-8} m/s.
 - Engineerable to reduce potential “internal” erosion/piping.

The key to the above suite of properties is to create a fill layer that possesses high strength, compacts well, is stable (i.e. not subject to significant vertical settlement under load or volume instability due to variation in moisture content) and importantly, provides an appropriately low level of permeability.

(ii) Rock Fill (for use as embankment fill)

The purpose of rock fill within an embankment would be to enhance structural stability as well as to provide erosion protection to external portions of the embankment. General requirements for rock fill would be as follows:

- High load bearing capacity.
- Stable and durable (with respect to potential settlement, volume instability, erosion potential and weathering).
- High permeability relative to adjacent embankment or subgrade zones.
- Geochemically stable (i.e. non-acid producing).

(iii) Rock Fill (for use as filter material)

The application of a filter material within the embankment would be to minimise migration of the fines fraction from adjacent material zones (i.e. to reduce the potential for fines migration from an earth fill zone into the adjacent rock fill). The design shall be carried out in accordance with Sherard and Dunnigan (1985).

3.3 OPERATIONAL CRITERIA

3.3.1 EFFECTS OF OVER-DRYING OF TAILINGS

As a means of reducing either oxidation of sulphides within the tailings material or dusting of the exposed tailings, both of which can be associated with prolonged drying of the tailings surface, the following considerations are of significance:

- (i) Minimise the area of tailings exposure.
- (ii) Schedule tailings deposition such that active beaches maintain an appropriate level of saturation, such that over-drying can be minimized.
- (iii) Schedule tailings system development, such that final landforms are developed as quickly as possible, to enable staged rehabilitation, thus stabilizing surfaces.

3.3.2 DECANT/RETURN WATER QUALITY

Appropriate practices with respect to maintaining the quality of decant/return water (to be reused within the process) are to be adopted. As a minimum, provisions to be made to limit the significant alteration of decant water quality within the TSF will include:

- (i) Maintaining a sufficiently large enough decant pond to enable sufficient residence time for settlement of suspended solids prior to recovery.

- (ii) Maintaining an appropriate tailings deposition regime (in terms of cycling periods) such that oxidation of tailings solids, with associated release of oxidation products to the decant pond, is limited. This relates to maintaining defined levels of saturation/moisture within the beach to inhibit oxidation.

3.3.3 SEEPAGE WATER QUALITY

Appropriate practices to limit the degradation of the quality of seepage water that may be released from the system are to be adopted. As a minimum, provisions to be made to maintain seepage water quality or the impact of seepage migration will include:

- (i) Maintaining an appropriate tailings deposition regime (in terms of cycling periods) such that oxidation of tailings solids, with associated release of oxidation products to seepage waters, is limited. This relates to maintaining defined levels of saturation/moisture within the beach to inhibit oxidation.
- (ii) Monitoring of surface water and groundwater quality around the TSF to detect excessive seepage migration.
- (iii) Implementation of effective, staged rehabilitation works to minimize the potential seepage footprint.

SECTION 4.0 - DESIGN BACKGROUND DATA

4.1 SITE CONDITIONS AND ASSOCIATED DESIGN IMPLICATIONS

4.1.1 SITING OPTIONS

Siting options for tailings disposal was previously considered by MPA Williams (MPA Williams, 1992) and reviewed as part of AWA (2003). Based on discussion with MRM and review of the above documents, the preferred siting of the TSF expansion was to incorporate into the existing TSF area based on the following:

- Minimise overall disturbance area, with a significant proportion of the TSF expansion located within the current disturbed TSF area.
- Maintain within existing impacted catchments with ongoing development works to enhance seepage and surface water management of the existing system.
- Existing site infrastructure.

4.1.2 SITE DESCRIPTION

The McArthur River mine site generally comprises near level to gently undulating alluvial backplains adjacent to the fluvial corridor of the McArthur River. The area allocated for TSF expansion is located within a gently inclined to undulating alluvial outwash fan pediplain (with slopes mostly in the range of 1 to 2%). Low, rounded hills and residual gravelly rises, with marginal slopes typically in the range of 10 to 20%, occur to the west and north-west of the TSF.

The primary drainages of the TSF area are Surprise and Barney Creeks (refer **Figure 2**), both of which flow to the east, discharging to McArthur River within the mine site.

It is understood that the MRM project area is prone to widespread flooding as a result of prolonged/intensive rainfall. This flooding is associated with backwater caused by a flow stricture within the McArthur River floodplain located to the north of the project area. It is understood that the entire TSF development area is likely subject to flood inundation of some depth.

The landform within the TSF expansion area is dominated by the existing TSF cells, with storage embankments some 6 to 8m above surrounding topography. The WMD is located within the TSF area adjacent to the south of Cell 2 and was initially developed for runoff containment from the initial central discharge concept.

It is noted that the existing tailings cells and WMD area are protected from stormwater flood inundation by the perimeter bunds.

4.1.3 HYDRO-METEOROLOGICAL CONDITIONS

The McArthur River/Borroloola region is characterised by moderate total average rainfall (748mm). Some 95% of this rainfall (on an average monthly basis) occurs during the "wet" season months of November to April. An excess of evaporation over rainfall (on average) exists for all months of the year.

Average monthly rainfall and evaporation data for McArthur River, as derived from Bureau of Meteorology Station No 014704, is presented in **Table 2**.

Table 2 – Rainfall and Evaporation for McArthur River

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
Average Rainfall (mm)	177	181	146	31	9.1	1.7	3.5	0.1	6.7	16	55	121	748
Average Evaporation (mm)	229	193	208	216	195	174	186	223	261	307	309	282	2,783

4.1.4 SITE GEOLOGY

(i) Geological Setting

Reference to the 1:100,000 scale mapping (NTGS, 1991) identifies the following geological formations that occur within the general vicinity of the MRM project area.

- The oldest rock types within the project area are those of the Middle Proterozoic McArthur Group Umbolooga Subgroup, which comprise a sequence of interbedded dolostones, dolomitic siltstone, sandstone and shale. This sequences is overlain by the Batten Subgroup, which consists of a succession of shallow marine deposits, chiefly dolomitic siltstone, cherty dolostone, pyritic shale, quartz sandstone and evaporates and outcrops as the low hills west and northwest of the TSF area.
- Local outcrops of quartz arenite, quartz sandstone, siltstone and shale of the Roper Group occur to the east of Emu Fault Zone in the north-eastern sector of the project area, which encompasses the TSF area. These comprise the youngest succession of the Proterozoic McArthur Basin sequence.
- Early Cambrian Bukalara Sandstone formation occurs further to the east of the mine site and east of the Emu Fault Zone. The formation is unconformable on the McArthur River Basin sequences and comprises fine to coarse grained, sometimes pebbly, feldspathic quartz sandstone.
- Cainozoic Tertiary to Quaternary sediments occur extensively within the area. These include gravelly residual soils underlain by bedrock, colluvial and outwash fan deposits, older alluvial and lacustrine deposits of clay, silt and sand.
- Quaternary recent alluvium consisting of silt, sand and gravel, occurs on the flood plains, levees, flood terraces and channel floors of the McArthur River and its major tributaries.

(ii) Subsurface Conditions within TSF Expansion Area

The TSF expansion area comprises a gently inclined and broadly undulating pediplain mostly with medium to deep red and yellow, medium to high plasticity sandy clay and clay type soils. These soils grade through clayey gravels to weathered dolomite or dolomitic siltstone bedrock at depths varying between 1.0m and in excess of 2.0m. Elsewhere, red to yellow gravelly silty clay underlain by weathered dolomitic shale/siltstone bedrock (around 2m depth) occurs locally on low rises.

4.1.5 HYDROGEOLOGICAL SETTING

Based on previous TSF design works and the available data within the TSF area, comprising geological structure, groundwater intersection depths and insitu permeabilities, the following interpretation of this data indicates the following with respect to the hydrogeological setting of the site:

- Groundwater, forming part of a regional unconfined aquifer system, exists within the MRM project area. The groundwater surface within the TSF development area is expected to be at a depth of some 10 to 12m.
- The regional groundwater system appears to be hosted within faulted/fractured dolomite and dolomitic siltstone. The permeability of these sequences is of the order of 5×10^{-6} to 10^{-6} m/s.
- Groundwater flow is generally a function of secondary porosity associated with geological structures. Groundwater flow is unknown, however is inferred to be sympathetic with topography, being generally towards the south-east.
- Aquifer recharge is likely to occur via direct infiltration of rainfall/stormwater runoff through surface sequences or via subcropping structures (generally coincident with creeklines/drainages).
- With a limited groundwater surface gradient and moderate aquifer permeabilities, the inferred rate of groundwater flow is low to moderate.

4.1.6 GEOTECHNICAL IMPLICATIONS ON TSF EXPANSION DESIGN

A geotechnical review of the TSF was undertaken by AWA and reported in AWA (2003). The implications of site geotechnical conditions on TSF expansion design, based on the geological/hydrogeological setting and geotechnical properties of subsurface materials, are summarised below:

- The soil profile across the site is shallow, of the order of 1.0m to 2.0m thick. These soils comprise generally colluvial and outwash fan deposits and floodplain alluvium. The underlying basement sequences comprise predominantly dolomite and dolomitic siltstone (refer **Section 4.1.2**).
- The engineering properties of the soil profile are as follows:
 - soils occurring within the site can generally be described as sandy/gravelly clay of medium plasticity;
 - the soil profile below any topsoil horizon is generally of high strength (inferred undrained shear strength of 100kPa);

- the insitu permeability of the soil profile is moderate (in the range of 5×10^{-6} to 10^{-6}), however subject to re-engineering, permeability decreases to around 5×10^{-8} m/s¹
- the soils are considered to be non-dispersive. In geological terms, this implies that soil particles are not subject to colloidal suspension in contact with water. Notwithstanding, given the variable and sometimes high silt/sand fraction, the soil may be considered to be “erodable” on slopes when subject to concentrated stormwater flow.
- Hydraulic connection between an unlined TSF and the regional groundwater system as described in **Section 4.1.4** is likely. The capacity of this connection and the likely rate of migration of seepage within groundwater outside the TSF area will be influenced by the permeability of the soil profile, as well as the groundwater-hosted sequences. It is likely however, that seepage beyond an unlined TSF area will occur, which may reflect in elevated contaminants in groundwater or in shallow seepage expression in adjacent creeks and drainages.

4.2 TAILINGS CHARACTERISATION AND ASSOCIATED DESIGN IMPLICATIONS

4.2.1 PHYSICAL CHARACTERISTICS

Physical and geotechnical testwork has been undertaken on a sample of the initial pilot plant tailings as reported under AWA (2003) as well as further tailings samples taken from the beach by MRM in December 2010. Testwork results are provided in **Appendix A** with a summary of the results presented in **Table 3**.

Table 3 – Physical Characteristics of Pilot Plant Tailings

Parameter	Result
Geotechnical Classification	SANDY SILT/SILTY SAND (SM-ML), Non-Plastic
Particle Density	3.14 t/m ³
Particle Size Distribution	Passing 2.36mm (Sand size) 100% Passing 0.075mm (Silt size) 78% Passing 0.002mm (Clay size) 3%
Atterberg Limits	Non-Plastic
Settling/Sedimentation	
- Undrained Test	End point dry density 1.25t/m ³ Moisture content at end point 48.2% Time to achieve end point 5 days
- Drained Test	End point dry density 1.30t/m ³ Moisture content at end point 45.0% Time to achieve end point 3 days
	(Note: As-tested solids concentration 57.6% wt/wt)
Permeability	5×10^{-7} m/s (at at density of 2.0t/m ³)

⁽¹⁾ Subject to compaction of 98% density ratio (Standard method)

4.2.2 TAILINGS GEOCHEMISTRY

Further geochemistry test work is currently being instigated as part of the Phase 3 detailed design studies and will be available under a separate cover. Notwithstanding the above, for the purpose of this assessment, available past geochemical data for tailings including MPA Williams (1993) and URS (2005) was reviewed and summarised as follows:

Tailings are high in metals and contain approximately 8% sulphides which are classified as potential acid forming. However the sulphides in the tailings although reactive, did not produce sufficient acid to lower the pH of the material which is typically around pH 8. It is therefore considered unlikely that oxidised zones within the TSF will significantly acidify.

Due to some of the sulphides being reactive when the tailings is exposed for extended periods, it is likely that sulphate salts will migrate upward and precipitate on the beach surface as water evaporates during dry periods.

4.2.3 INFERRED TAILINGS BEHAVIOUR

Based on the tailings characteristics as defined in **Sections 4.2.1** and by correlation with available literature and previous experience with tailings of similar properties, the following potential behaviour related to tailings slurry deposition has been interpreted:

(i) Tailings Dam Densities

Due to the relatively high SG of the tailings and the very low clay fraction (i.e. less than 2µm particle size), the tailings are likely to settle rapidly following deposition. Achievable settled densities are likely to be as follows:

Settled Condition	Condition Description	Achievable Settled Density (t/m ³)
Undrained	<ul style="list-style-type: none"> Initial beaching on a low permeability foundation. Settlement around the decant (supernatant water pond) 	1.25
Drained	<ul style="list-style-type: none"> Beaching on a previously air-dried layer of tailings (or a permeable foundation). 	1.30

Assuming controlled thin layer, sub-aerial beaching of tailings based on a nominal rate of tailings surface rise of 3m/annum, it is anticipated that a lower-bound average dry density for tailings will be of the order of 1.6t/m³. This is consistent with estimates within the initial MRM design studies (as reported in MPA Williams, 1992). Depending on the standard of storage management throughout the life of the facility, it is expected that average densities as high as 1.9t/m³ are achievable and is comparable with currently achieved densities as advised by MRM.

(ii) Tailings Water Recoveries

Based on the achievable densities as outlined above, and taking into account losses of water to evaporation, seepage and storage within the tailings mass, a conservative (lower bound) rate of tailings water recovery of some 25% of the total tailings water input is likely to apply. Note that the water recovery potential can be affected by the quantity of rainfall experienced, as well as the relative areas of exposed tailings beach/decant pond, as well as the condition of the beach on which the tailings are discharged.

(iii) Beach Slopes

Beach slopes expected to be achieved, subject to sub-aerial deposition methods, would be of the order of 0.75 to 1.0%.

(iv) Tailings Permeabilities

The measured permeability for the tailings subject to drained settlement of 5×10^{-7} m/s is considered typical. For the purpose of design, saturated permeabilities for tailings within a range of 10^{-6} to 10^{-8} m/s is considered reasonable, with the upper-bound values being representative for the coarse tailings fraction and the lower-bound values, for the fine fraction.

SECTION 5.0 - TSF EXPANSION CONCEPT

5.1 EXPANSION AREA CONDITIONS

The area allocated for TSF expansion is largely within the existing TSF area with Cell 4 extending to the west of the existing TSF. The basic outline of the expansion area is shown on **Figure 4**. The overall configuration of this area is constrained by Surprise Creek to the north and the mine lease boundary to the west and Carpentaria Highway to the east.

The current condition of the TSF expansion area is as follows:

- Within the WMD area (refer **Figure 3**), a quantity of stormwater is stored permanently, with this water previously accessed as process water, although due to the large volume of water within Cell 2, water has not been extracted from the WMD over the past 12 months.
- Further to the west, the TSF expansion area is largely undisturbed, with current access-availability. It is noted, however, that such access can be limited during wet season periods with significant ponding of water adjacent to the WMD and against the perimeter diversion bund.

5.2 TSF DEVELOPMENT CONCEPT

Based on the conditions of the TSF expansion area, as well as the limited fall over the site, an elevated impoundment-type storage is necessary. This is consistent with the configuration of the existing TSF cells, with opportunities therefore to integrate the expanded TSF with the existing system. Furthermore, it is considered appropriate that the TSF will be developed as a series of cells, with staged construction of cells in advance of storage requirements, thus minimising or deferring up-front capital expenditure. The sizing of individual cells would be based on the following constraints:

- (i) large enough to enable effective deposition to be achieved, thus maximizing insitu densities;
- (ii) small enough such that the total water balance condition for the site is not severely affected; and
- (iii) small enough to substantially reduce the potential for over-drying of the tailings surface to occur, thus limiting the potential for acid-production through oxidation of sulphides, and limiting the potential for dusting and particulate emission from the tailings surface.

Observation of current conditions within the existing TSF cells, and based on the physical tailings testwork (refer **Section 4.2.1**) infers a target deposition cycle time of 60 days.

Given the evaporative potential of the project site (refer **Section 4.1.2**), it is considered that a 3.0m annual tailings surface rise is acceptable. In areas of longer wet season duration, or lesser evaporative potential, an acceptable rate of rise would be limited to around 2m per annum.

Based on these conditions, against a tailings production rate average of some 4.2 million tonnes per annum and assuming average tailings dry density of 1.8 t/m³, a nominal cell area of 80 to 100ha has been selected.

It is emphasised that the capital cost-effectiveness of a single tailings storage cell can be improved by limiting the initial (starter) embankment height, with subsequent lifts to raise the cell storage to a defined ultimate level. Given the proposed configuration of the TSF, and also the potential geotechnical integrity of the tailings surface subject to sub-aerial deposition conditions (as observed within the existing TSF), the most economical method of storage lifting is by “upstream” construction techniques. Upstream lifts are formed by construction over the exposed tailings beach, upstream of the existing embankment crest. Lift embankments would likely be formed by earth fill construction, although the use of engineered tailings may be feasible (subject to trials and analysis). The possible limitation existing with respect to upstream lifting is the maximum lift embankment height based on the geotechnical integrity of the tailings beach. Typically embankment heights up to 6m are feasible subject to the strength of the beach, with heights of between 2 and 4m on fine-grained tailings generally considered to be optimum. For the purpose of this study, lift heights ranging between 3 and 4m have been adopted.

To facilitate upstream lift construction, a competent tailings beach surface on which lift construction is to occur, would be required, thereby necessitating a period of drying. Common practice to achieve these conditions is to develop and operate two storage cells in parallel (or but subdividing an operating cell), one cell being used for tailings deposition, with the second used for resting/drying and subsequent lifting. Based on a 3m lift embankment height, lift construction works would be required every one to two years of operation. As each cell reaches the defined ultimate height of the TSF landform, the surface of the cell would be rehabilitated, with a replacement cell concurrently constructed.

Figure 4 shows the proposed ultimate layout of the expanded TSF, based on a project life of 25 years. The TSF landform abuts the existing TSF cells, with the existing Cell 2 being raised and partially extended over the Cell 1 surface. The characteristics of the landform shown are as follows:

- Total Surface Area (Cells 2,3 and 4) 300ha
- Ultimate landform surface level RL 68m
- Maximum height of landform 35m (northern corner)
- Total tailings storage capacity 56,000ML (56 million m³)
- Total number of cells 4

Significant features of the TSF development are outlined below.

5.2.1 STARTER EMBANKMENTS

Embankments will be formed by earth and rock fill construction, with the earth fill component being a centrally located core zone with rock fill embankment shoulders enhancing overall stability whilst providing flood erosion protection. The Starter embankment crest level will be RL 55m, with a maximum impoundment level for tailings/water of RL 54m, thereby providing for a spillway depth of 1.0m. Crest widths for external (outer) embankments will be 7m (based on machine limits).

It is anticipated that earth fill for use in embankment construction will be sourced from borrows located within the storage area (where accessible). Rock fill will be sourced from the open cut operation or alternatively from local borrow. It is expected that some dewatering of a ponding area within the Cell 4 area may be required to enable access.

Typical embankment profiles for the initial (starter) development are shown on **Figure 7**. The earth fill core zone will incorporate a cut off key to intersect the upper soil profile and extend into competent basement sequences.

5.2.2 STORAGE LINING

Storage lining of Cells 3 and 4 is proposed based on observed performance of Cells 1 and 2, to minimise seepage potential from the new TSF cells. Lining proposed shall comprise a composite liner of 1.5mm HDPE proprietary product overlying a compacted earthen base, and wrapping approximately 1m up the earthen perimeter embankment. In addition, to protect the HDPE liner in Cell 4, an earthen protection layer would be placed over the HDPE liner. Consideration of alternate proprietary liners would also be undertaken as part of the detailed design subject to achieving a performance that exceeds the analysed HDPE liner.

Construction and installation of the liner would be in accordance with ANCOLD and/or ICOLD guidelines (specifically ICOLD Bulletin 135, 2010) and current industry best practise, including a detailed quality assurance and quality control test program during installation.

5.2.3 UNDERDRAINAGE

Incorporated with the storage lining, underdrainage (beneath the HDPE liner) would be required to minimise uplift pressures on the lining system whilst operated as a water management dam. The configuration of the underdrainage system would be subject to detailed design, notwithstanding, it is considered that the system would comprise a herring bone configuration with drains located at maximum 100m centres and discharging at the low point, adjacent to the Cell 3 (the system would be extended beneath Cell 3 at the time of cell construction). Monitoring the underdrainage system would also provide leak detection of the liner and in the event of a leak, reduce the hydraulic head and seepage through the underlying sequences.

In addition to the underdrainage, the lined cells would also incorporate above liner drainage to be installed at the commencement of tailings deposition to provide drainage of the tailings to improve consolidation and maximise tailings densities and strength. The tailings cell drainage would be subject to detailed design, notwithstanding, based on tailings physical characteristics it is envisaged that the drainage system would comprise a drainage net type product with filter.

5.2.4 EMERGENCY SPILLWAYS

Emergency spillways for the TSF development will be provided for each cell and stage, and located such that spills will be directed into the WMD except for the case where Cell 3 embankment exceeds the height of Cell 4, with the latter cell alternatively discharged to Little Barney Creek as per the WMD discharge location. It is emphasised that these spillways are for emergency release only with risk of the storages getting to spill level very low due to the requirement of maintaining a freeboard as outlined in **Section 3.2**. The spillways will comprise a broad crested section with a crest level typically 1m below the embankment crest level. The

spillway will be armoured by concrete, rock fill or a geomembrane/liner. A coarse rock fill energy dissipation zone will be required at the toe of the embankment.

The design capacity for the emergency spillway, based on **Section 3.2** will be based on the worst of:

- (i) PMF on highest pond level in normal year, or
- (ii) Worst wet season on record, less water returned to plant, plus 100 year ARI storm plus waves.

Based on a spillway depth of 1.0m, and allowing for a flow freeboard of 0.3m, preliminary analysis indicates a spillway width for a cell of some 40m.

Typical details for the emergency spillway and overflow are shown on **Figure 7**.

In conjunction with the TSF development, the capped Cell 1 will include the construction of drop structures at the eastern and western low points which will direct surface runoff off site via sediment/detention structures. The purpose of the sediment/detention structures would allow final settling of sediments as well as providing for a storage buffer which would permit water quality sampling and redirection (if required).

5.2.5 DECANT FACILITY

A decant facility for recovery of tailings supernatant/liquor will be incorporated into each tailings storage cell. The proposed decant concept is for a rock fill causeway to be located centrally within each cell, with the decant pumps to be located within the enclosed pond. Tailings water would be decanted using a submersible decant pump, and returned via a pipeline to the process plant pond. A detail concept for the decant structure is shown on **Figure 7**.

Furthermore, access to the decant would need to be maintained to enable ongoing raising of the causeway. To facilitate operation of this decant system configuration, tailings deposition predominantly from the entire perimeter embankment for each cell would be required.

5.2.6 WATER MANAGEMENT DAM

The proposed reconfiguration of the water management dam is shown on **Figure 4**.

5.3 DEVELOPMENT SCHEDULE

Based on the TSF development concepts as outlined in **Section 5.2**, scheduling of the development works (incorporating Cells 2, 3 and 4) will be as outlined in **Table 4**. The proposed layouts of storage lifts for years 2012, 2015, 2020, 2025 and 2030 are shown on **Figures 8 through 10**.

Table 4 – Stage 1 Development Schedule

Lift Stage No.	Cell No.	Embankment Level (RLm)	Storage Capacity Increase (ML)	Timing*
1	Cell 2	52	3,310	2012
	Cell 4 (Starter)	55	4,300	
2	Cell 2	55	3,440	2014
3	Cell 3 (Starter)	55	10,400	2015
4	Cell 2	58	3,620	2019
5	Cell 3	58	2,670	2021
6	Cell 2	61	3,430	2022
7	Cell 3	61	2,600	2024
8	Cell 2	64	3,200	2025
9	Cell 3	64	2,500	2026
10	Cell 2	68	3,920	2028
11	Cell 3	68	3,190	2030
12	Cell 4	58	1,980	2032
13	Cell 4	61	2,140	2035

* In terms of commencement of deposition, allowing for a flood storage capacity (i.e. between the tailings surface and spill level) prior to lifting of 1,500ML per cell.

Concept details for embankment raising by upstream construction methods in relation to the above schedule is shown on the Figures. Concepts for centreline lifting of the internal decant causeway are also presented. It is noted that upstream lifts would be constructed using clay fill or tailings fill (subject to fill suitability), with external rock fill armouring for erosion control purposes.

SECTION 6.0 - ENGINEERING ANALYSES

6.1 SEEPAGE ANALYSES

Steady-state seepage analyses have been undertaken with respect to the expanded TSF concept to:

- (i) estimate potential tailings water seepage losses from the TSF; and
- (ii) estimate potential hydrostatic heads developed within the TSF embankments, as a basis for assessment of embankment stability (refer **Section 6.2**)

The seepage analyses comprised computer-based numerical seepage modelling using the SEEP/W finite element package. SEEP/W is formulated on the basis of Darcy's Law for both saturated and unsaturated flow. The model iteratively solves mass balance differential equations for a grid of finite elements, based on appropriate boundary conditions.

Three embankment conditions were analysed as follows:

- Condition 1: Starter Embankment - Unlined Storage (refer **Figure 6**)
- Condition 2: Ultimate Embankment Configuration (refer **Figure 6**)
- Condition 3: Starter Embankment - Lined Storage (proposed Cells 3 and 4) (refer **Figure 6**)

In each condition, the tailings beach was assumed formed to the maximum impoundment level (i.e. 1m below embankment crest) and it was also assumed that the beach is "active" (in terms of deposition) with fully saturated conditions existing. The permeability values adopted in the analyses, based on geotechnical conditions as described in **Section 4.1**, were as provided in **Table 5**.

Table 5 – Permeability Values Adopted in Seepage Analyses

Zone Description	Adopted Saturated Permeability (m/s)
<ul style="list-style-type: none"> • In situ Materials 	
Upper profile-soils	1×10^{-6}
Lower profile-basement	9×10^{-7}
<ul style="list-style-type: none"> • Engineered/Tailings Materials 	
Earth Fill/Tailings Fill	1×10^{-8}
Rock Fill	1×10^{-6}
Deposited Tailings	1×10^{-7}
PE Liner	1×10^{-10}

The results of the seepage analyses for Conditions 1 and 2 are presented on **Plates 1, 2 and 3**, showing lines of equal head (equipotential lines) and flow vectors. These outputs indicate the following:

- (i) Under Condition 1, significant head loss is achieved across the earth fill core within the starter embankment configuration, with a fall in the phreatic surface resulting on the downstream side of this zone. Flow vectors suggest that the

majority of seepage through the section analysed occurs beneath the cut-off key.

- (ii) Under Condition 2, a significant head loss occurs via the upper lift embankment, with a uniform (almost linear) head loss beneath the lower lifts and starter embankment. Similar to Condition 1, seepage flow is concentrated beneath the cut-off key of the starter embankment.
- (iii) Under Condition 3, a significant head (energy) loss occurs across the PE Liner and reduces seepage by greater than an order of magnitude compared to the unlined condition

Calculated steady-state seepage rates through the analysed section under Conditions 1 and 2 are as follows:

- Condition 1 255L/day/m of embankment length
- Condition 2 230L/day/m of embankment length
- Condition 3 6L/day/m of embankment length

Plate 1 - Condition 1 Seepage Results

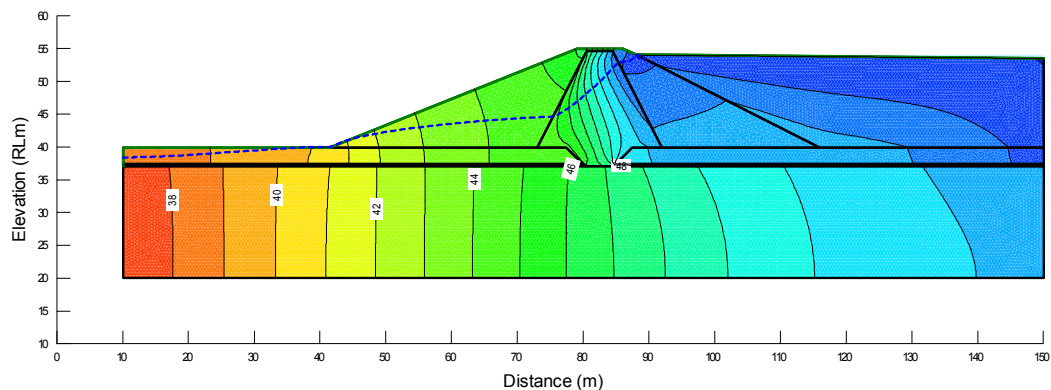


Plate 2 - Condition 2 Seepage Results

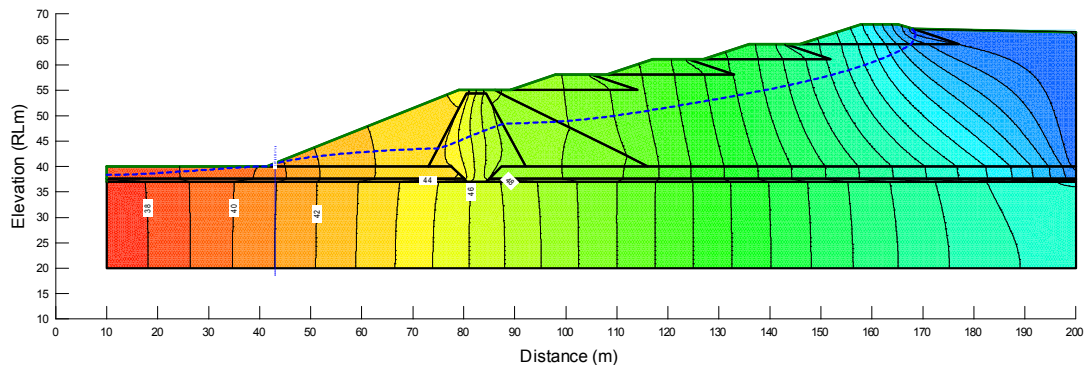
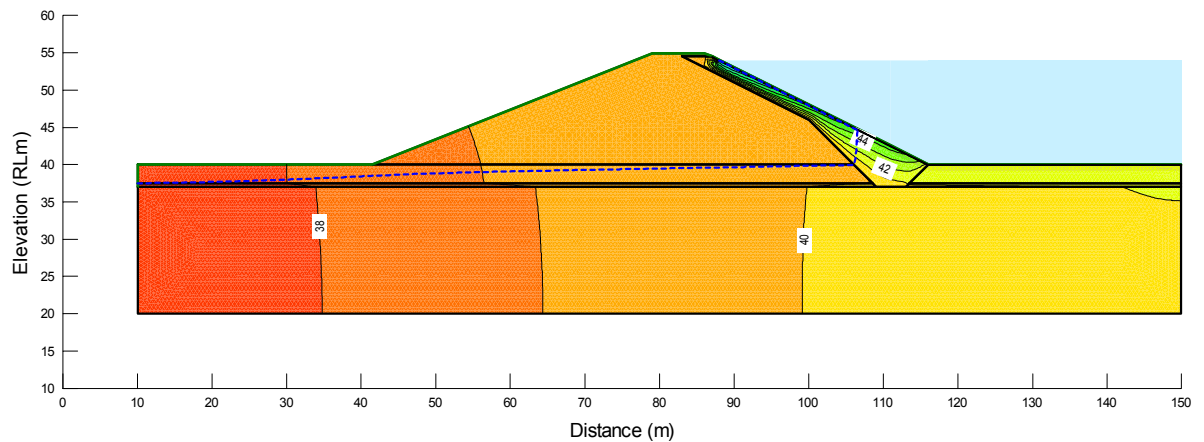


Plate 3 - Condition 3 Seepage Results



6.2 TSF EMBANKMENT STABILITY ANALYSES

Stability analyses with respect to the proposed TSF embankment configuration have been undertaken to confirm the suitability of the adopted configurations, including batter slopes. Stability modelling was carried out using the General Limit Equilibrium (GLE) method, which calculates a factor of safety against slope failure based on moment and force equilibrium. Slope stability analyses were completed using the SLOPE/W computer package with the Bishop Simplified method of analysis selected. Based on the seepage analyses (**Section 6.1**), two embankment conditions were analysed as follows:

- Condition 1: Starter (Cell 3 and 4) Embankment (refer **Figure 6**)
- Condition 2: Ultimate Embankment Configuration (refer **Figure 6**)

The analysed cross-section under each condition was taken through the portion of the Stage 1 TSF embankment of greatest height.

It is noted that stability analyses in relation to internal embankments was not undertaken, as these embankments will not be exposed for extended periods of time. Furthermore, given the preliminary phase of design works, end-of-construction and rapid drawdown conditions were not analysed.

The following outlines and quantifies the design parameters adopted in the stability analyses completed:

(i) Material Parameters

Parameters for insitu, engineered and placed materials forming the analysed TSF embankment cross sections, quantified based on geotechnical conditions as outlined in **Section 4.1** and on selection criteria for construction methods as outlined in **Section 3.0**, are summarised in **Table 6**.

Table 6 – Material Parameters Adopted for Stability Analyses

Material Type/Sequence	Bulk Density (kN/m ³)	Effective Cohesion (kPa)	Effective Friction Angle (degrees)
Foundation sequences:			
• Upper profile-soils	18.0	5	30
• Lower profile-basement	22.0	200	40
Construction Methods			
• Clay fill	17.0	5	32
• Rock fill	21.0	0	38
• Tailings Fill (Lift Sections)*	17.0	0	32
Deposited Tailings*	16.0	0	28

(ii) Hydrostatic Conditions within Embankment

Output from the steady-state seepage modelling for Conditions 1 and 2 provides a profile of the developed phreatic surface within the TSF embankment. The hydrostatic conditions represented by this phreatic surface profiles provide direct input the slope stability analyses, via coupled SEEP/SLOPE modelling. The phreatic surface used in analysis for Conditions 1 and 2 is shown on **Plates 1 and 2** respectively.

(iii) Seismic Effects

The effects of seismic loading were also considered as part of the slope stability analysis. Based on AS 1170-4 (1993), the McArthur River area is considered to fall within a zone of relatively low seismicity risk, with an acceleration coefficient (a) of around 0.05 for a 500 year ARI (operating base earthquake, OBE). For the purpose of the feasibility assessment, the estimated seismic coefficient for maximum design earthquake for use in the stability analysis was calculated by multiplying the OBE by a factor of 2.5, resulting in a seismic coefficient of 0.125.

The results of the stability analyses under the conditions as described above are summarised in **Table 7**.

Table 7 – Results of Stability Analyses

Modelling Condition	Target Minimum Factor of Safety*	Condition 1	Condition 2
Steady State Seepage	1.50	2.04	1.67
Steady State Seepage with Seismic Effects	1.1	1.52	1.28

* Based on **Section 3.0**

The critical failure surfaces for Conditions 1 and 2 under steady state seepage conditions are shown on **Plates 4, and 5**, respectively. The results of these analyses, compared with the nominated target minimum factors of safety, indicates that the adopted embankment configuration is stable.

Plate 4 - Condition 1 Stability Result (Steady State)

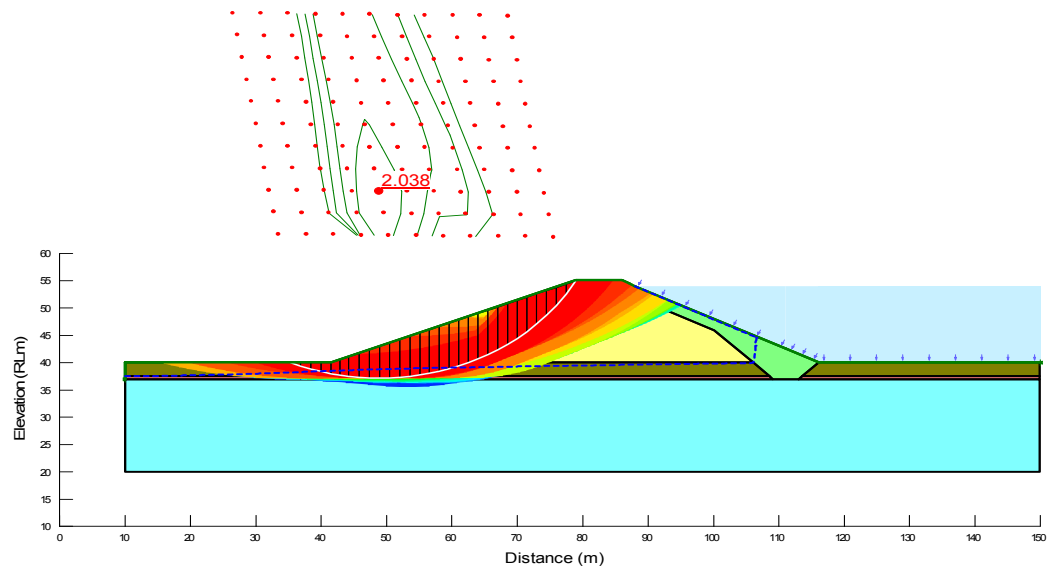
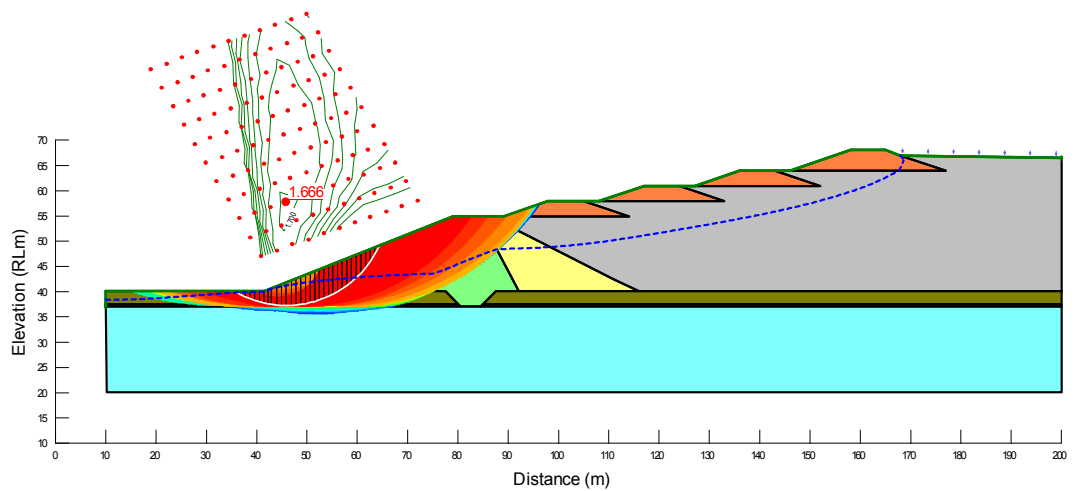


Plate 5 - Condition 2 Stability Results (Steady State)



SECTION 7.0 - OPERATIONAL AND CLOSURE ASPECTS

A number of operational and closure issues apply to the expanded TSF to maintain consistency with the concept design philosophies adopted. These issues are outlined as follows:

7.1 TAILINGS DEPOSITION PRACTICES

As outlined in **Section 3.0**, the general design philosophy adopted for the TSF expansion is based on the use of sub-aerial techniques for tailings deposition. Such techniques involve discharge of tailings from multiple locations on the perimeter of each cell. Water liberated in conjunction with the deposition phase is recovered for return to the process plant via the water management dam. **Figure 7** provides a general layout of Cells 2, 3 and 4 indicating the tailings deposition regime and associated decant locations.

The significance of sub-aerial deposition techniques in the context of the proposed TSF development concept is such that:

- tailings storage efficiencies are maximized; and
- a tailings surface is developed, possessing characteristics suitable for external embankment upstream lift construction and final rehabilitation works.

Appropriate sequencing of tailings deposition is also required to ensure that over-drying of exposed tailings surface is avoided to minimise the potential for oxidation of sulphides within the tailings or dusting of the tailings surface. Notwithstanding this requirement, it is recognised that prolonged drying of the exposed tailings surface within an inactive/resting cell will occur. A management process will be therefore required in relation to this cell to avoid the implications of over-drying. Such a process may include periodic irrigation of the beach, primarily for disposal of excess water as a means of improving the site water balance (as required). Alternatively, application of an appropriate surface treatment to limit oxidation and dusting may be undertaken.

7.2 TAILINGS WATER MANAGEMENT

Tailings water recovery from the tailings storage cell surface is integral to sub-aerial deposition techniques. During the operation of the system, a level of flexibility exists with respect to the mechanism for transferring tailings water from the cells to the water management dam, with a view to balancing the risk of spill from each of these cells, recognising that spill from the system should only occur in the event of an extreme rainfall period, and should cease generally within 24 hours of cessation of the event. Attention during operation should also be made to avoid surcharging the system with excess water volumes from alternative sources. As a general requirement, the following TSF operating condition should be maintained against which the operating conditions for tailings cell may be defined.

*At the commencement of the wet season (normally 1 November of any year), a storage allowance equivalent to a 200 year ARI, 2-month duration event (refer **Section 3.1**) should be available within each cell.*

7.3 SEEPAGE FATE AND CONTROL

Conceptually, during the operation of the TSF and into the post closure phase, seepage from the storage would occur by development of a seepage plume, initially migrating slowly downwards into the foundation sequences. Over some time, a local groundwater mound would form beneath the storage, either directly connected with the underlying groundwater system, or perched above a horizon of lower permeability (possibly the surface of the basement profile). This mound would eventually move hydraulically downgradient, likely towards the east (refer **Section 4.1.4**). The time taken for such seepage to occur would depend on the hydraulic capacity of the seepage pathways that may exist, either through the basement or beneath the cut-off key.

It is likely that the fate of seepage from the storage would be to concentrate through the drainage line to the east of the storage. Evidence of seepage from the storage would likely occur as follows:

- Expression of seepage at ground surface directly downstream from the embankment, through the drainage lines.
- Depending on the continuity of surface soils, some seepage springs may appear in depressions/hollows or intersecting drainages further downstream.

From the seepage analysis completed (refer **Section 6.1**), it appears that the most significant mechanism for seepage from the TSF to occur is through the embankment foundation units, or to a lesser extent, through the embankment. There are a number of feasible measures, focussing on these seepage mechanisms, which can reduce the magnitude of seepage from the storage. The seepage control measures that have been incorporated into the seepage model and reflected in the TSF concept design are as follows:

- A foundation cut-off key to intersect the basement sequences.
- A low permeability embankment core zone.

The seepage rates estimated from the analysis, based on the above control measures (recognising that these results are conservative based on the saturated conditions assumed), are of a magnitude that are considered manageable, and represent only a small proportion of the total water inputs to the tailings dam. It is appropriate, however, that seepage collection points be formed downstream from the embankment to enable recovery of any seepage expression occurring beyond the storage.

In addition to the proposed seepage control measures, monitoring and if necessary, subsequent implementation of additional seepage controls is a fundamental component of the TSF development. Groundwater monitoring, particularly downgradient from the TSF should be implemented. Where additional controls are considered necessary, such controls may comprise one or a combination of the following:

- Installation of pumps in the groundwater monitoring bores, or construction of dedicated groundwater recovery wells;
- Refinement of the water recovery practices adopted to reduce the volume of water retained within the system.

As previously discussed, MRM will initially utilise the Cell 4 area for excess water management associated with the dewatering of the former underground workings within the proposed open pit development. Notwithstanding that no detailed assessment of water quality associated with the dewatering has been carried out under this cover, it is considered that the HDPE liner for the base of the Cell area will significantly improve the seepage performance of the cell whilst utilised as water storage facility.

7.4 TSF REHABILITATION

The typical objectives to be adopted for rehabilitation of the TSF would be to create a landform that is:

- (i) stable and sustainable;
- (ii) compatible with the surrounding landform; and
- (iii) of minimum long term environmental impact (i.e. non-polluting).

Based on these objectives, a concept for the TSF expansion is as follows:

- Landform Development

It is envisaged that the final TSF landform would comprise long-term stable external batters with an upper surface found such that ponding is substantially avoided. This would therefore necessitate a final campaign of tailings deposition within each cell to infill any significant depression. Final drainage channelling along the internal embankment alignment may then be formed, as required.

- Tailings Surface Capping

A tailings surface cap would serve the following purposes:

- (a) facilitate ongoing surface water drainage and prevent ponding;
- (b) stabilise the surface to mitigate against potential ongoing erosion; and
- (c) reduce potential rainfall infiltration into the tailings as recharge to seepage.

To meet these performance standards, the cap would comprise the following components. This configuration assumes that the tailings would remain geochemically benign.

- *Tailings Surface Stabilisation Layer*

To provide a geotechnically competent surface over the surface of the tailings, a stabilisation layer may be necessary. The purpose of the stabilisation layer would be to provide a competent subgrade or bridging layer, which would limit the effective surcharge onto the tailings surface and thereby limit potential settlements. The area most likely to require stabilisation would be the decant pond surface, due to the likely extent of saturated slimes materials.

The stabilisation layer would typically comprise rock mattress (the rock comprising competent and durable material).

- *Sealing Layer*

A sealing layer would be required to reduce the downward infiltration of surface water, which would act as a recharge to seepage. The sealing layer would be constructed using a clay fill material, which would possess similar characteristics to the clay fill proposed for use in the embankment construction. The sealing layer would extend over the full surface area of the storage.

- *Surface Protection Layer*

To protect the tailings surface from erosion and exposure deterioration (through wetting and drying), a surface protection layer would be required. This layer could also be utilised as a rooting zone for vegetation depending on the proposed end land use.

This layer would be formed typically using select run-of-mine waste rock from the open pit area. Geochemically, the waste should be non-acid producing. From a geotechnical perspective, the material should be non-erosive/dispersible.

The thickness of this layer would be selected to not only maintain drainage, but also to compensate for settlement within the underlying tailings. A hummocky final land surface may also have some benefit with respect to maintaining moisture within the surface layers to support vegetation growth and to reduce erosion potential. The final surface landform would be subject to further, ongoing assessment through the life of the facility.

A more detailed assessment of a suitable capping configuration would need to be completed, subject to more data being available with respect to the physical and geochemical characteristics of the tailings. In particular, geochemical compatibility between the tailings and capping materials must be confirmed to ensure the integrity of the capping horizon is not compromised.

SECTION 1.0 - REFERENCES

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13. Vick, S.G (1983); *Planning, Design and Analysis of Tailings Dams*, John Wiley and Sons.

FIGURES

TIMOR SEA



DARWIN

JABIRU

PINE CREEK

KATHERINE

TINDAL

MATARANKA

GULF OF CARPENTARIA

TIMBER CREEK

BORROLOOLA

KALKARINGI

NEWCASTLE WATERS

McARTHUR RIVER MINE

WESTERN AUSTRALIA

NORTHERN TERRITORY

TENNANT CREEK

QUEENSLAND

BARROW CREEK

ALICE SPRINGS

YULARA

SOUTH AUSTRALIA

0km 100km 200km 300km 400km 500km



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CLIENT **McARTHUR RIVER MINING PTY LTD**

JOB NUMBER **0328-MRM-003**

PROJECT **McARTHUR RIVER MINE PHASE 3 DEVELOPMENT
TSF CONCEPT DESIGN**

DRAWING

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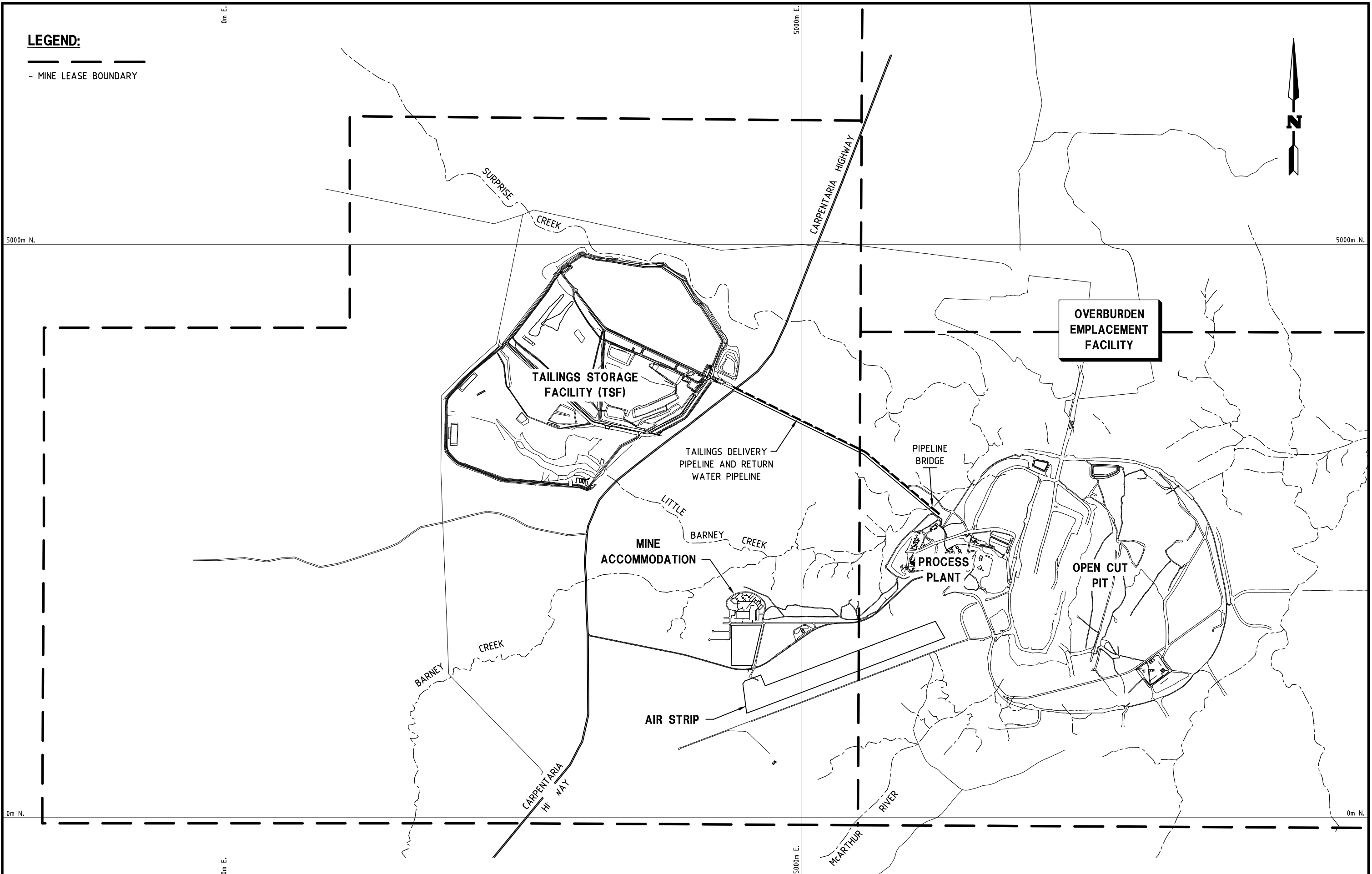
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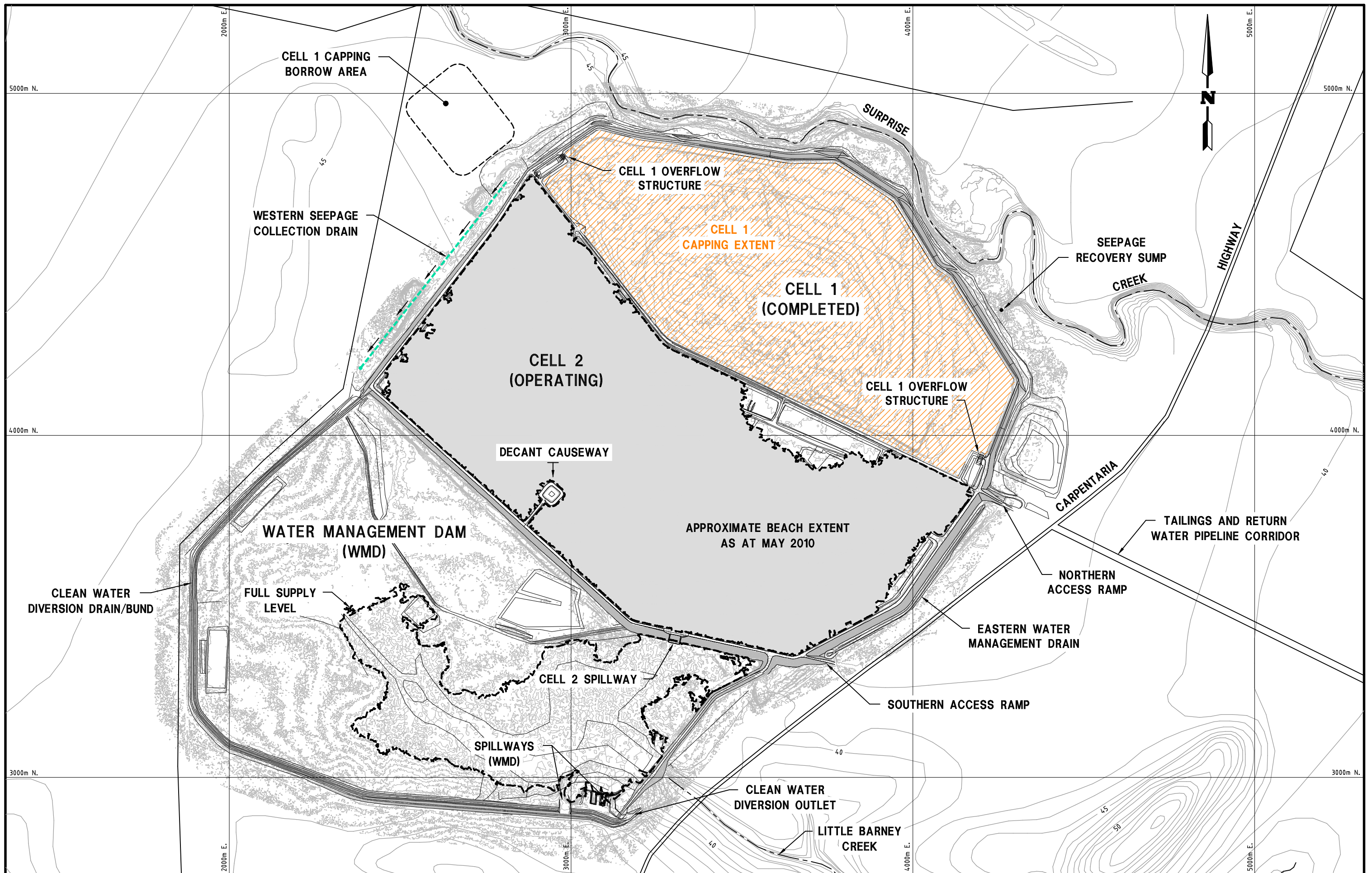
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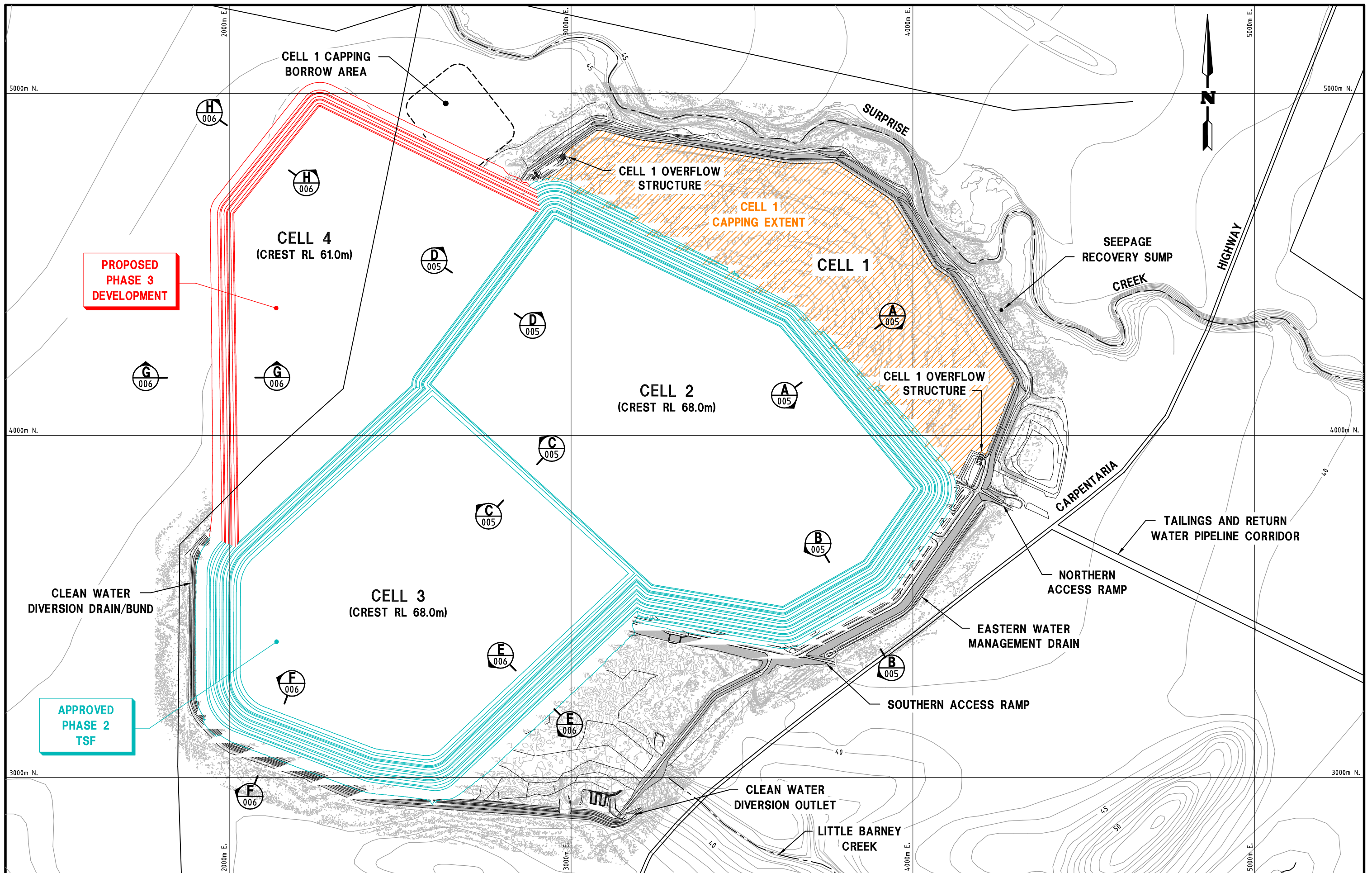


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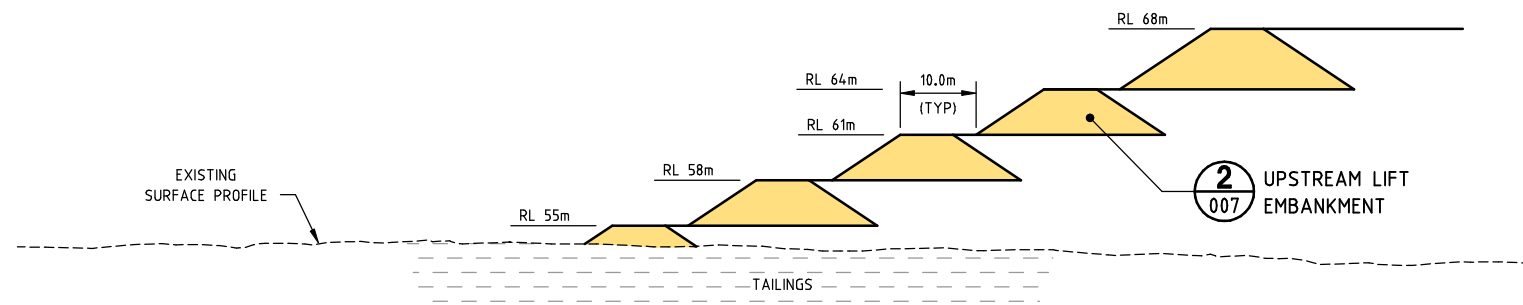


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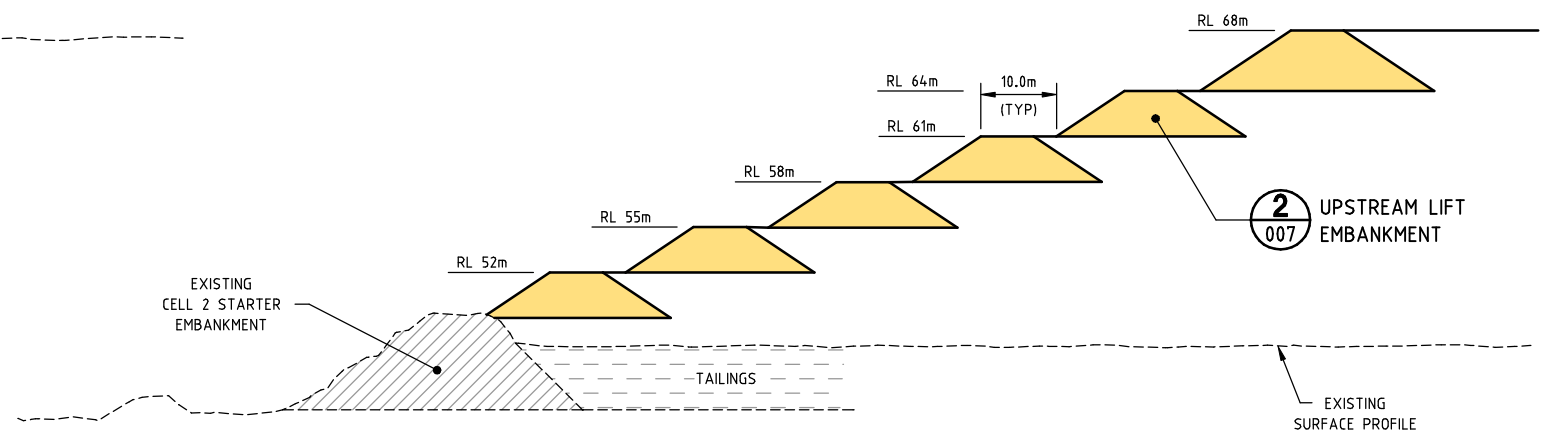
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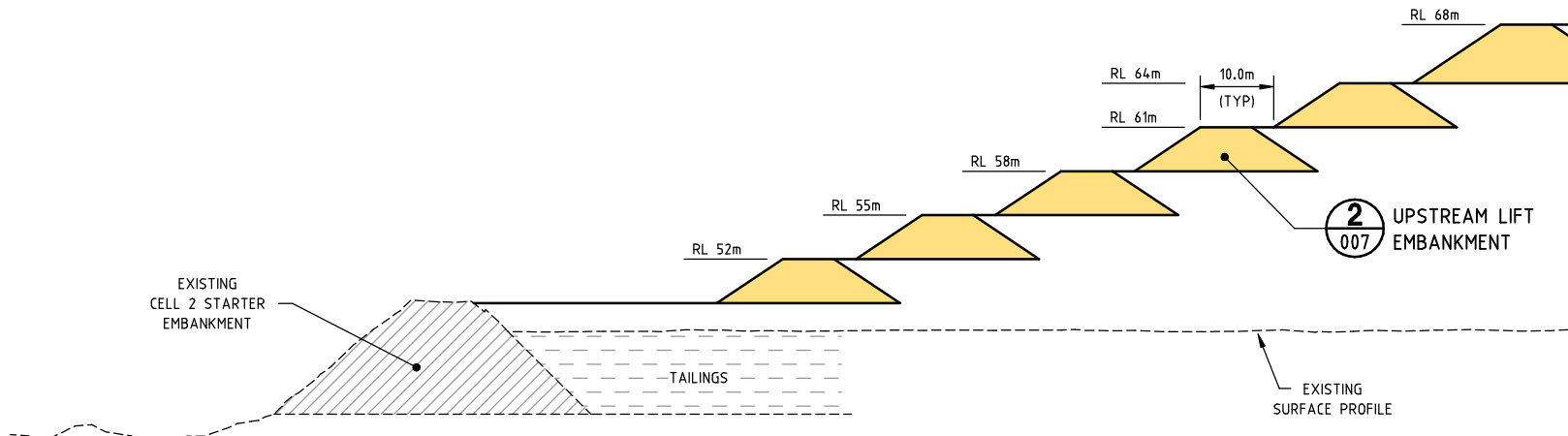
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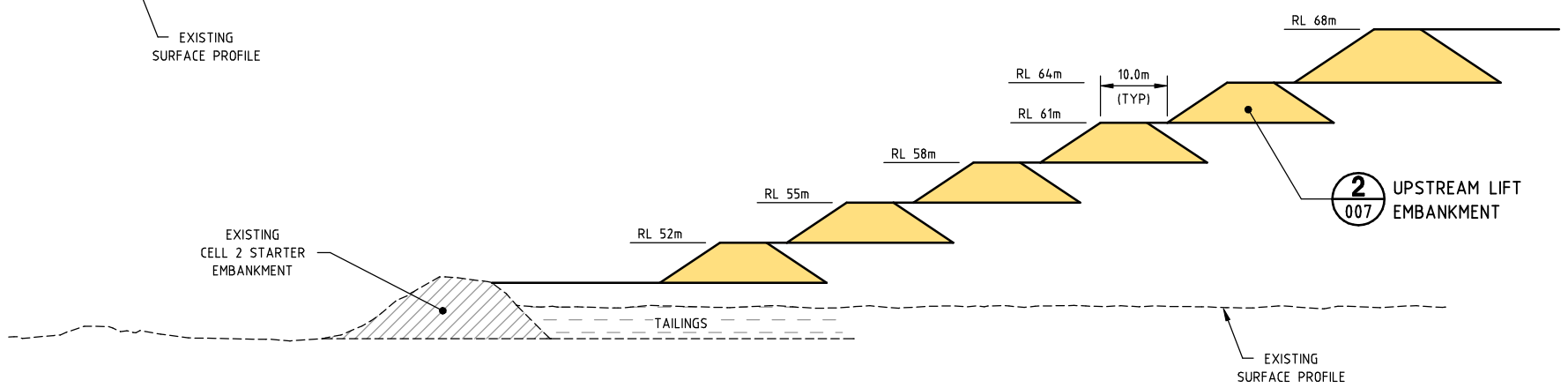
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SECTION B TSF CELL 2 EMBANKMENT
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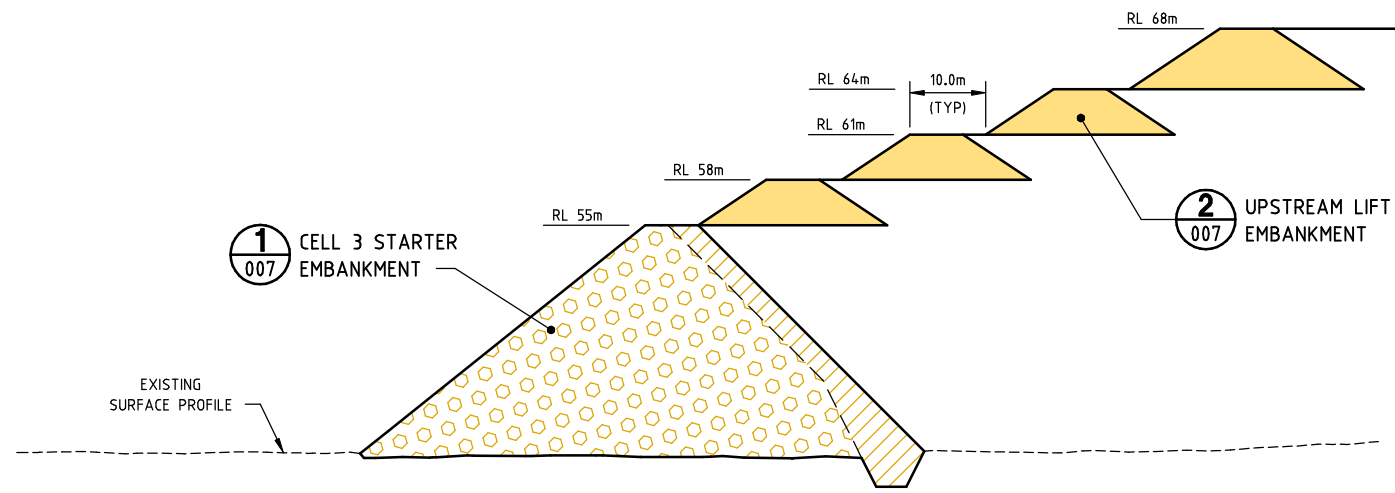
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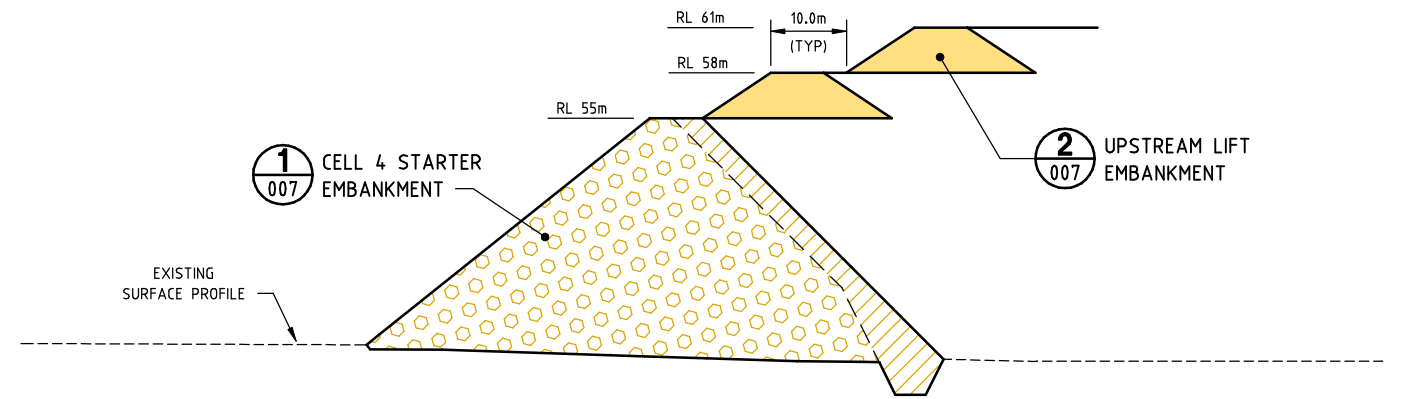
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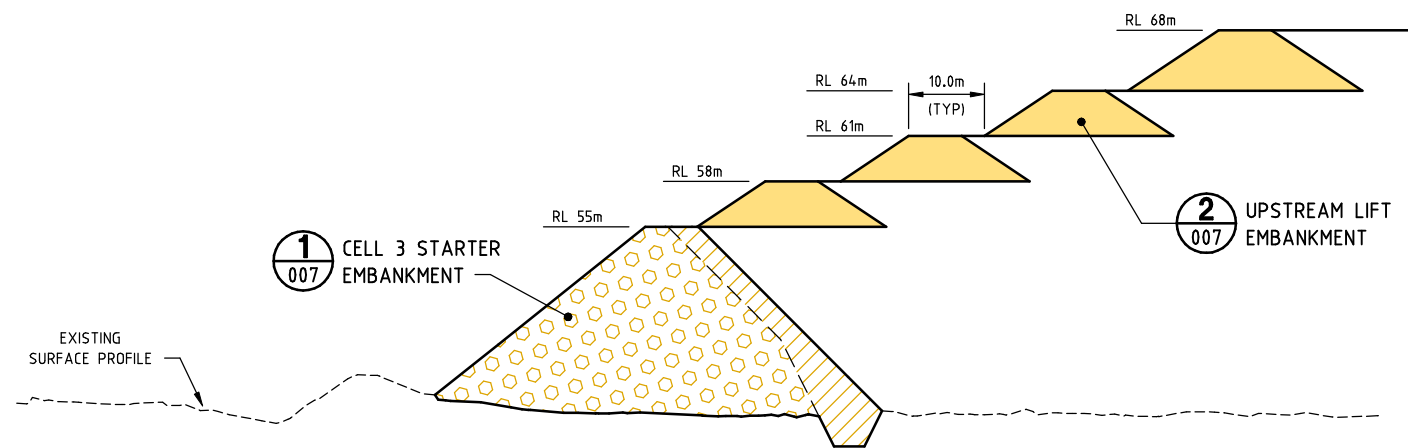
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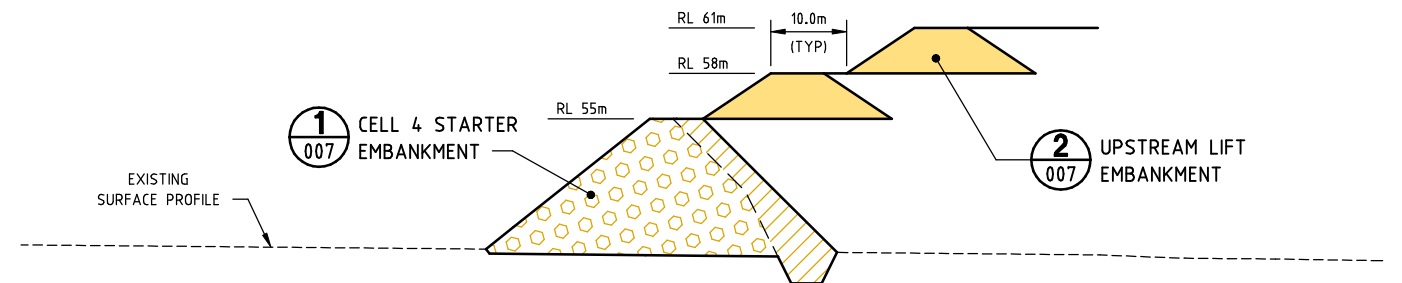
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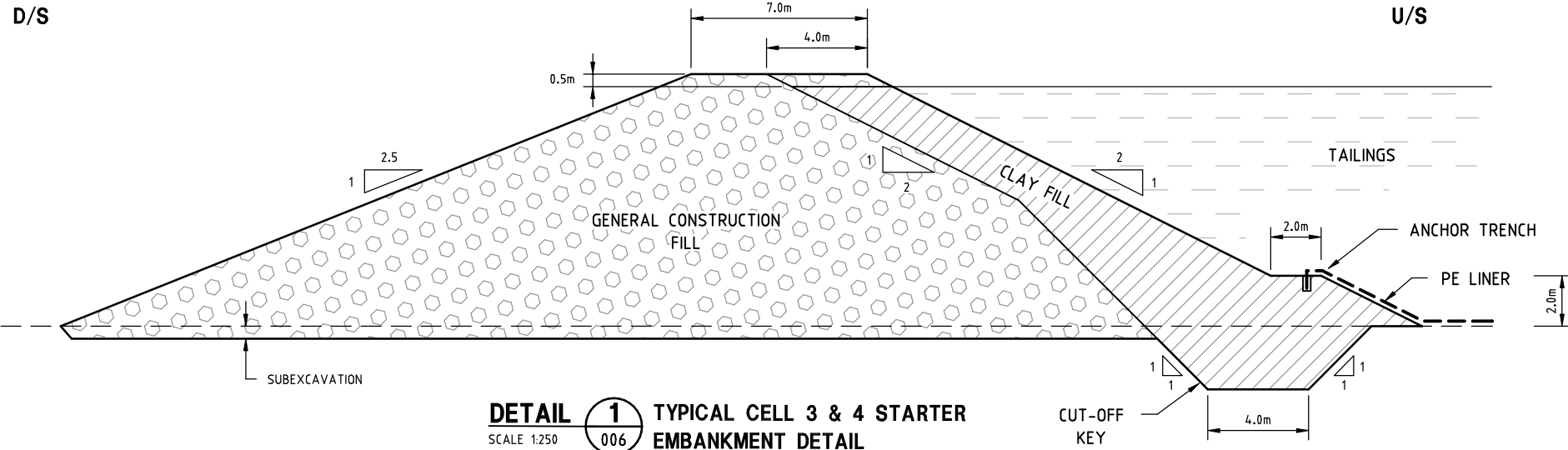


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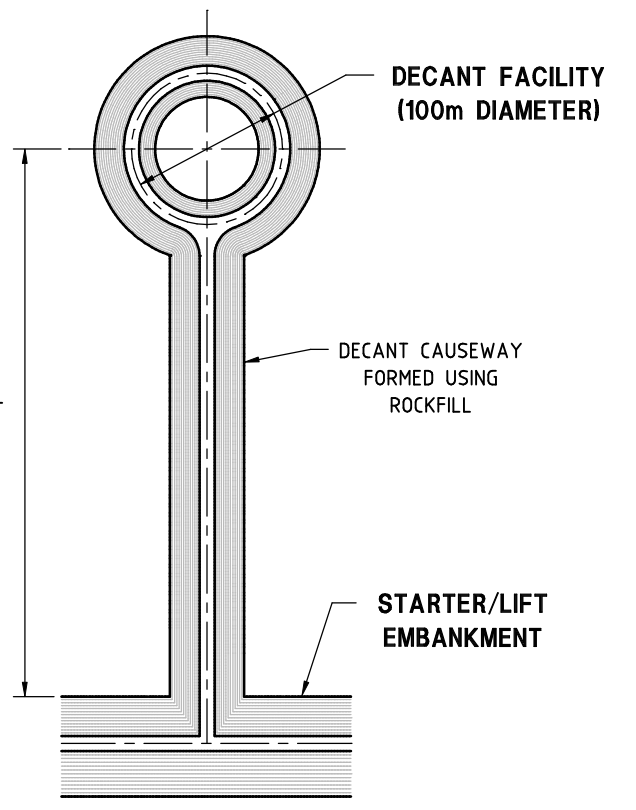
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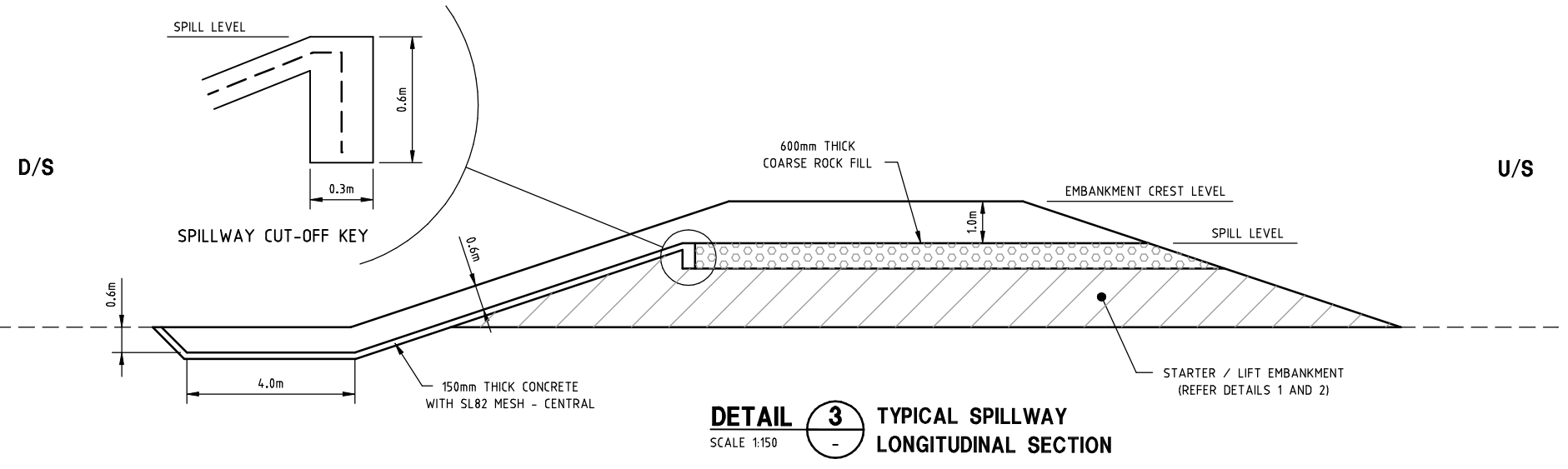
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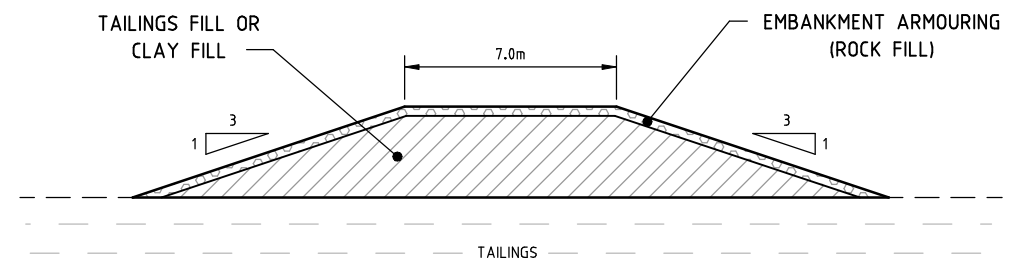
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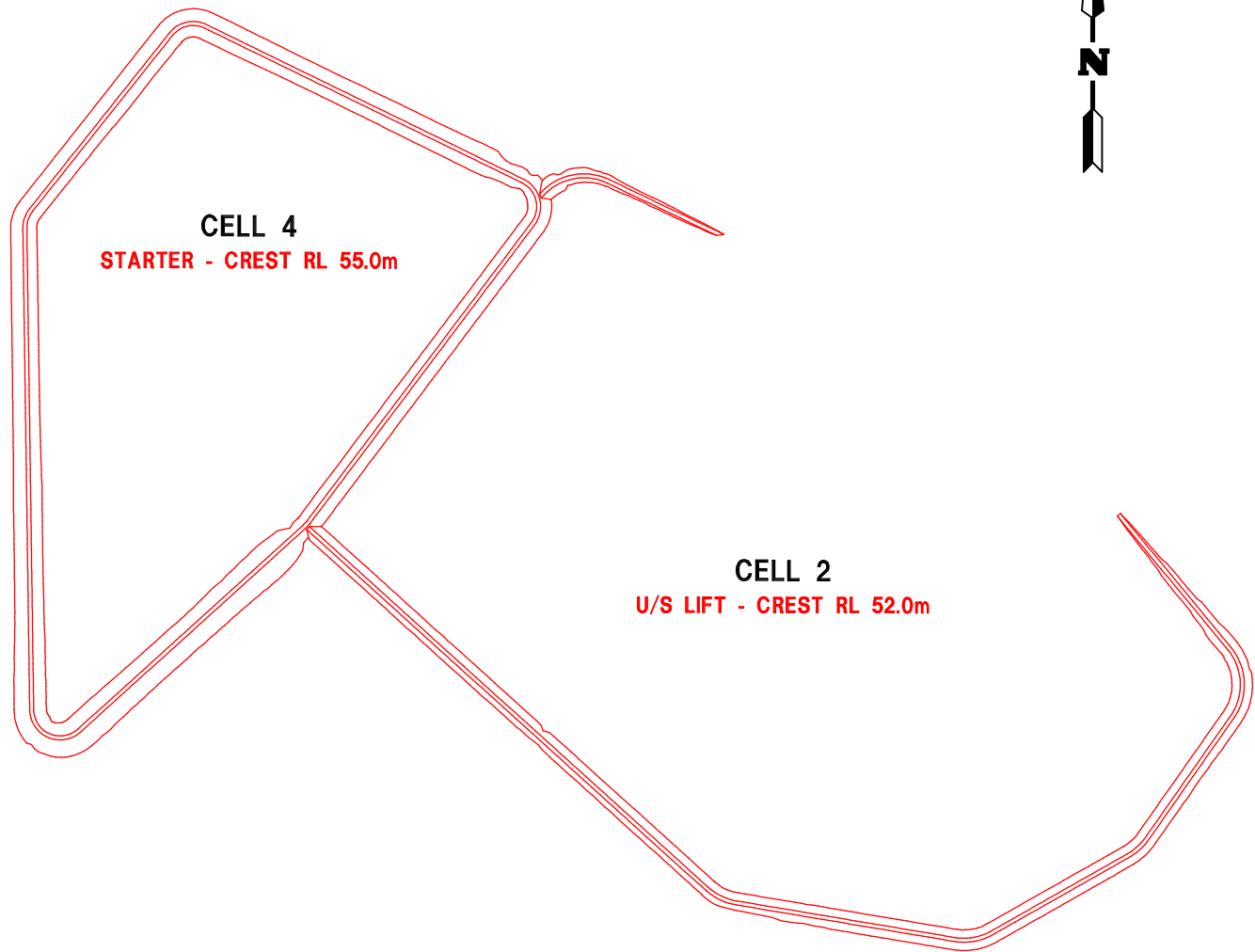
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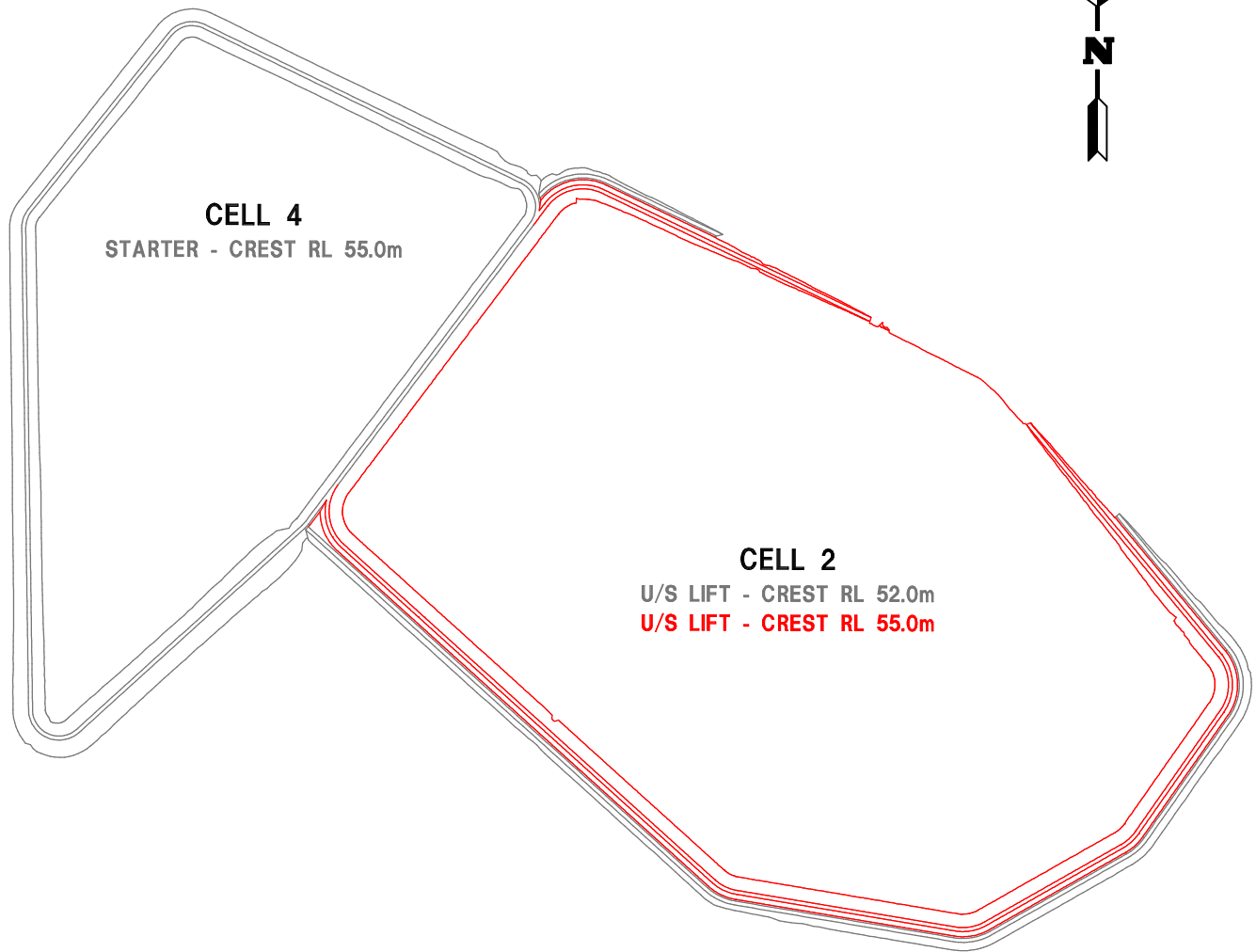
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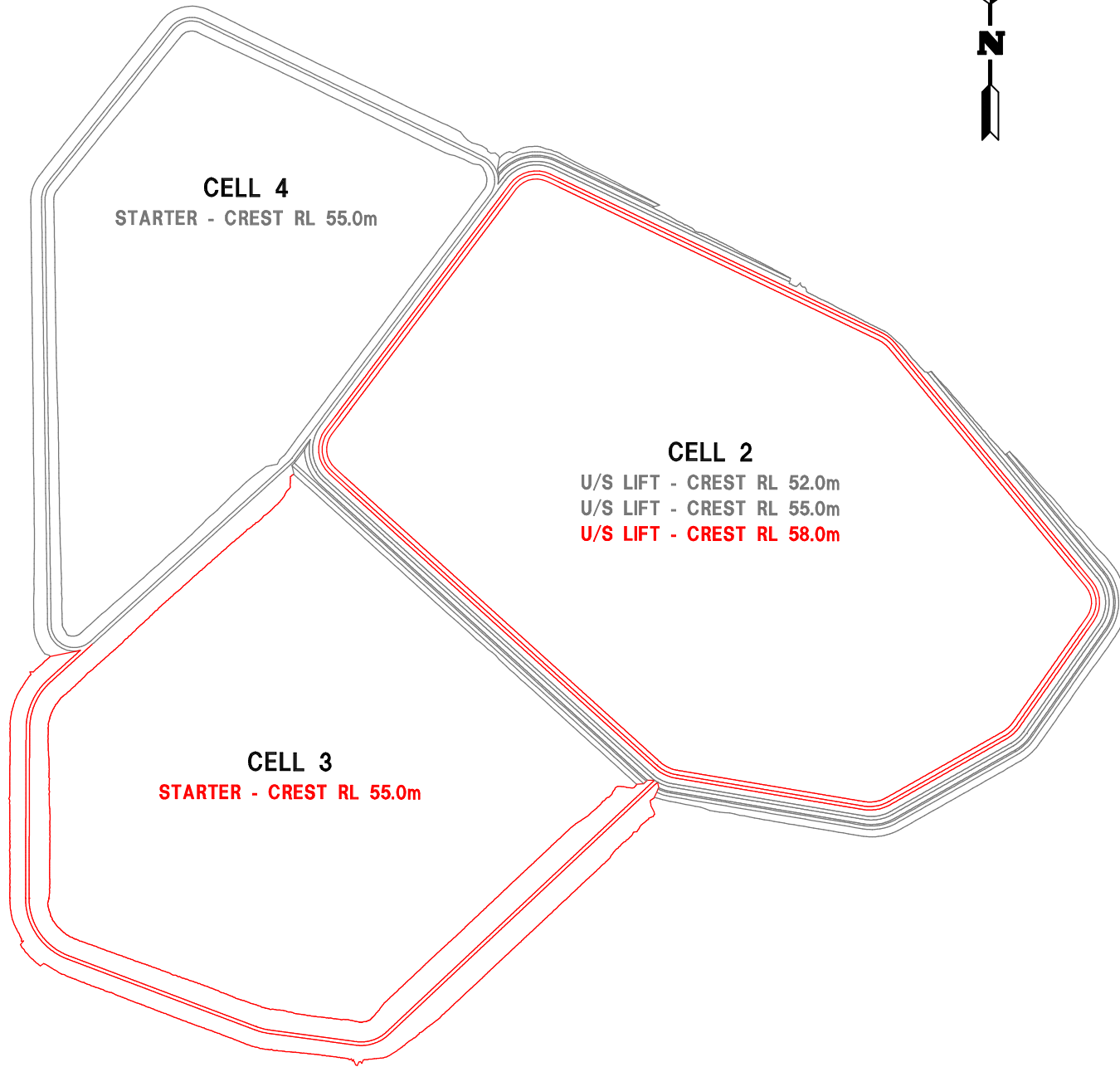
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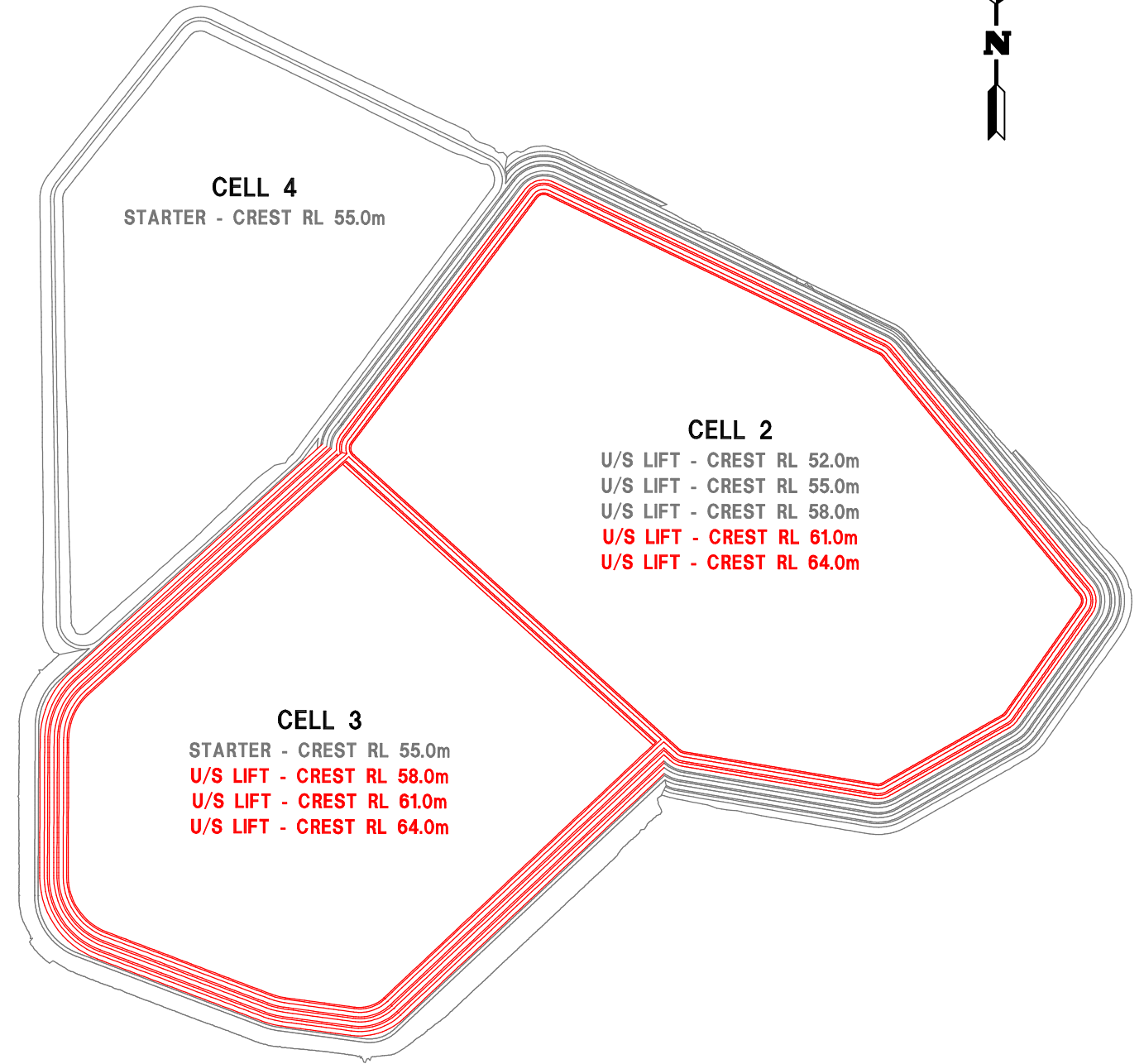
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JOB NUMBER 0328-MRM-003
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**TSF DEVELOPMENT SNAPSHOT
YEAR 2020**



**TSF DEVELOPMENT SNAPSHOT
YEAR 2025**

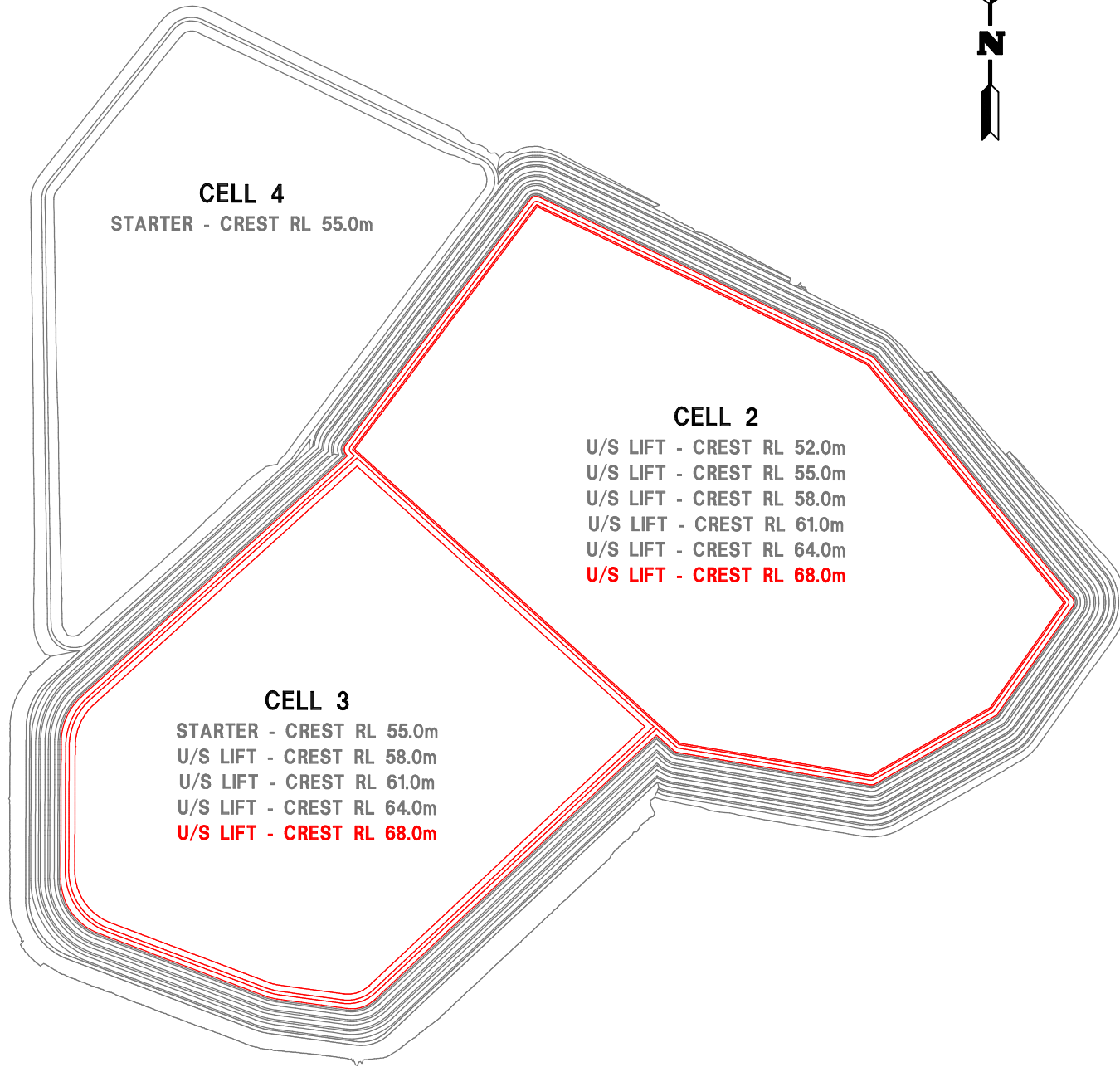
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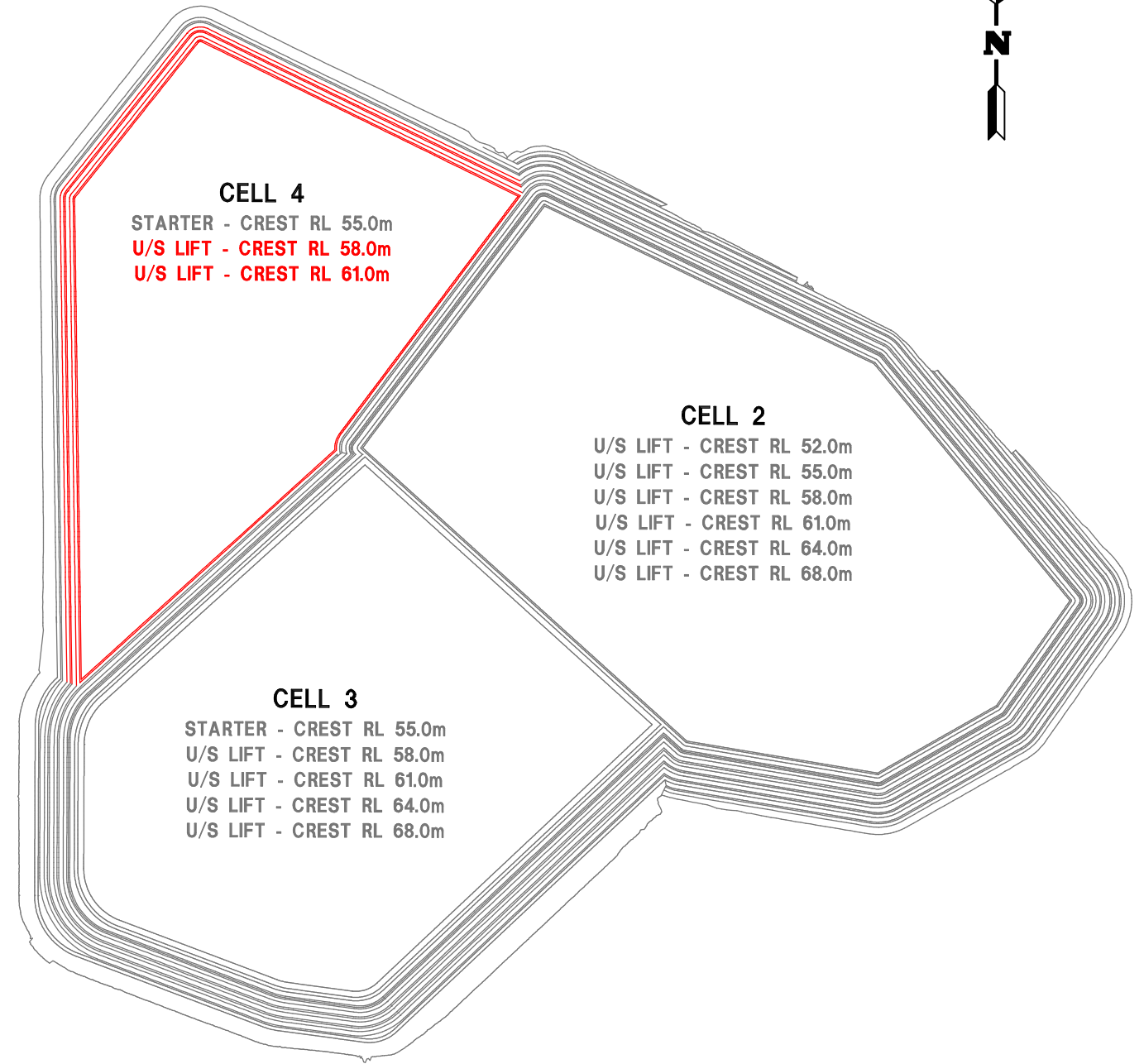
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DESIGNED	SCALE 1:12,500	CLIENT
DRAWN RJS	LEVEL DATUM	PROJECT McARTHUR RIVER MINE PHASE 3 DEVELOPMENT TSF CONCEPT DESIGN
CHECKED RJH	SHEET SIZE A3	
APPROVED	CAD FILE 0328-MRM-003-010	TITLE TAILINGS STORAGE FACILITY DEVELOPMENT SNAPSHOTS YEAR 2020 AND YEAR 2025
DATE SEPT. 2011	ISSUE REVIEW	REV

CLIENT McARTHUR RIVER MINING PTY LTD	JOB NUMBER 0328-MRM-003
PROJECT McARTHUR RIVER MINE PHASE 3 DEVELOPMENT TSF CONCEPT DESIGN	DRAWING 009
TITLE TAILINGS STORAGE FACILITY DEVELOPMENT SNAPSHOTS YEAR 2020 AND YEAR 2025	REV



**TSF DEVELOPMENT SNAPSHOT
YEAR 2030**



**TSF DEVELOPMENT SNAPSHOT
YEAR 2036 (FINAL)**

REV	DESCRIPTION	DATE	APPROVED



ALLAN WATSON ASSOCIATES
Waste and Water Management Consultants
ABN 24 081 272 406
PO Box 43
Alderley QLD 4051
PH (07) 3352 7222
FAX (07) 3856 3557

DESIGNED	SCALE	CLIENT
	1:12,500	McARTHUR RIVER MINING PTY LTD
DRAWN RJS	LEVEL DATUM	PROJECT
CHECKED RJH	SHEET SIZE A3	
APPROVED	CAD FILE 0328-MRM-003-011	TITLE
DATE SEPT. 2011	ISSUE REVIEW	

CLIENT	PROJECT	TITLE
McARTHUR RIVER MINING PTY LTD	McARTHUR RIVER MINE PHASE 3 DEVELOPMENT TSF CONCEPT DESIGN	TAILINGS STORAGE FACILITY DEVELOPMENT SNAPSHOTS YEAR 2030 AND YEAR 2036 (FINAL)

JOB NUMBER	DRAWING	REV
0328-MRM-003	010	

APPENDICES

APPENDIX A
TAILINGS CHARACTERISATION TESTWORK DATA

ATTERBERG LIMITS TEST REPORT

Test Method: AS1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client: Allan Watson Associates Pty Ltd	Report No. 10110310-AL
Project: 0328-MRM-002	Test Date: 21/12/10 Report Date: 10/01/11

Client ID: Sample1	Depth(m): 2.0	Sample No. 10110310
Liquid Limit (%):	Not Obtainable	Linear Shrinkage (%): Not Obtainable
Plastic Limit (%):	Not Obtainable	Field Moisture Content (%): 11.6
Plasticity Index (%):	Non Plastic	

Client ID: Sample 2	Depth(m): 15.0	Sample No. 10110311
Liquid Limit (%):	Not Obtainable	Linear Shrinkage (%): Not Obtainable
Plastic Limit (%):	Not Obtainable	Field Moisture Content (%): 10.2
Plasticity Index (%):	Non Plastic	

Client ID: Sample 3	Depth(m): 30.0	Sample No. 10110312
Liquid Limit (%):	Not Obtainable	Linear Shrinkage (%): Not Obtainable
Plastic Limit (%):	Not Obtainable	Field Moisture Content (%): 9.7
Plasticity Index (%):	Non Plastic	

Client ID: Sample 4	Depth(m): 50.0	Sample No.10110313
Liquid Limit (%):	Not Obtainable	Linear Shrinkage (%): Not Obtainable
Plastic Limit (%):	Not Obtainable	Field Moisture Content (%): 12.7
Plasticity Index (%):	Non Plastic	

Remarks: The sample/s were tested oven dried, dry sieved and in a 125 – 250mm mould.
 *Crumbling occurred.
 +Curling occurred

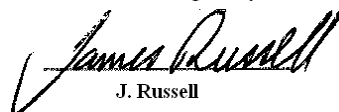
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Sample/s supplied by the client Page: 1 of 1



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J. Russell

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 Form Number:GT004-5

Manager

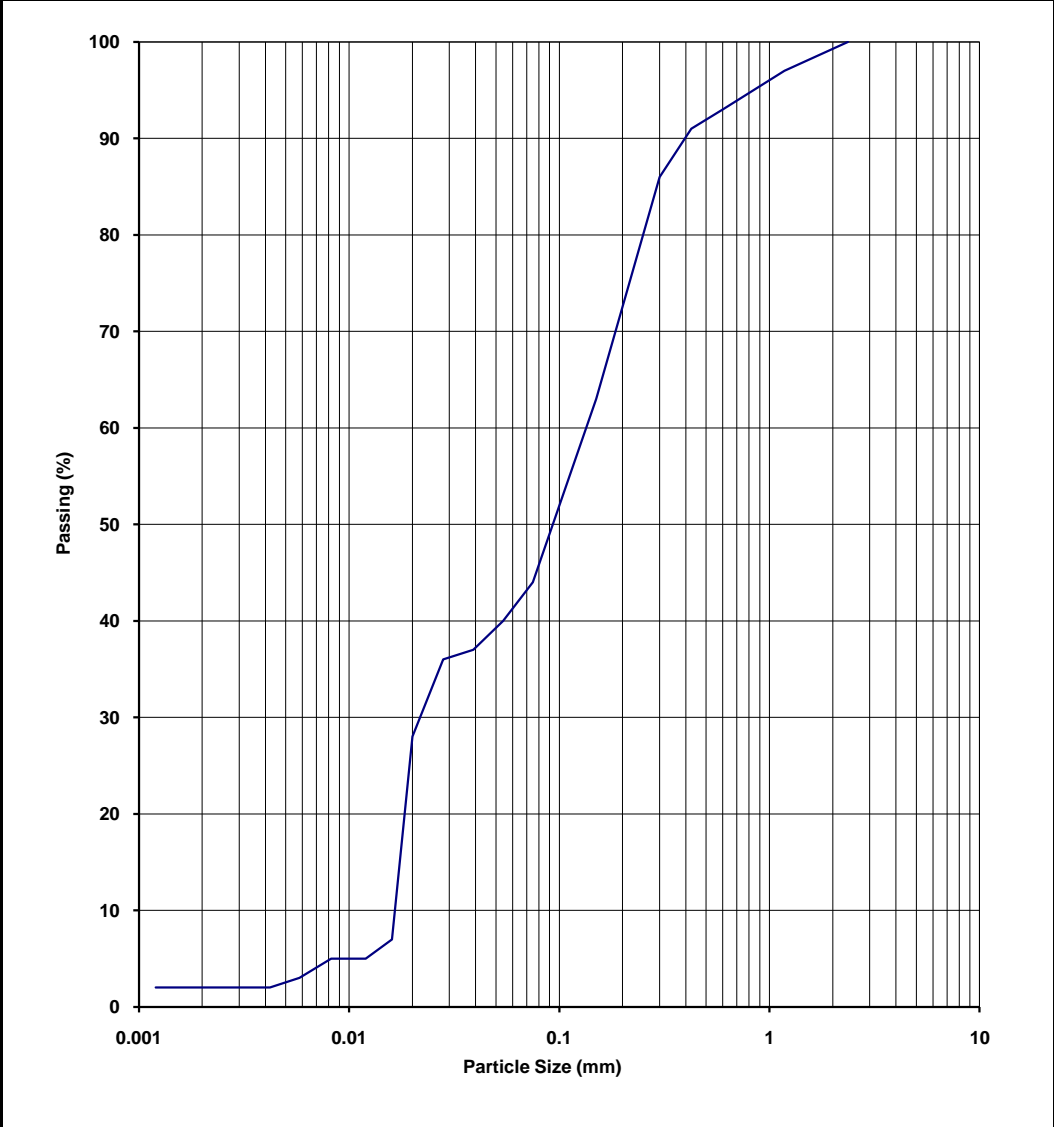


PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Allan Watson Associates Pty Ltd	Report No.	10110310-G
Project	0328-MRM-002	Test Date	17/12/2010
Client ID	Sample No. 1	Report Date	10/1/2011
		Depth (m)	2.00

Sieve Size (mm)	Passing %
150.0	
75.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	100
1.18	97
0.600	93
0.425	91
0.300	86
0.150	63
0.075	44
0.054	40
0.039	37
0.028	36
0.02	28
0.016	7
0.012	5
0.0082	5
0.0058	3
0.0042	2
0.0034	2
0.003	2
0.0024	2
0.0021	2
0.0012	2



NOTES/REMARKS:

Moisture Content 11.6% -2.36mm Soil Particle Density(t/m³) 3.36
 Sample/s supplied by the client

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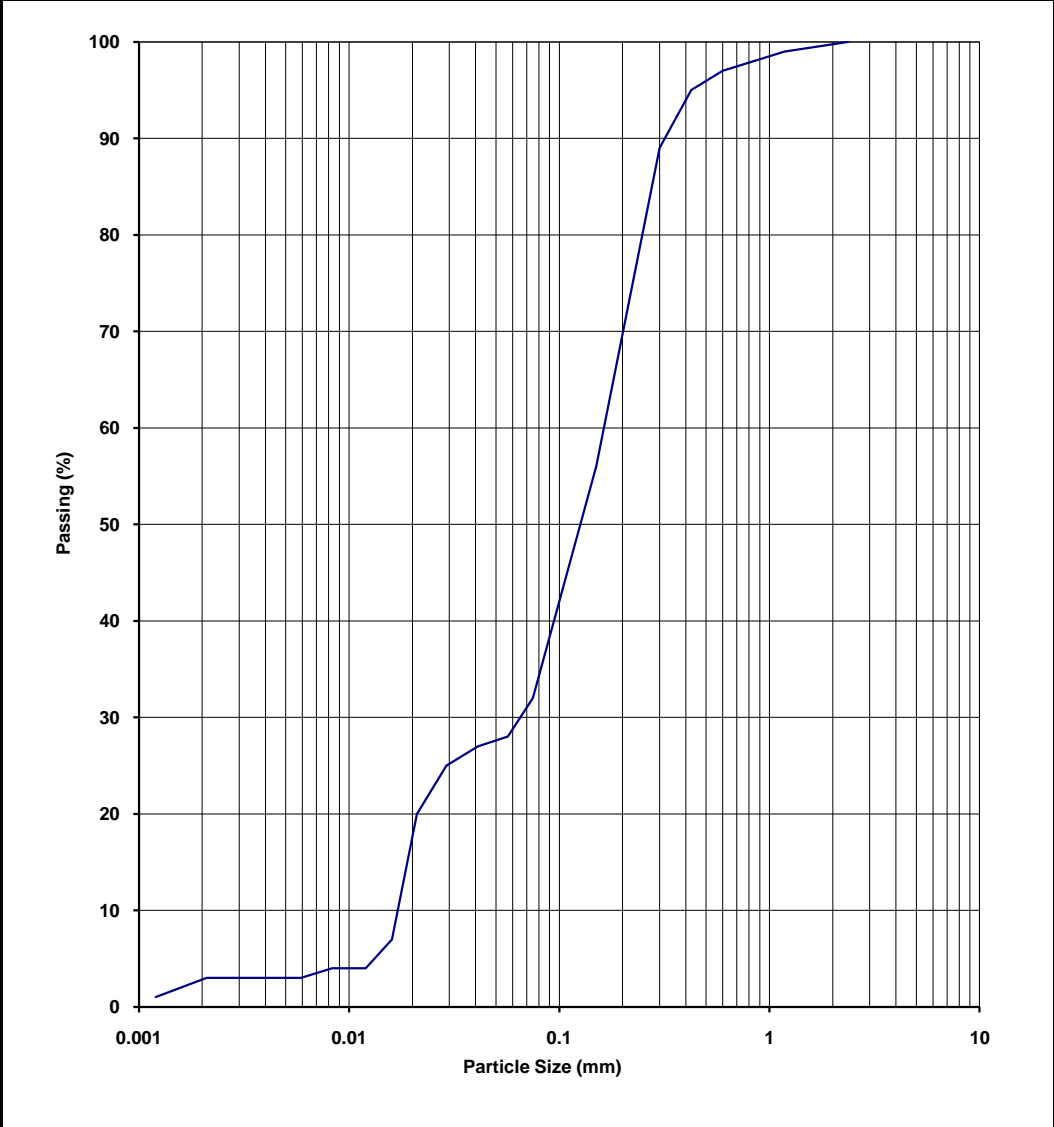
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Allan Watson Associates Pty Ltd	Report No.	10110311-G
Project	0328-MRM-002	Test Date	17/12/2010
		Report Date	10/1/2011
Client ID	Sample No. 2	Depth (m)	15.00

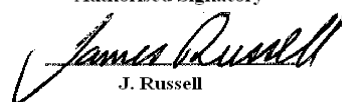
Sieve Size (mm)	Passing %
150.0	
75.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	100
1.18	99
0.600	97
0.425	95
0.300	89
0.150	56
0.075	32
0.057	28
0.041	27
0.029	25
0.021	20
0.016	7
0.012	4
0.0083	4
0.0059	3
0.0042	3
0.0034	3
0.003	3
0.0024	3
0.0021	3
0.0012	1



NOTES/REMARKS:

Moisture Content 10.2% -2.36mm Soil Particle Density(t/m³) 3.31
 Sample/s supplied by the client

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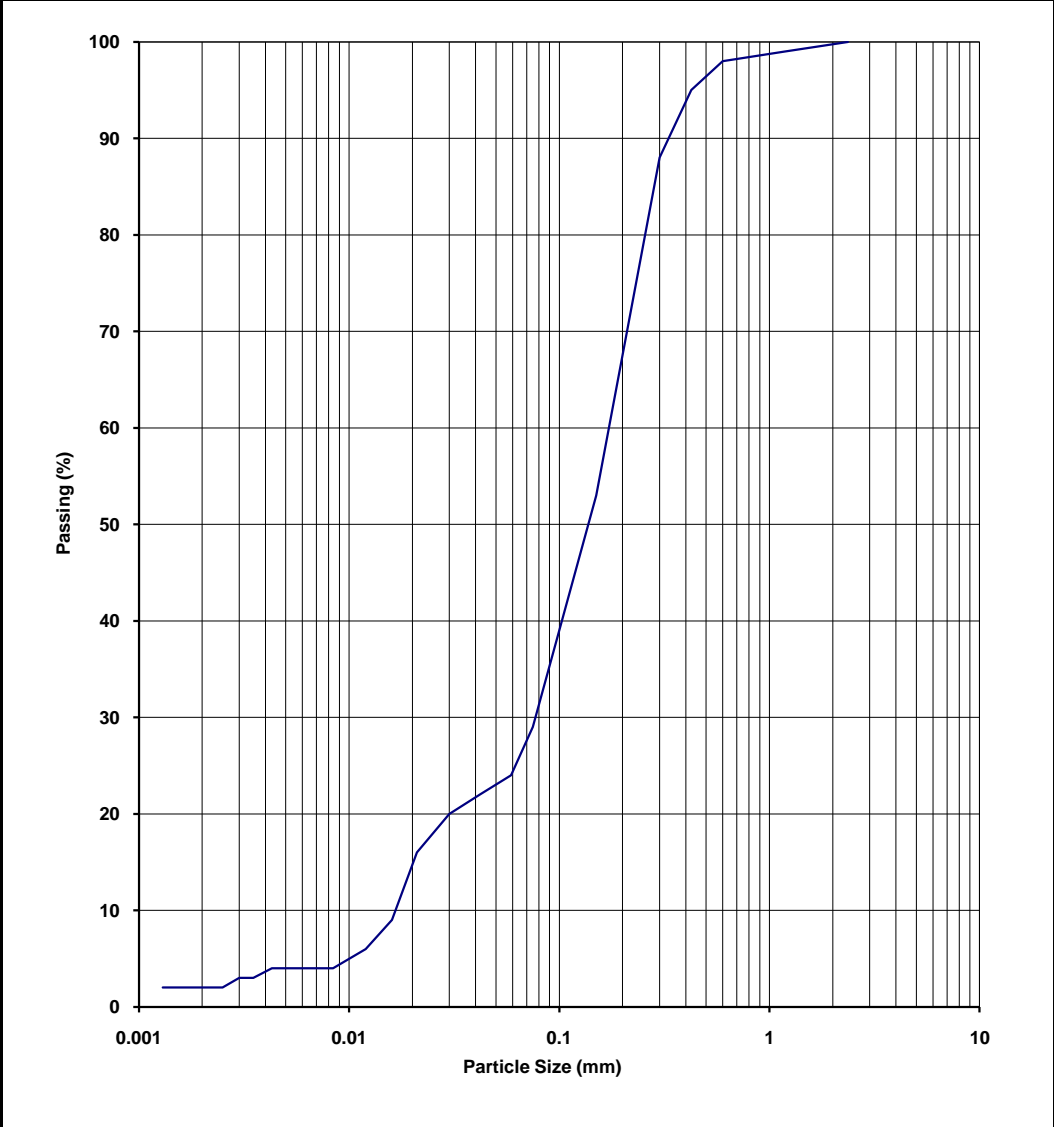
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client Allan Watson Associates Pty Ltd	Report No. 10110312-G
Project 0328-MRM-002	Test Date 17/12/2010
	Report Date 10/1/2011
Client ID Sample No. 3	Depth (m) 30.00

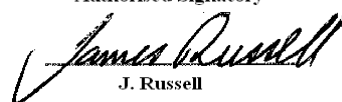
Sieve Size (mm)	Passing %
150.0	
75.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	100
1.18	99
0.600	98
0.425	95
0.300	88
0.150	53
0.075	29
0.059	24
0.042	22
0.03	20
0.021	16
0.016	9
0.012	6
0.0084	4
0.006	4
0.0043	4
0.0035	3
0.003	3
0.0025	2
0.0021	2
0.0013	2



NOTES/REMARKS:

Moisture Content 9.7% -2.36mm Soil Particle Density(t/m³) 3.24
 Sample/s supplied by the client

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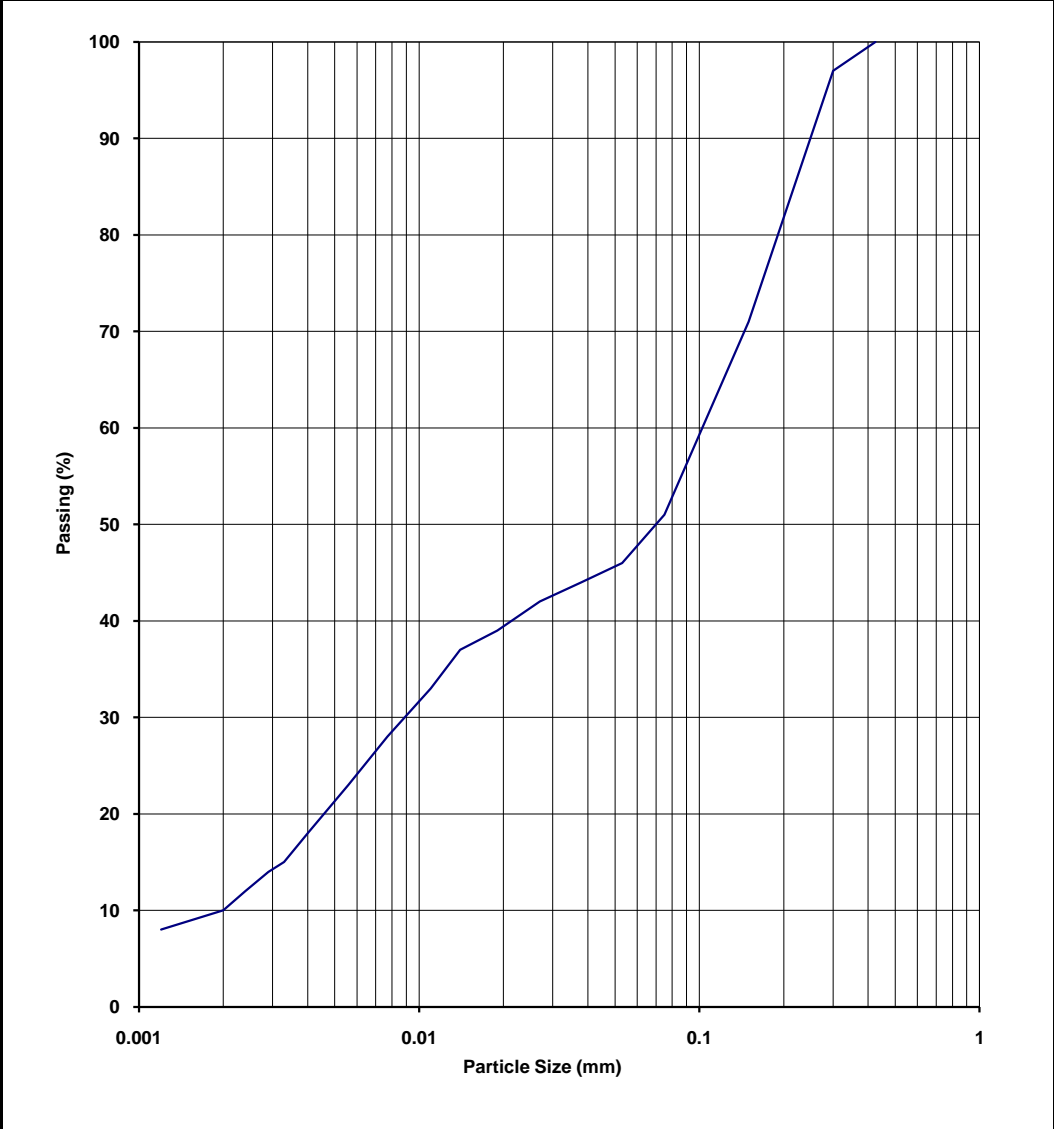
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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client	Allan Watson Associates Pty Ltd	Report No.	10110313-G
Project	0328-MRM-002	Test Date	17/12/2010
Client ID	Sample No. 4	Report Date	10/1/2011
		Depth (m)	50.00

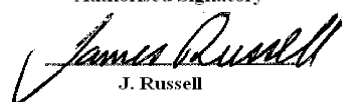
Sieve Size (mm)	Passing %
150.0	
75.0	
53.0	
37.5	
26.5	
19.0	
9.5	
4.75	
2.36	
1.18	
0.600	
0.425	100
0.300	97
0.150	71
0.075	51
0.053	46
0.038	44
0.027	42
0.019	39
0.014	37
0.011	33
0.0077	28
0.0056	23
0.004	18
0.0033	15
0.0029	14
0.0024	12
0.002	10
0.0012	8



NOTES/REMARKS:

Moisture Content 12.7% -2.36mm Soil Particle Density(t/m³) 3.33
 Sample/s supplied by the client

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test@trilab.com.au +61 7 3357 5535 www.trilab.com.au

PERMEABILITY BY FALLING HEAD TEST REPORT

Test Method: AS1289 6.7.2, KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client: Allan Watson Associates Pty Ltd	Report No. 10110314a-FHP
Project: 0328-MRM-002	Test Date: 16/12/10 Report Date: 10/01/11
Sample No:	10110314
Client ID:	Composite
Depth (m):	2m-15m-30-50m
Standard Maximum Dry Density (t/m ³):	2.07
Standard Optimum Moisture Content (%):	14.0
Placement Moisture Content (%):	14.1
Placement Wet Density (t/m ³):	2.31
Density Ratio at Placement (%):	98.0
Moisture Ratio at Placement (%):	101.0
Surcharge & Pressure applied (kPa):	0/11.6
PERMEABILITY:	$K_{20} = 5 \times 10^{-7}$ m/s
Remarks: The specimen was remoulded to a target of 98% of Standard Maximum Dry Density and at Standard Optimum Moisture Content.	
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Sample/s supplied by the client	Page: 1 of 1



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Manager

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 20/12/2010
	Report Date: 6/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m

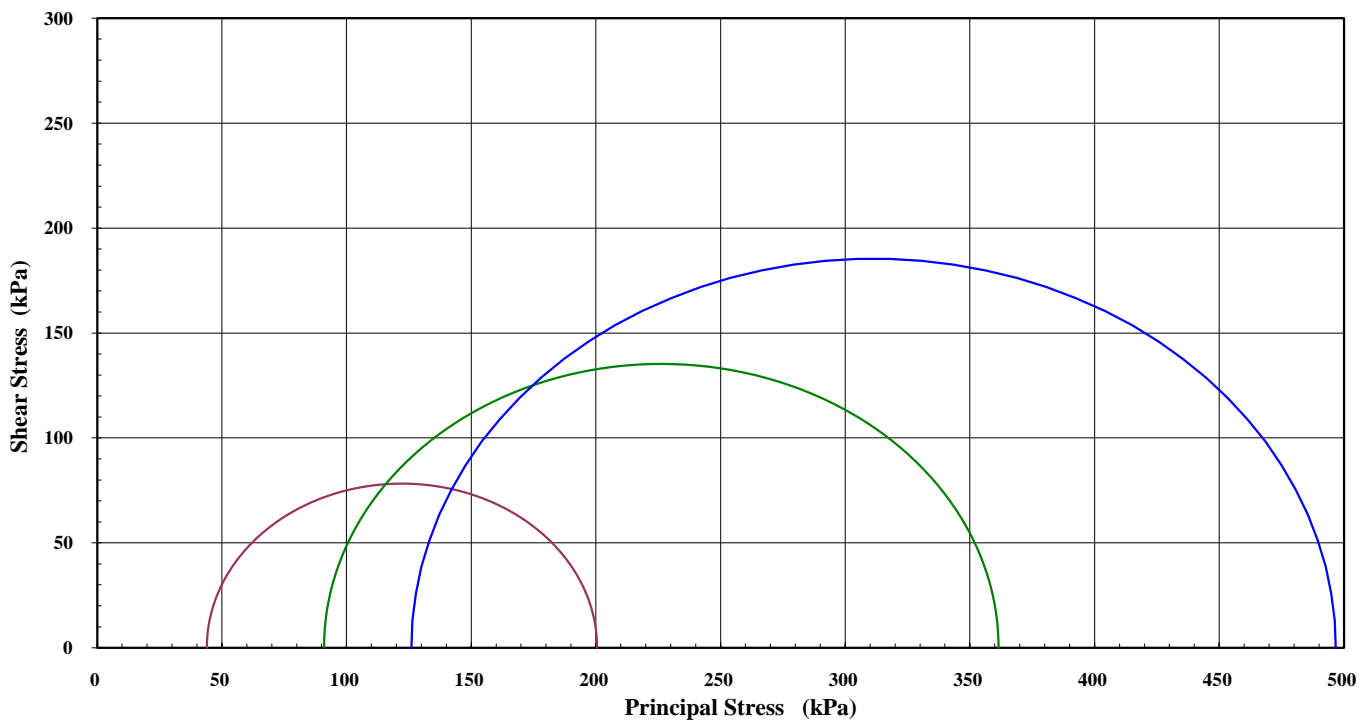
Description: Lead Zinc Tailings

SAMPLE & TEST DETAILS

Initial Height: 95.5 mm	Initial Moisture Content: 14.3 %	Rate of Strain: 0.007 %/min
Initial Diameter: 48.0 mm	Final Moisture Content: 16.6 %	B Response: 98 %
L/D Ratio: 2.0 : 1	Wet Density: 2.25 t/m ³	
	Dry Density: 1.97 t/m ³	

Failure Criteria: Peak Principal Stress Ratio

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	13.4	2.6	10.3
Angle of Shear Resistance Φ' (Degrees) :	33.3	36.1	34.5

Sample Type: Single Individual Specimen Remoulded to a target of 95% of Standard Maximum Dry Density and at Standard Optimum Moisture Content

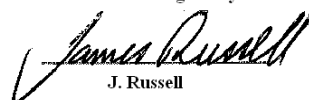
Sample/s supplied by the client Note: Graph not to scale



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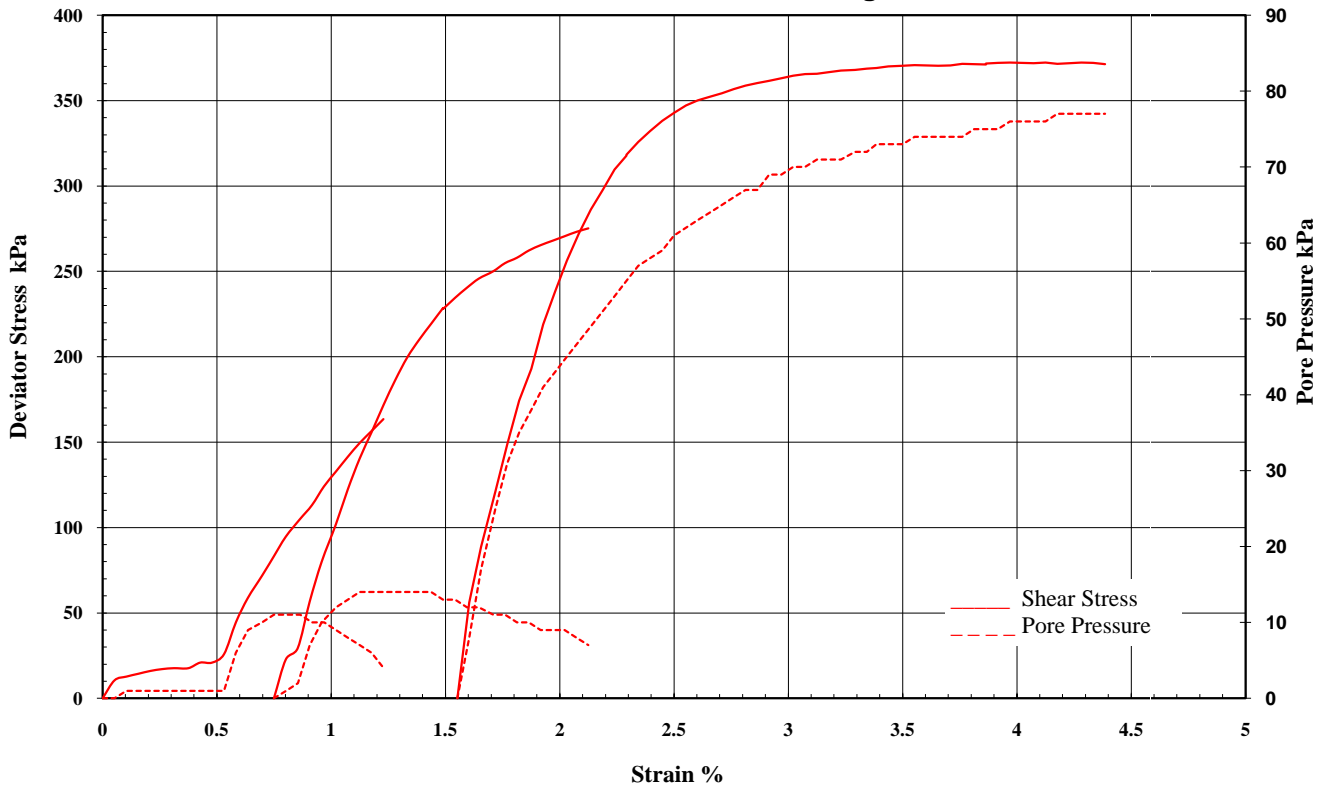
TRIAxIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 20/12/2010
	Report Date: 6/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m

Description: Lead Zinc Tailings

Stress/Strain & Pore Pressure/Strain Diagram



FAILURE DETAILS

Confining Pressure	Back Pressure	Initial Pore	Failure Pore	Principal Effective Stresses			Deviator Stress	Strain
				σ'_1	σ'_3	σ'_1 / σ'_3		
550 kPa	500 kPa	500 kPa	506 kPa	200 kPa	44 kPa	4.556	156 kPa	1.18 %
605 kPa	505 kPa	505 kPa	514 kPa	362 kPa	91 kPa	3.973	271 kPa	2.02 %
705 kPa	505 kPa	505 kPa	582 kPa	497 kPa	126 kPa	3.942	371 kPa	3.55 %

Sample Type: Single Individual Specimen Remoulded to a target of 95% of Standard Maximum Dry Density and at Standard Optimum Moisture Content

Sample/s supplied by the client Note: Graph not to scale



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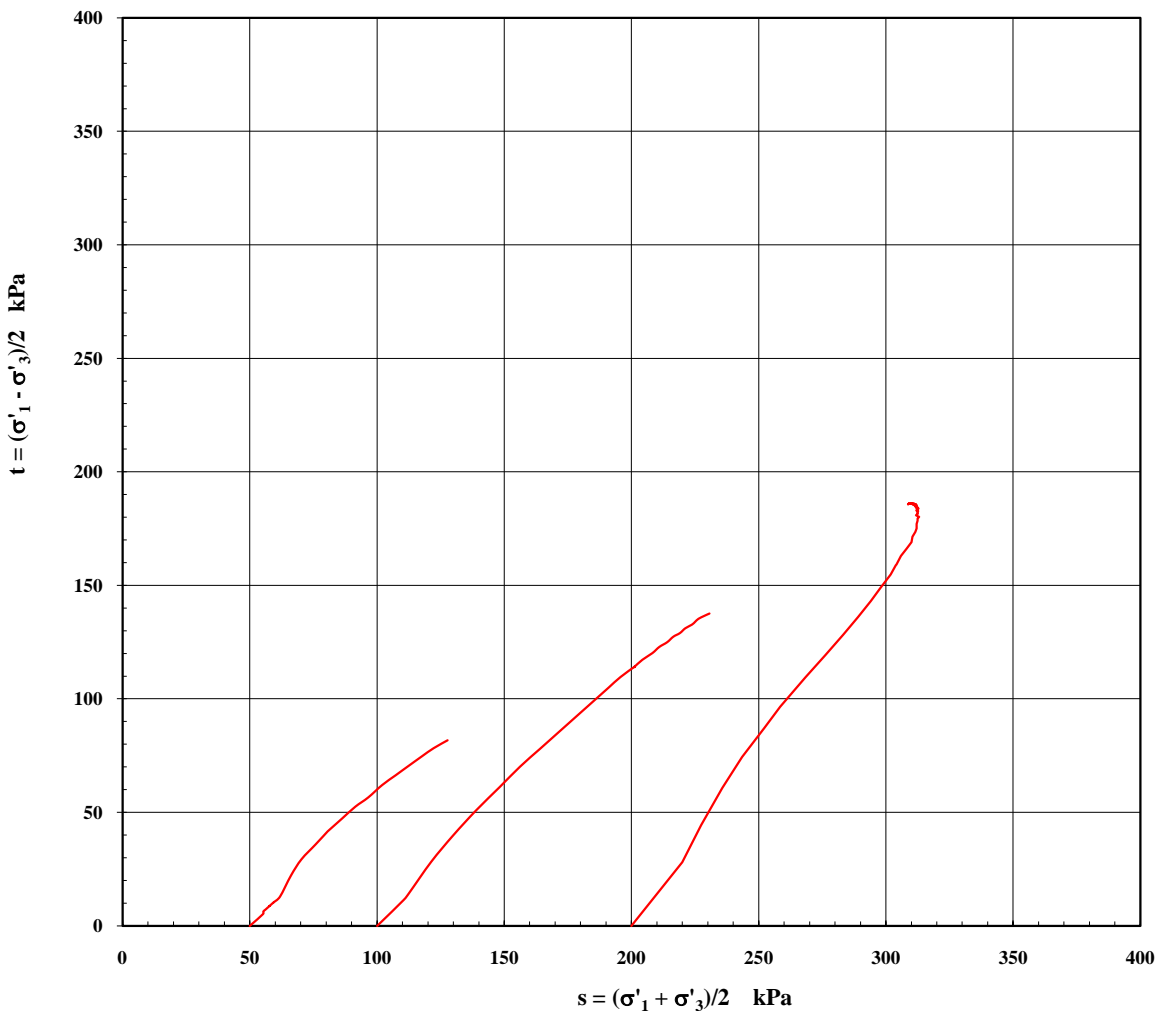
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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 20/12/2010 Report Date: 6/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m
Description: Lead Zinc Tailings	

MIT Method - Effective Stress Path



Note: Graph not to scale.

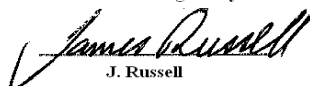
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Sample/s supplied by the client Note: Graph not to scale



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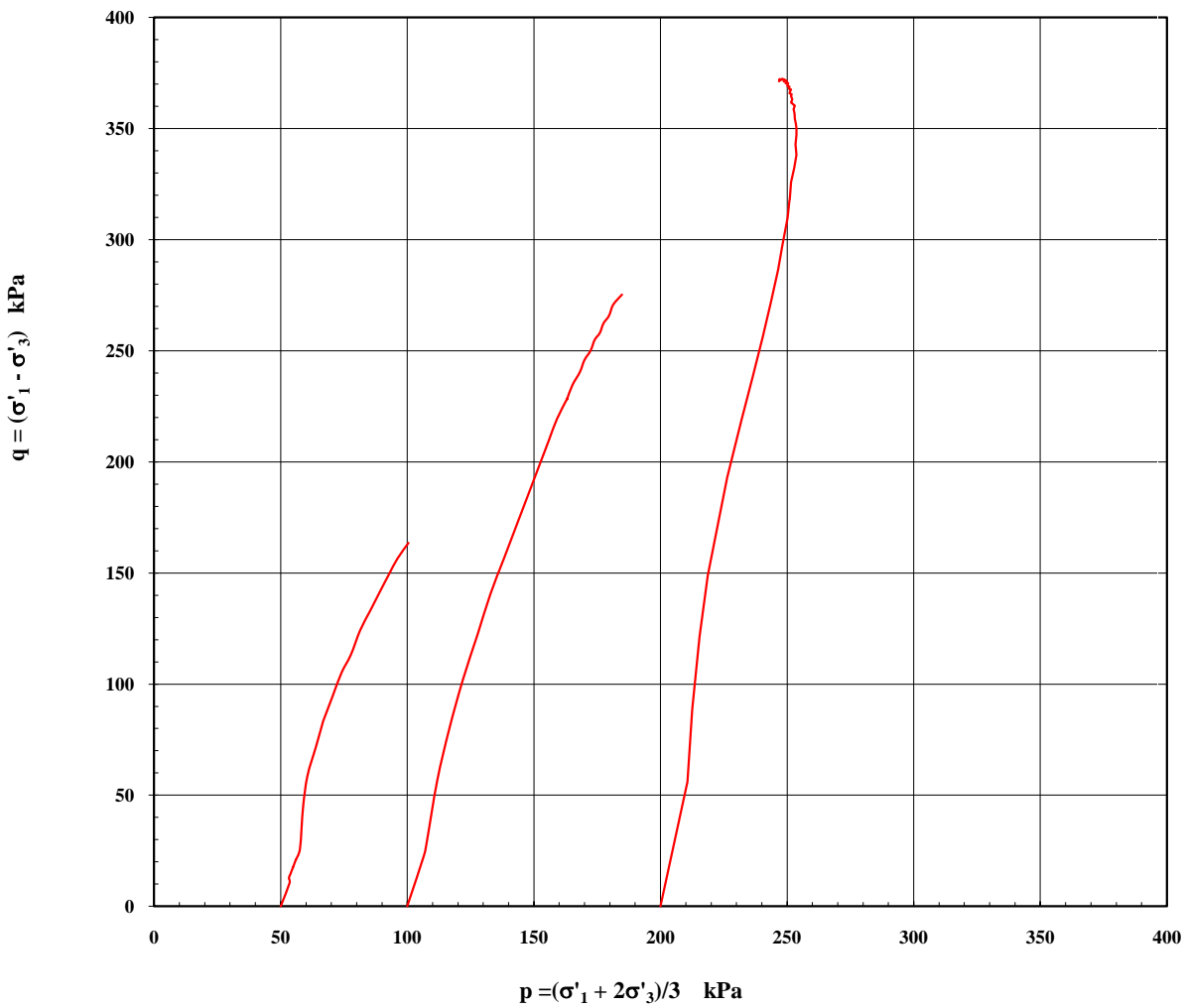
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ABN 25 065 630 506

TRIAxIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 20/12/2010
	Report Date: 6/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m
Description: Lead Zinc Tailings	

Cambridge Method - Effective Stress Path



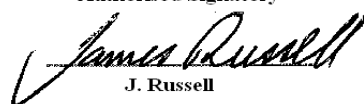
Note: Graph not to scale.

Sample Type: Single Individual Specimen Remoulded to a target of 95% of Standard Maximum Dry Density and at Standard Optimum Moisture Content	Note: Graph not to scale
Sample/s supplied by the client	



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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 20/12/2010 Report Date: 6/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m
Description: Lead Zinc Tailings	



Sample Type: Single Individual Specimen Remoulded to a target of 95% of Standard Maximum Dry Density and at Standard Optimum Moisture Content	Note: Graph not to scale
Sample/s supplied by the client	



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Trilab Pty Ltd
ABN 25 065 630 506

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 4/01/2011
	Report Date: 10/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m

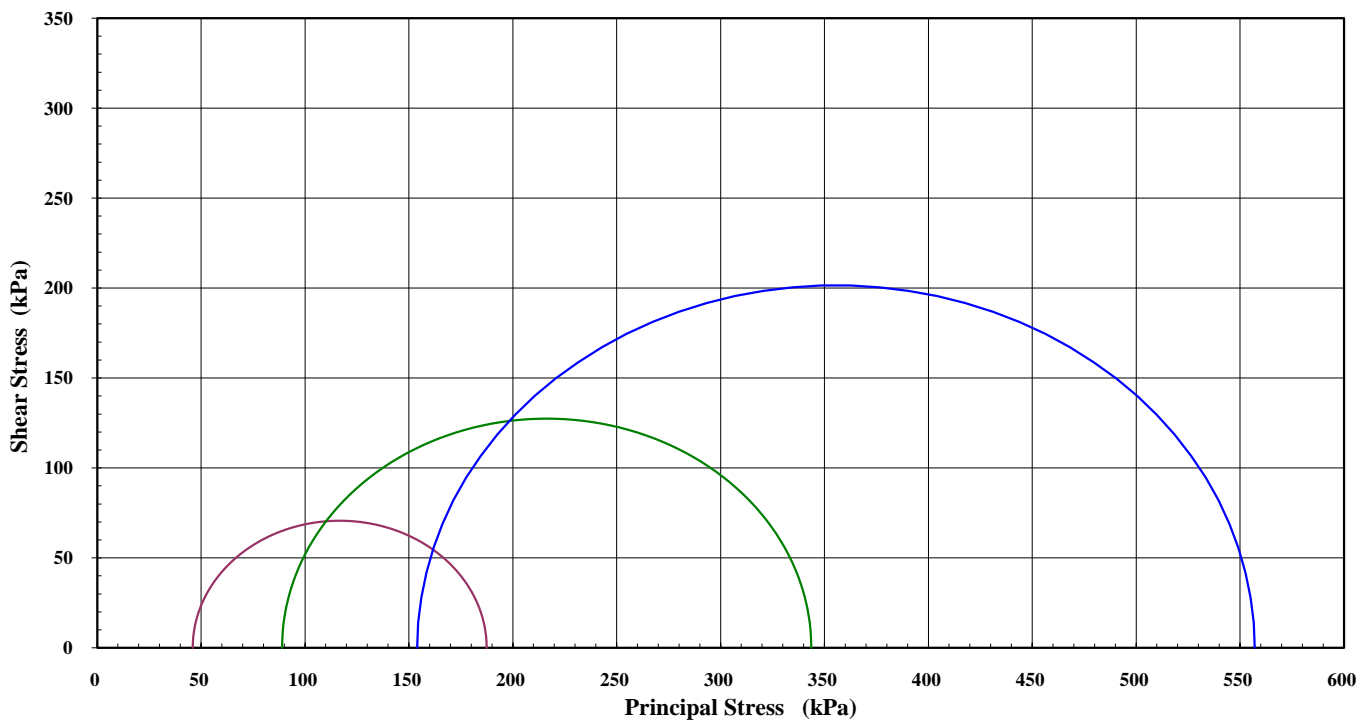
Description: Lead Zinc Tailings

SAMPLE & TEST DETAILS

Initial Height: 95.5 mm	Initial Moisture Content: 13.8 %	Rate of Strain: 0.007 %/min
Initial Diameter: 48.0 mm	Final Moisture Content: 15.0 %	B Response: 98 %
L/D Ratio: 2.0 : 1	Wet Density: 2.32 t/m ³	
	Dry Density: 2.04 t/m ³	

Failure Criteria: Peak Principal Stress Ratio

Mohr Circle Diagram



Interpretation between stages :	1 to 2	2 to 3	1 to 3
Cohesion C' (kPa) :	5.3	14.2	9.2
Angle of Shear Resistance Φ' (Degrees) :	34.7	32.2	33.2

Sample Type: Single Individual Specimen Remoulded to a target of 98% of Standard Maximum Dry Density and at Standard Optimum Moisture Content

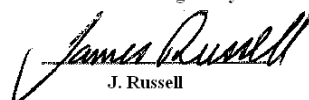
Sample/s supplied by the client Note: Graph not to scale



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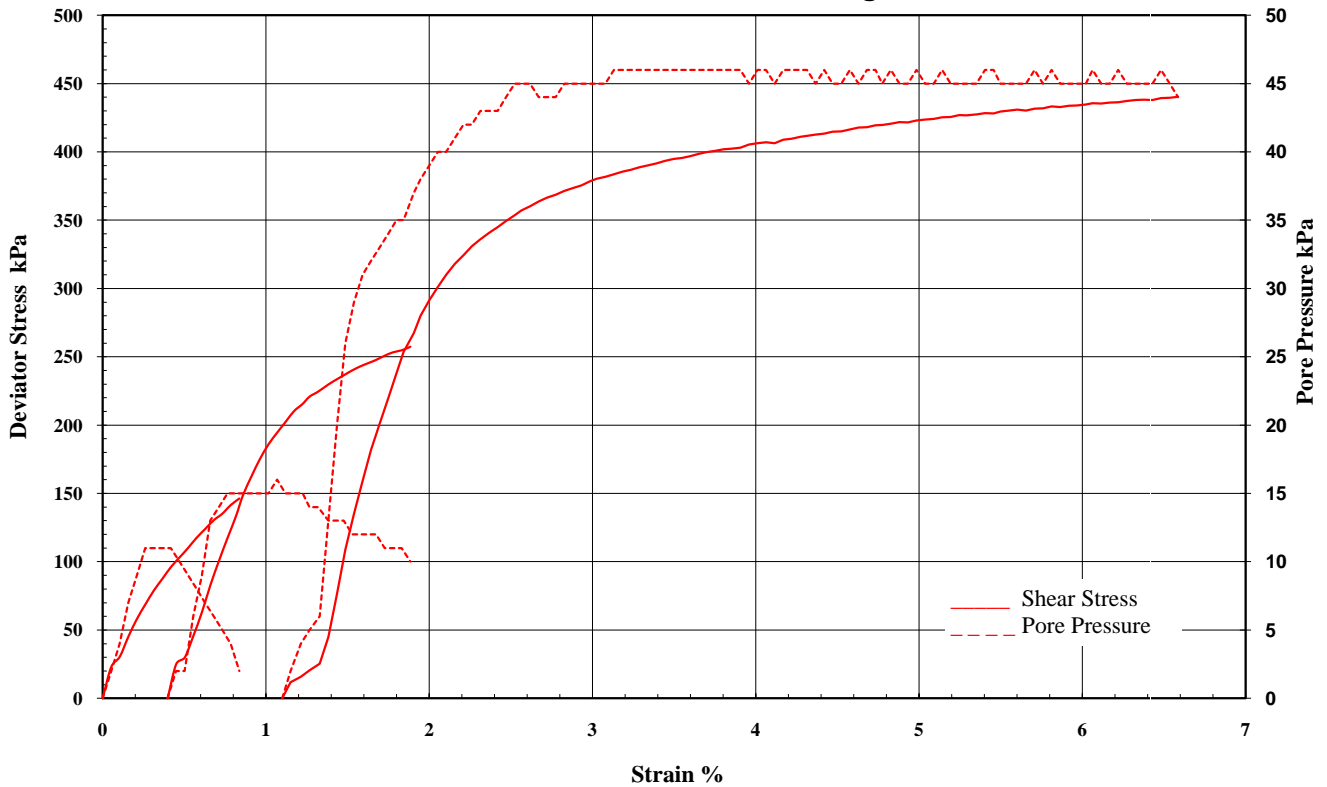
TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 4/01/2011
	Report Date: 10/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m

Description: Lead Zinc Tailings

Stress/Strain & Pore Pressure/Strain Diagram



FAILURE DETAILS

Confining Pressure	Back Pressure	Initial Pore	Failure Pore	Principal Effective Stresses			Deviator Stress	Strain
				σ'_1	σ'_3	σ'_1 / σ'_3		
555 kPa	505 kPa	505 kPa	509 kPa	187 kPa	46 kPa	4.074	141 kPa	0.79 %
605 kPa	505 kPa	505 kPa	516 kPa	344 kPa	89 kPa	3.862	255 kPa	1.83 %
706 kPa	506 kPa	506 kPa	552 kPa	557 kPa	154 kPa	3.617	403 kPa	3.91 %

Sample Type: Single Individual Specimen Remoulded to a target of 98% of Standard Maximum Dry Density and at Standard Optimum Moisture Content

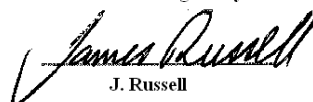
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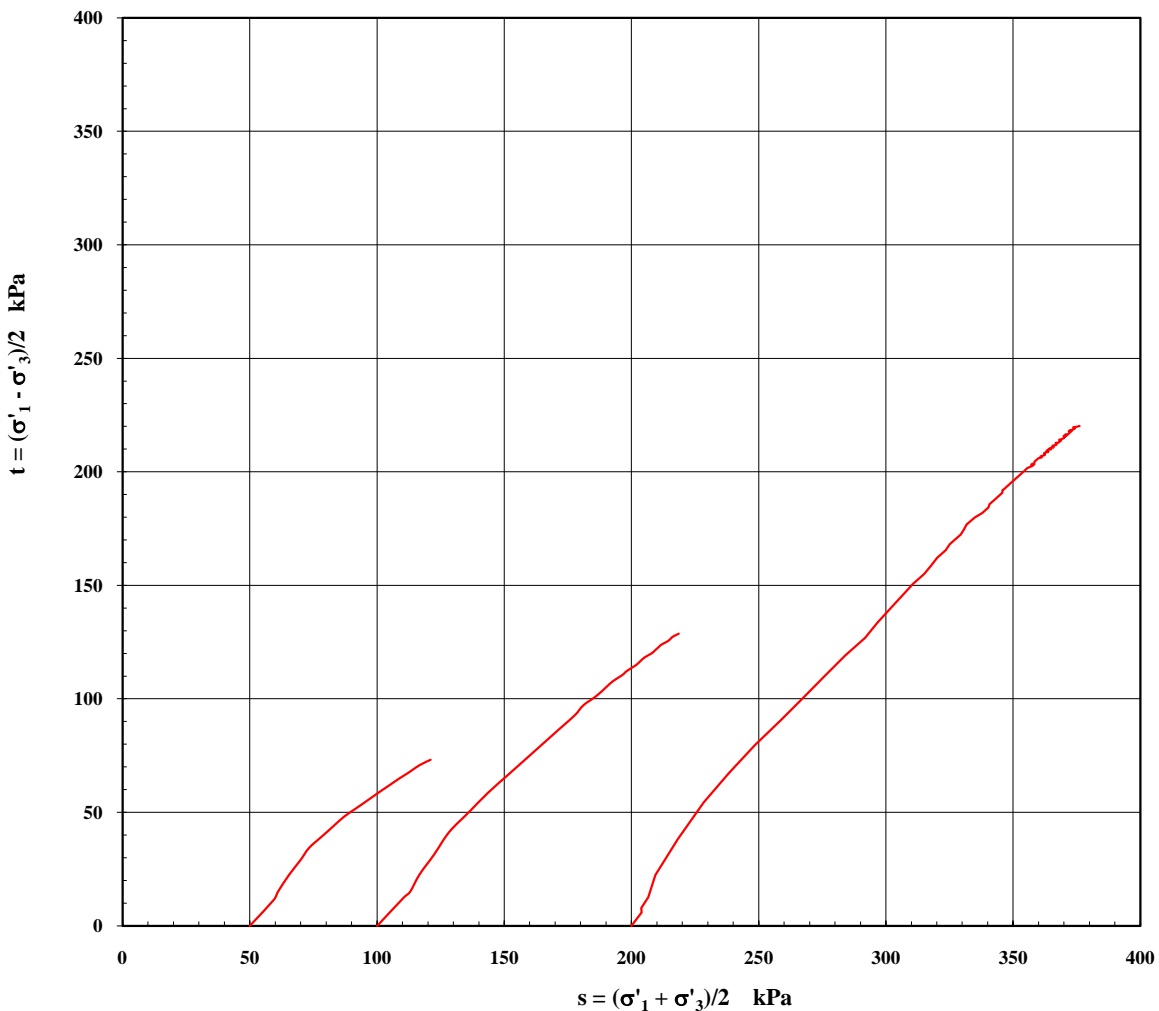
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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 4/01/2011 Report Date: 10/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m
Description: Lead Zinc Tailings	

MIT Method - Effective Stress Path



Note: Graph not to scale.

Sample Type: Single Individual Specimen Remoulded to a target of 98% of Standard Maximum Dry Density and at Standard Optimum Moisture Content
Sample/s supplied by the client Note: Graph not to scale



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Authorised Signatory



J. Russell

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Doc. Id.: REP03001

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.

Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.

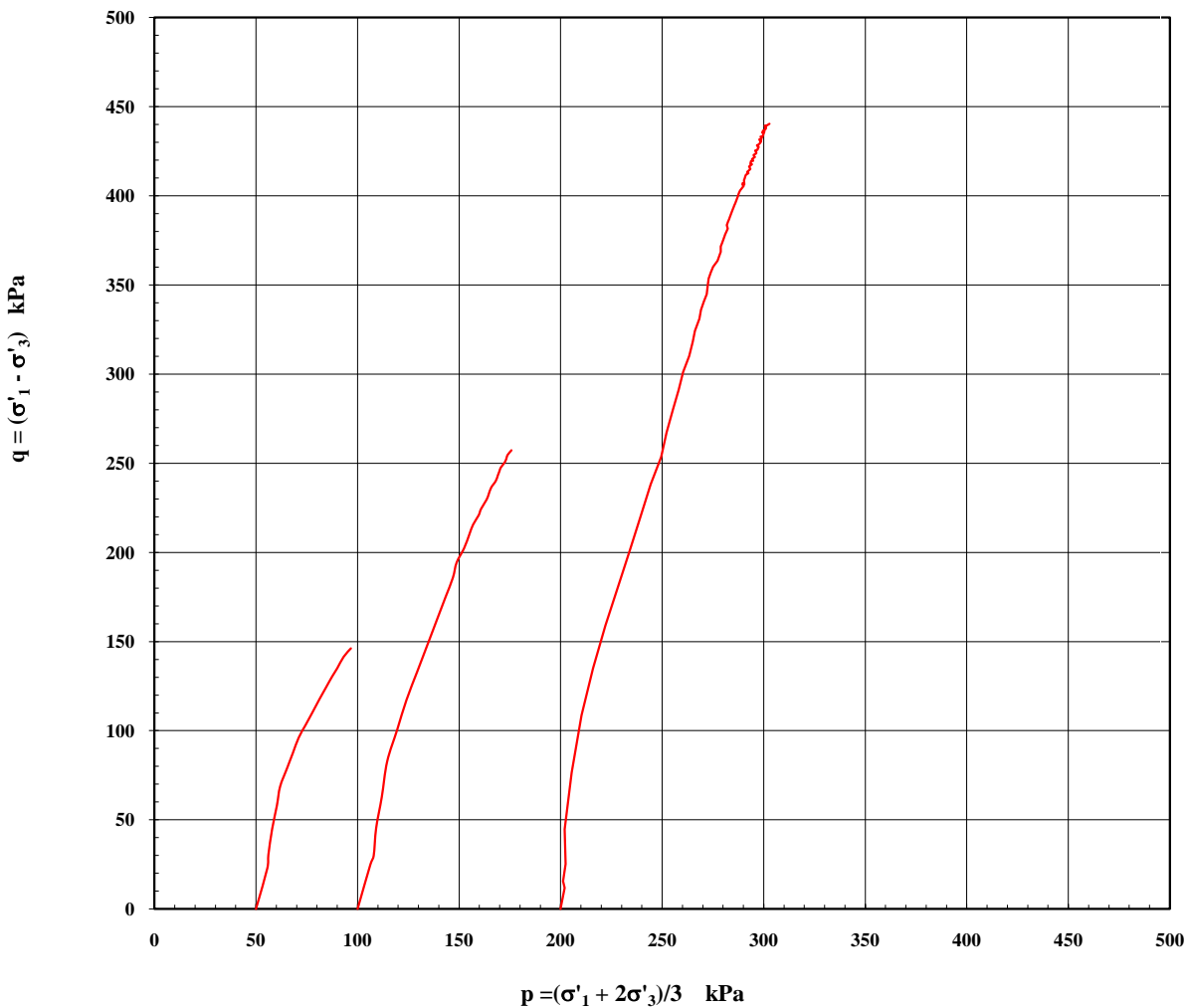
Trilab Pty Ltd
ABN 25 065 630 506

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 4/01/2011 Report Date: 10/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m
Description: Lead Zinc Tailings	

Cambridge Method - Effective Stress Path



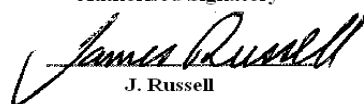
Note: Graph not to scale.

Sample Type: Single Individual Specimen Remoulded to a target of 98% of Standard Maximum Dry Density and at Standard Optimum Moisture Content	Note: Graph not to scale
Sample/s supplied by the client	



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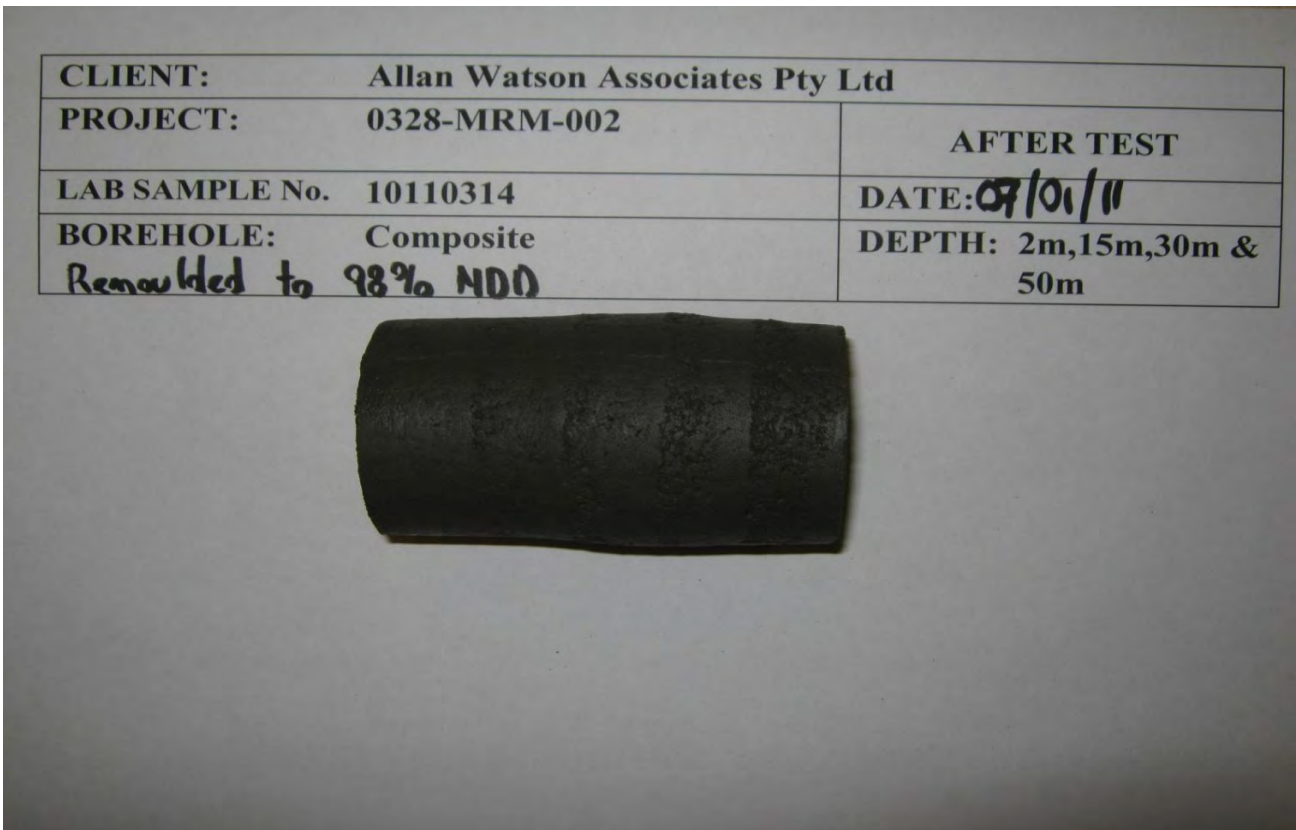
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.

Trilab Pty Ltd
ABN 25 065 630 506

TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client: Allan Watson Associates Pty Ltd	Report No.: 10110314 - CU
Project: 0328-MRM-002	Test Date: 4/01/2011 Report Date: 10/01/2011
Client Id.: Composite	Depth (m): 2m,15m,30m & 50m
Description: Lead Zinc Tailings	



Sample Type: Single Individual Specimen Remoulded to a target of 98% of Standard Maximum Dry Density and at Standard Optimum Moisture Content

Sample/s supplied by the client

Note: Graph not to scale



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Doc. Id.: REP03001



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PERMEABILITY BY FALLING HEAD TEST REPORT

Test Method: AS1289 6.7.2, KH 2 (Based on K H Head (1988) Manual of Laboratory Testing, 10.7)

Client: Allan Watson Associates Pty Ltd	Report No. 10110314-FHP
Project: 0328-MRM-002	Test Date: 16/12/10 Report Date: 10/01/11
Sample No:	10110314
Client ID:	Composite
Depth (m):	2m-15m-30-50m
Standard Maximum Dry Density (t/m ³):	2.07
Standard Optimum Moisture Content (%):	14.0
Placement Moisture Content (%):	14.0
Placement Wet Density (t/m ³):	2.24
Density Ratio at Placement (%):	95.0
Moisture Ratio at Placement (%):	100.0
Surcharge & Pressure applied (kPa):	0/11.6
PERMEABILITY:	$K_{20} = 4 \times 10^{-7}$ m/s
Remarks: The specimen was remoulded to a target of 95% of Standard Maximum Dry Density and at Standard Optimum Moisture Content.	
The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated. Reference should be made to Trilab Pty Ltd "Standard Terms and Conditions of Business" for further details.	
Sample/s supplied by the client	Page: 1 of 1



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N ATA Accredited Laboratory Number 9926
 Form Number: GT010-5

Authorised Signatory

James Russell
 J. Russell

Manager

APPENDIX B
TSF BILL OF QUANTITIES

Budget Project Costing and Scheduling

McArthur River Mine
TSF Development Assessment (96Mt)

CELL 2															
Schedule Item	Description	Unit	Rate	Lift RL52m		Lift RL55m		Lift RL58m		Lift RL61m		Lift RL64m		Lift RL68m	
				Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount
EMBANKMENT CONSTRUCTION (CONVENTIONAL)															
Clearing and Stripping	Removal of vegetation and topsoil (typically 200mm), including grubbing of stumps within embankment footprint														
storage area		m2													
borrow area		m2													
Excavations															
Subexcavation	Stripping of weak and compressible materials from the stripped embankment foundations, typical depth 600mm	m2													
Cut-off key	Excavation of cut-off key to intersect foundations, nominal depth of 2m, base width 4m minimum and batter slopes of 1h:1v	m													
Embankment Construction															
Earth/Clay Fill Construction	Condition in borrow to OMC, win, haul place and compact to 98% Std MDD	m3													
Rock Fill/General Construction Fill	Sourced from Mine overburden/waste rock dump, haul, place in 1m thick layers and compact with 6 passes using a 18t vibrating roller	m3													
EMBANKMENT CONSTRUCTION (U/S RAISES)															
Foundation Preparation/Mattress	Sourced from Mine overburden/waste rock dump, haul, place in 1m thick layer and compact a minimum 6 passes with a D9 or equivalent	m2		115,000		125,000		135,000		130,000		125,000		145,000	
Earth/Clay Fill Construction	Condition in borrow to OMC, win, haul place and compact to 98% Std MDD	m3		165,000		180,000		190,000		185,000		180,000		274,000	
Batter and Crest Armouring	Selectively source from mine overburden or local borrow, well graded rock fill (max 200mm dia), place, spread and compact by track rolling or tamping with bucket to form 200mm thick armouring layer	m2		87,000		98,000		103,000		100,000		97,000		94,000	
ASSOCIATED WORKS															
Storage Liner		m2													
Pipe work															
Tailings delivery line (NOT INCLUDED)		m													
Return water line (NOT INCLUDED)		m													
Seepage collection system	Perimeter Seepage drain comprising 2m deep 1m wide trench with 150mm pvc slotted pipe and backfilled with drainage aggregate. Allow 3 Manholes, 1500mm dia x 4.88m and equipped with return pumps (5L/s)	m													
Embankment Drainage															
Bench Drains	Bench drains comprising a 2m wide 300mm minimum deep trapezoidal channel, 200mm rock armouring. Assumes bench drainage to drop structures at 200m centres centres	m		3,500		3,930		4150		4030		3910		3800	

Bench Drains	Bench drains comprising a 2m wide 300mm minimum deep trapezoidal channel, 200mm rock armouring. Assumes bench drainage to drop structures at 200m centres	m			2,680	2650	2620	2590
Drop Structures	Allow for 20m long trapezoidal drop structures to be constructed at 200m centres, channels comprising 2m wide 300mm minimum deep trapezoidal channel, concrete lined (150mm thick F32MPa with SL82 mesh)	No			15	15	15	14
<u>External Clean water Diversion</u>	Excavation of perimeter diversion channel, typically 5m wide, 1m deep with 3h:1v batters							
<u>Emergency spillway</u>	Allow for a 20m wide concrete slab (150mm thick 32MPa with SL82 mesh placed centrally) channel on embankment batter	No		1	1	1	1	1
<u>Monitoring/Instrumentation</u>	Survey monuments and embankment piezometers - 6 per cell	No		6	6	6	6	6
<u>Rehabilitation</u>								
Earthworks	Capping to comprise a 1000mm thick no-fines rockfill trafficking layer, 600mm clay fill/earth fill compacted to 98% MDD and 200mm topsoil	ha		-	-	0	0	77
Revegetation		ha						
<u>Contingency</u>		%						
TOTAL								

Budget Project Costing and Scheduling

McArthur River Mine
TSF Development Assessment (96Mt)

CELL 4 Opt 3

Schedule Item	Description	Unit	Rate	Starter RL55m		Downstream Lift RL61m	
				Quantity	Amount	Quantity	Amount
EMBANKMENT CONSTRUCTION (CONVENTIONAL)							
Clearing and Stripping	Removal of vegetation and topsoil (typically 200mm), including grubbing of stumps within embankment footprint						
storage area and embankment footprint		m2		725,000		-	
borrow area		m2		-		-	
Excavations							
Subexcavation	Stripping of weak and compressible materials from the stripped embankment foundations, typical depth 600mm	m2		105,000		62,000	
Cut-off key	Excavation of cut-off key to intersect foundations, nominal depth of 2m, base width 4m minimum and batter slopes of 1h:1v	m		2,250		-	
Embankment Construction							
Earth/Clay Fill Construction	Condition in borrow to OMC, win, haul place and compact to 98% Std MDD	m3		210,000		60,000	
Rock Fill/General Construction Fill	Sourced from Mine overburden/waste rock dump, haul, place in 1m thick layers and compact with 6 passes using a 18t vibrating roller	m3		400,000		760,000	
EMBANKMENT CONSTRUCTION (U/S RAISES)							
Foundation Preparation/Mattress	Sourced from Mine overburden/waste rock dump, haul, place in 1m thick layer and compact a minimum 6 passes with a D9 or equivalent	m2					
Earth/Clay Fill Construction	Condition in borrow to OMC, win, haul place and compact to 98% Std MDD	m3					
Batter and Crest Armouring	Selectively source from mine overburden or local borrow, well graded rock fill (max 200mm dia), place, spread and compact by track rolling or tamping with bucket to form 200mm thick armouring layer	m2					
ASSOCIATED WORKS							
Storage Liner		m2		620,000		-	
Pipe work							
Tailings delivery line (NOT INCLUDED)		m					
Return water line (NOT INCLUDED)		m					
Seepage collection system	Perimeter Seepage drain comprising 2m deep 1m wide trench with 150mm pvc slotted pipe and backfilled with drainage aggregate. Allow 3 Manholes, 1500mm dia x 4.88m and equipped with return pumps (5L/s)	m		2,250		-	
Embankment Drainage							

Bench Drains	Bench drains comprising a 2m wide 300mm minimum deep trapezoidal channel, 200mm rock armouring. Assumes bench drainage to drop structures at 200m centres	m			
Drop Structures	Allow for 20m long trapezoidal drop structures to be constructed at 200m centres, channels comprising 2m wide 300mm minimum deep trapezoidal channel, concrete lined (150mm thick F32MPa with SL82 mesh)	No			
<u>External Clean water Diversion</u>	Excavation of perimeter diversion channel, typically 5m wide, 1m deep with 3h:1v batters	m		2,000	-
<u>Emergency spillway</u>	Allow for a 20m wide concrete slab (150mm thick 32MPa with SL82 mesh placed centrally) channel on embankment batter	No		1	1
<u>Monitoring/Instrumentation</u>	Survey monuments and embankment piezometers - 6 per cell	No		6	6
<u>Rehabilitation</u>					
Earthworks	Capping to comprise a 1000mm thick no-fines rockfill trafficking layer, 600mm clay fill/earth fill compacted to 98% MDD and 200mm topsoil	ha			62
Revegetation		ha			
<u>Contingency</u>		%			
TOTAL					