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Tailings Storage Facility Management Plan

**McARTHUR RIVER MINE PHASE 3
DEVELOPMENT PROJECT**

January 2012

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Appendix E1 – TSF Management Plan

McArthur River Mine Phase 3 Development Project Tailings Storage Facility Management Plan January 2012

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1 Scope and Purpose

1.1 Overview

This document provides a summary of the Tailings Storage Facility (TSF) design and current and future management practices at the McArthur River Mine (MRM). It has been prepared for submission with the Draft Environmental Impact Statement (EIS) for the McArthur River Mine Phase 3 Development Project (the Project) as supporting information for the proposed TSF expansion.

Tailings are water-based fine waste products generated through MRM's ore processing operations that are currently taken by pipeline to the TSF. Tailings are essentially the slurried waste products left over from the production of MRM zinc product (bulk concentrate). Tailings have been produced and sent to the existing TSF since the commencement of operations in 1995.

1.2 Existing TSF

The TSF is located within the Project area on the western side of the Carpentaria Highway, south of Surprise Creek. The maximum disturbed area at the TSF to complete the current approved operations would be approximately 380 ha. The TSF enclosure is bounded by a 6,670 m engineered clay perimeter wall.

Cell 1 of the TSF, which is closest to Surprise Creek, has been decommissioned and is now undergoing rehabilitation. The successful rehabilitation of Cell 1 will serve to inform MRM's future seepage management and development plans.

Cell 2 is now used for tailings deposition, with water re-drawn to the processing plant and recycled. In 2010, MRM increased its recycled water usage by 17% on the previous year to more than 95% of all water used onsite.

Cell 3 is not currently in use for tailings deposition. It is used as a water management dam for fresh water evaporation purposes and as an overflow depository for Cell 2 decant water. Cell 3 will be used for tailings deposition in future years of the operation.

The existing TSF is shown in Figure 1. The existing TSF is an already approved structure at McArthur River Mine and is not subject to the Project's EIS process.

1.3 Phase 3 Development Project – TSF Design Parameters

The existing and approved TSF footprint will be utilised for the Project's operations, but additional land disturbance will be necessary to accommodate all of the tailings that will be produced by the Project. The Project includes the utilisation of a fourth TSF cell that is planned to adjoin Cells 2 and 3 on the northwest side of the current TSF (Figure 2).

To construct Cell 4, an additional 2,350 m of embankment wall will be required. The internal wall between Cell 4 and the existing TSF will be 1,460 m. The initial construction to RL 55 m will have a surface area of 65 ha and have a capacity of 4,300 ML.

At its final height of RL 61 m, the surface area of Cell 4 will be 68 ha and the capacity will be 8,400 ML. Cell 4 will initially be used for water storage until approximately 2032 when tailings deposition will commence after Cell 3 is full. The maximum disturbance at the TSF for the Project will be 460 ha.

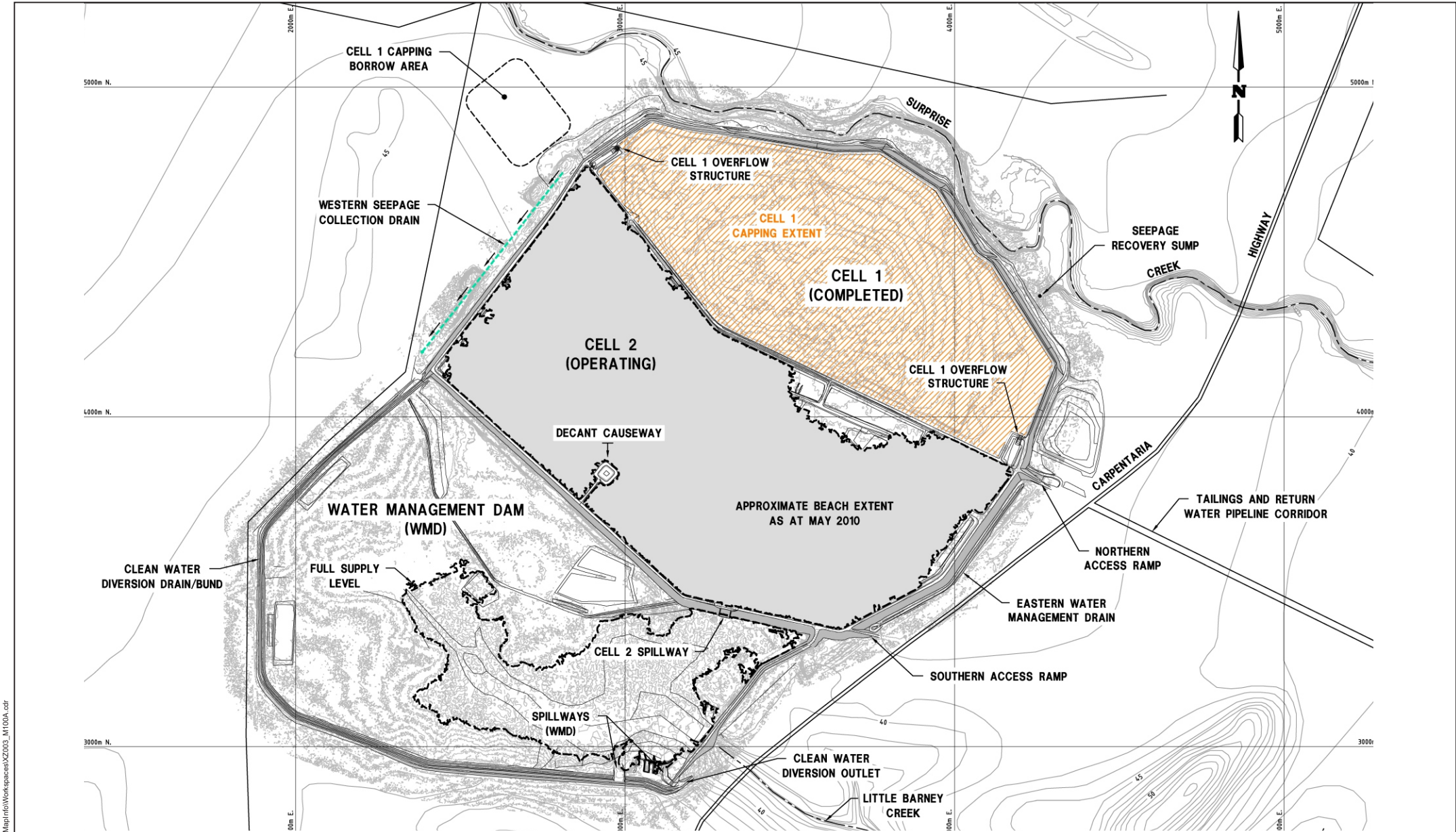
The Project will extend the life of the mine to 2036. Life of Mine (LOM) characteristics and key design parameters of the TSF are detailed in Table 1:

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Table 1 MRM TSF Characteristics

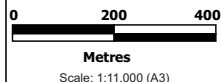
Parameter	Existing TSF	Proposed TSF
Total surface area	380 ha	460 ha
Ultimate landform surface	RL 68 m	RL 68 m (RL 61 m for Cell 4)
Maximum height of landform	35 m (northern corner)	35 m (northern corner)
Total tailings storage capacity	47,600 ML	56,000 ML
Total TSF cells	3	4

Cell 4 is required at the site initially for water management purposes, and will be subject to approval under the Northern Territory Mining Management Plan process.



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Mining & Geology Technical Services Pty Ltd



Data Source: Allan Watson Associates

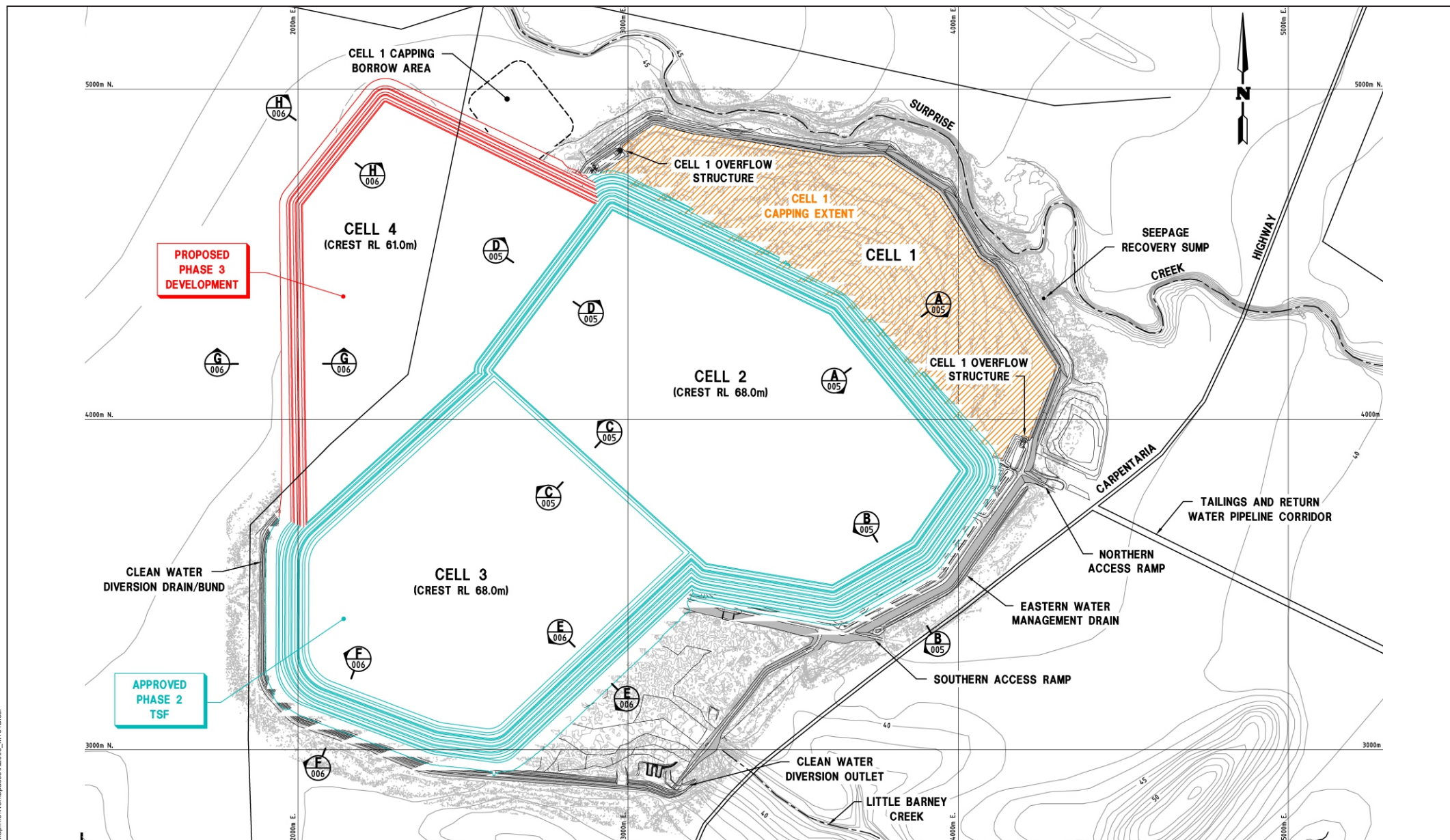
McArthur River Mine Phase 3 Development Project

Existing TSF

21/12/2011

Datum/Projection:
Mine Grid System

FIGURE 1



McArthur River Mine Phase 3 Development Project

Proposed TSF with Cell 4

21/12/2011

 Datum/Projection:
Mine Grid System

FIGURE 2

2 Potential Environmental Risks – TSF

2.1 TSF Risk Assessment

A risk identification and mitigation approach has been adopted to ensure that the design, operational and closure criteria for the TSF will have minimal risk of impacts to the receiving environment.

A low risk rating will be achieved because of the 'multiple lines of defence' approach that has been taken to TSF management. Risk minimisation aspects include:

- the predicted long-term seepage volumes are generally low and are of the order of 30 to 40 L/day/m width of the TSF wall because of the relatively low permeability of the embankment core, the tailings and the underlying dolomitic siltstone material
- decant water will be stored at the centre of the TSF, rather than on the periphery thereby reducing the potential for seepage under the embankment
- the tailings will be deposited sub-aerially in thin layers, maximising the density of the tailings beach against the embankment, thus providing a low permeability layer between the decant water pond and the perimeter embankment
- the perimeter spigot discharge system maintains an appropriate level of saturation/moisture within the tailings beach during the cycling between the spigots, limiting the potential for oxidation of tailings that could generate sulphates/acidic water
- geochemical testing indicates that the tailings have an inherent Acid Neutralising Capacity (ANC), reducing the risk of the tailings oxidising and generating acidic conditions
- the underlying basement sequence has significant buffering capacity, should acidic seepage be generated
- any seepage that does occur will be contained by a combination of measures including the low permeability clay core and cut-off key in the TSF embankment, the geopolymer cut-off barrier, the network of recovery bores and surface perimeter drains, and underliner drainage to designed collection zones
- water balance modelling indicates that the TSF water management dam will comply with its target overflow probability of a 1-in-500 year annual exceedance. Should such an unlikely large rainfall event occur, any discharge from the TSF would be into a significant flood flow with dilutions estimated to be greater than 1,000 times
- capping and revegetating the TSF progressively and after mine closure will limit the potential for future oxidation of the stored tailings, and enable clean runoff to be discharged to the surrounding environment
- operation of the seepage recovery bores after mine closure (if required, based on monitoring performance) will reduce the groundwater head within the TSF, so that expression of ongoing seepage will not occur on the surface
- a comprehensive monitoring program will be maintained over the life of the TSF and will include the following components:
 - piezometric levels within the embankment
 - surface water monitoring
 - groundwater monitoring
 - water quality
 - decant pond water levels

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- decant pond water quality
- embankment condition.
- MRM will continue to be responsible for post mine closure monitoring, and maintenance of the recovery system (if required), until closure criteria have been met and it is demonstrated that recovery wells are no longer required.

MRM has invested more than \$10 million since 2006 to continuously improve the performance and management of the TSF.

MRM is committed to reducing the off-site environmental risks of the TSF, as shown by the TSF commitments outlined in Section 7.

A summary of the TSF risks and contingency plans are shown in Table 2.

Table 2 TSF Risk Assessment, Mitigation Measures, and Contingency Plans

Risk	Mitigation	Monitoring	Contingency
Surface water overflow	Runoff and decant water to flow to Water Management Dam. Water Management Dam designed to be above the 1 in 500-year flood level Maintain a suitable freeboard before each wet season. All runoff and decant water in the Water Management Dam to be reused in the processing plant, evaporated or discharged as per the discharge license.	Regular updating of the water balance modelling of the site water management system, to minimise overflow risk. Regular inspection of the decant system, to ensure efficient operation.	Pump water from Water Management Dam to other storages. Increase the capacity of the Water Management Dam. Discharge as per approved discharge licenses.
Failure of TSF embankment	Design in accordance with ANCOLD guidelines for high hazard dams. Engineering analysis of embankment stability has confirmed a factor of safety well in excess of minimum requirements.	Regular inspection of embankment integrity to be undertaken. Monthly piezometric monitoring of phreatic surface levels within embankment. Independent annual inspections.	Engineered remediation measures in accordance with ANCOLD guidelines.
Erosion of outer face of TSF embankment	Only hard durable NAF rock that is resistant to erosion is to be used on outer face.	Regular inspection of rock face integrity to be undertaken.	Replace any rocks showing signs of erosion with more competent material.
Seepage from TSF	Embankment has clay core with cut-off key. Ponded water in TSF kept away from perimeter embankment. Geopolymer barrier installed around eastern embankment. Network of recovery bores installed in identified seepage areas. TSF to be capped with low permeability layer, to prevent ongoing entry of water at closure. Maintain recovery bores post closure (if required), until seepage head in TSF reaches design level.	Ongoing monitoring of seepage rates through recovery bores and observation bores. Monthly inspection of embankment for evidence of seepage.	Increase the number or pumping rate of recovery bores. Install seepage collection trenches.

2.2 Environmental Protection Measures

MRM considered a number of options for the TSF design but found the best is one which combines six 'lines of defence' or strategies to guard against seepage and to protect the environment. This strategy will be used for the design, operation, and ultimate closure and rehabilitation of the TSF and will be reviewed and updated regularly. These six strategies for environmental protection are detailed below.

2.2.1 Tailings Deposition Method

Spreading the tailings in thin layers against the cell wall provides a 'beach' of tailings between the water and the wall which will prevent water from seeping. This also offers a number of benefits in the management of tailings as it:

- supports the system of raising the embankments to increase the tailings capacity
- limits the potential for oxidising tailings thus generating sulphates (salt deposits).

2.2.2 Embankment Construction

The high embankment around the outside of the TSF is made of compacted clay covered with rocks with a low permeability. This two metre thick, four-layered embankment cap is designed to be safe and stable in both wet and dry seasons. Only Non-Acid Forming (NAF) material is used for this outer surface to ensure there are no contaminants in the water runoff.

Proper design and construction will occur for the TSF until the end of mine life.

2.2.3 Continued use of geopolymer barriers

In the past two years, MRM has successfully trialled a geopolymer barrier on 2.25 km of the existing TSF wall. Under this system, a glue-like polymer is injected every two metres around the base of the TSF wall. This forms a hard barrier that minimises seepage outside the wall. The barrier will be applied to other areas if required.

2.2.4 Recovery bore system around the TSF perimeter

A recovery bore system around selected areas of the TSF perimeter wall will cut any seepage from the TSF off before it reaches freshwater systems. Seepage will be collected and pumped for recycling in the processing plant. These bores are between 10 m and 30 m deep. Monitoring data provides feedback on the performance of the recovery bore system which feeds into design reviews.

Plans show that these bores will be successful in trapping seepage within the footprint of the TSF and before it reaches the natural groundwater system. There are numerous mines in Queensland which use a similar TSF design strategy to MRM and these have been successful in protecting against environmental impact.

2.2.5 Flood protection for a 1-in-500 year event

The height of the TSF embankment is greater than the 1-in-500 year flood levels. But an emergency spillway will be located in the north-west corner of the TSF to allow for overflows in extreme weather conditions above the 1-in-500 year levels. This is also based on the ANCOLD guidelines for the worst possible flood or rainfall experience.

2.2.6 Thorough monthly monitoring program

Water levels within each TSF cell are checked daily. Groundwater and surface water quality are checked through monitoring bores and water samples taken from the sediment ponds as well as Surprise and Barney Creeks every month. TSF decant water is also monitored for levels and quality. The condition of the embankment is also inspected regularly.

3 Existing TSF Design, Construction and Performance

3.1 Overview

This design for the MRM TSF is in accordance with the standards set by the Australian National Committee on Large Dams (ANCOLD) Guidelines on Tailings Dam Design, Construction and Operation. Hence, the TSF is built to the same safety standard as all major water storage dams. ANCOLD has specific guidelines for Tailings Dam Design, Construction and Operation. These are regarded as the best practice standards under Australian conditions and are recognised as the industry standard by State and Territory Governments.

The existing TSF has been approved by previous environmental impact assessments and the information presented in this section is for supporting information in regards to the TSF expansion – Cell 4, which is discussed in Section 4.

Descriptions of the existing TSF cells are shown below.

3.1.1 Cell 1

The initial tailings impoundment area (containing the TSF and water storage), developed as part of the MRM underground operation with the initial operational concept being for discharge of thickened tailings from an elevated, central location to form a conical shaped stack.

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

- Embankment Crest Level
 - External RL 49 m to RL 53.5 m
 - Internal (Cell1/2) RL 48 m to RL 54.5 m
- Embankment Length
 - External 2,000 m
 - Internal 1,700 m
- Spillway/overflow level
 - Western overflow RL 48.5 m
 - Eastern overflow RL 48 m
- Total Cell 1 surface area: 78 ha.

3.1.2 Cell 2

The perimeter embankments of TSF Cell 2 were designed in accordance with the ANCOLD Guidelines (1999). Studies undertaken as part of the design include:

- characterisation of the physical properties of the tailings, foundation materials and potential construction materials
- development of design criteria for a range of embankment loading conditions
- analysis of long-term embankment stability for a range of loading conditions.

Based on the historic performance of TSF Cell 1, a revised TSF design concept was developed as part of the environmental impact assessment process for the conversion of MRM from an underground to an open-cut pit mine (Phase 2 Project) to improve the overall performance of the TSF, particularly with respect to seepage.

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The location and design objectives of future TSF cells were developed with the following objectives:

- improved tailings placement techniques – the previous TSF cell (Cell 1) deposited tailings using a central thickened discharge with water collected adjacent to the perimeter embankments and diverted to water storage dams within the non-active deposition area of the TSF. Given the historic seepage from Cell 1, the tailings placement strategy has been changed to a perimeter spigoted discharge with a central decant pond to keep water away from the perimeter embankments and hence reduce the potential for seepage
- provide stable landform – the Cell 2 perimeter embankments were designed in accordance with the requirements of the Australian National Committee of Large Dam Guidelines to ensure that adequate factors of safety were provided across the landform both during the various stages of TSF development during mine operations and post mining after closure of the TSF. The design considered the geotechnical and seismic stability of the embankment materials as well as the surface stability and erosion resistance of the outer slopes to both rainfall and potential flood events
- no excessive or uncontrolled emissions to the environment – based on the observed performance of Cell 1, additional design measures were developed for the future TSF cells to ensure that no excessive or uncontrolled emissions to the environment arise from the TSF. The emissions of particular concern relate to dust, erosion of embankment slopes, surface runoff, and seepage
- minimise the area of the disturbance footprint – preliminary site layout studies considered the potential to relocate the TSF. The footprint of the existing TSF was already approved by the Northern Territory Government for tailings disposal and had sufficient capacity to accommodate the expansion required for the Phase 2 Project. Furthermore, given the consistent subsurface conditions across the site, there was no significant benefit in disturbing additional areas at the site as no significantly improved subsurface conditions are available
- storage efficiency – the perimeter spigoted tailings discharge system requires higher perimeter embankments than the existing central thickened discharge system. Therefore a staged embankment arrangement was developed incorporating upstream lifting techniques to reduce the materials and resources required to construct the perimeter embankments of the expanded TSF.

(MRM, 2010)

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

- Embankment Crest Level: RL 49.0 m
- Embankment Lengths
 - Eastern Embankment: 850 m
 - Western Embankment: 800 m
 - Northern Embankment (Internal Cell 1/2): 1,600 m
 - Southern Embankment (Internal Cell 2/WMD): 1,550 m
- Spillway Level: RL 48.0 m
- Total Cell 2 surface area: 112 ha.

3.1.3 Water Management Dam (Cell 3)

The primary objective of the Water Management Dam (WMD) is to act as a water catchment for Cell 2

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overflow in extreme rainfall events. Clean Water from the Water Management Dam (WMD) is to be used to supplement bore water requirements and to act as an emergency reservoir in case of bore field drawdown or mechanical failure of bore pumps.

The current WMD (Cell 3) is designed to collect rainwater for process water makeup in the subsequent dry season and act as an emergency storage facility if Cell 2 overtops. The spillway on Cell 2 is directed to the WMD. The WMD is an engineered purpose built water storage dam which is physically capable of storing water as evidenced during the 2000/2001 wet season when the dam was completely full.

The original surface of the WMD is intact so the underlying clay base is relatively undisturbed and provides a liner to the dam. The water that is directed to the WMD, either directly from the mine or from the rainfall runoff (overtopping) from Cell 2 will be diluted with the clean rainfall captured in the WMD. The inputs to the WMD and the WMD water quality is monitored weekly.

The current capacity of the WMD is 1,834 ML.

3.2 Tailings Delivery and Deposition Method

Tailings are currently pumped to a 55 m diameter tailings thickener where flocculants thicken the solid and allow the supernatant water to overflow for recycling. Thickened tailings are then transported to the TSF via two sets of staged pumps. 100% of the free water present in Cell 2 is collected by a submersible 90 kW pump and returned for use as process water in the processing plant via a 250 mm water return line. This water is used as make up water for the processing plant, which is normally sourced from the open pit.

Evaporation of the TSF decant water is maximised through the deposition of tailings in thin laminar sheets across wide beaches and the use of a 37 kW pump and sprinkler distribution system. Return water is stored in the Anti-Pollution Pond (APP) prior to recycling in the processing plant allowing evaporation to occur.

The process of tailings deposition is under constant review and refinement to increase tailings density and reduce water retention. This allows optimal use of the TSF storage capacity and limits the potential for TSF subsidence and reduces TSF seepage.

The current general operational philosophy for Cell 2 is based on the use of sub-aerial techniques for tailings deposition. Sub-aerial deposition involves the discharge of tailings from multiple locations around the perimeter of the active cell. At each discharge location the tailings slurry will produce a near laminar flow over the gently sloping tails beach to enable segregation and deposition of tailings solids. This is a change from the modified central discharge and paddock system that was adopted in Cell 1.

Subsequent evaporation from the exposed beach surface areas will consolidate the tailings as a means of increasing in-situ deposited densities and beach strengths. Water liberated from the tailings through the deposition phase and stormwater runoff will accumulate in a decant pond at the toe of the beach.

From there the decant water can be pumped directly from Cell 2 to the APP. Water from the WMD can be returned to the concentrator for reuse. This arrangement for Cells 1 and 2 is shown in Figure 3.

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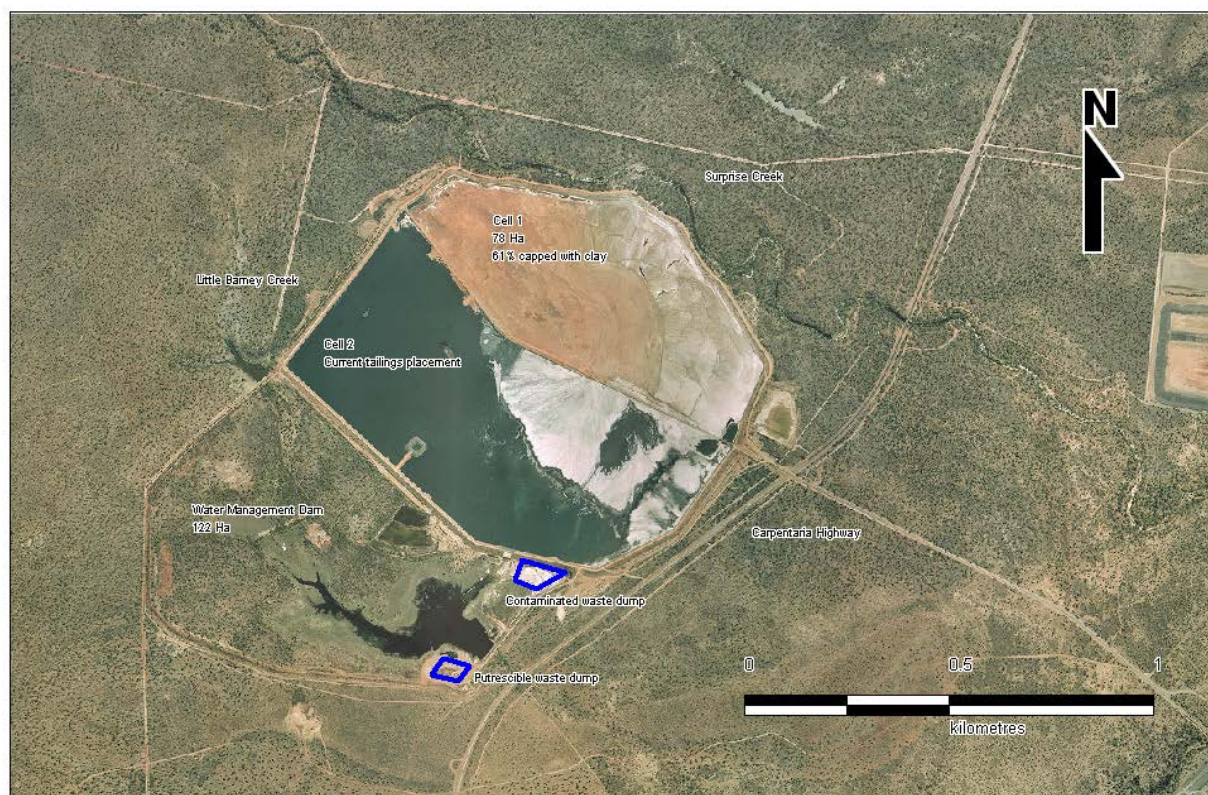


Figure 3 Existing TSF

Placing tailings using a spigotted discharge system around the cell perimeter will minimise the risk of seepage from the TSF (including Cell 4), with the key benefits including:

- the tailings will be deposited sub-aerially in thin layers to maximise the density of the tailings against the embankment, providing a low permeability beach of tailings between the decant water pond and the perimeter
- the perimeter spigot discharge also maintains an appropriate level of saturation/moisture within the tailings beach during the cycling between spigots. This limits the potential for oxidation of tailings that could generate sulphates/acidic water
- the sub-aerial beach achieves relatively high strength tailings adjacent to the perimeter embankment that allows for further increase in the TSF capacity using upstream lifting with the embankment raised directly on tailings. This approach allows for:
 - progressive rehabilitation of the outer slopes of the perimeter embankments
 - providing access to the various upstream lift benches to install seepage control measures, such as drains, if required
 - flatter overall slopes and phreatic surface (groundwater) profiles that improve the geotechnical stability of the wall.

The operation of the spigot points aim to maintain a uniform moisture level over the beach surface to minimise oxidation and dust generation. A record of the operational times for each spigot will be maintained to enable long term operational procedures to be developed.

3.3 Tailings Characterisation

3.3.1 Tailings Properties

Previous characterisation of tailings and potential cover materials have included in-situ testing such as paste pH and conductivity as well as a laboratory program examining the particle size distribution of sampled materials.

The key findings of the material characterisation program are the following:

- the paste pH and conductivity of the tailings material are in the range of 5.4 to 7.8 and 0.9 mS/cm to 19.2 mS/cm, respectively. Near surface material exhibited relatively high conductivity and low pH. The trend in data would suggest that oxidation of the tailings material is occurring and oxidation products are evapo-concentrating at the surface
- dry density and moisture content measured within one metre of the tailings profile ranged from 1.8 mg/m³ to 1.9 mg/m³ and from 20% to 22%, respectively.

3.3.2 Tailings Geochemistry

In general, tailings are high in metals and contain approximately 8% sulphides which are classified as Potential Acid Forming (PAF). 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.

In 2010, Golder Associates were commissioned to conduct a hydrogeochemical investigation of the TSF. The scope of this work included:

- the installation of three piezometers in Cell 1 of the TSF
- analysis of drilled material for sources of acid and/or metalliferous drainage
- sampling and analysis of groundwater samples
- hydrogeochemical modelling of TSF seepage.

The Golder Associates investigation identified the potential for lead and zinc seepage from the TSF. The report identified fractured geological structure as preferred seepage pathways that have limited the effectiveness of trialled seepage mitigation efforts.

Based on the outcome of the Golder Report, a comprehensive review of the TSF will be conducted in 2012 and will be comprised of:

- further geochemical characterisation of the tailings material, including kinetic tests
- desktop study and validation of Golder report conclusions regarding zinc and lead seepage
- reassessment of the cover design to mitigate seepage
- geophysical investigation of the TSF and preferential seepage flow paths
- any further necessary engineering works to mitigate adverse environmental effects of seepage from the TSF.

This management plan will be reviewed and updated to reflect the outcomes of this verification process and report.

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3.3.3 Geotechnical Properties

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. 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 equipment) is not available on a tailings surface less than six weeks old.

The anticipated (minimum) beach strength beyond six weeks is inferred to be as follows:

- three months: 10 to 25 kPa
- six months: 25 to 50 kPa
- twelve months: Greater than 50 kPa.

Based on these conditions, access to and construction on a dried tailings surface beyond an age of three months is considered feasible. It is understood that such conditions enabled upstream lifting of the pipeline embankment associated with previous works as well as the capping of Cell 1 which utilized conventional earthmoving equipment.

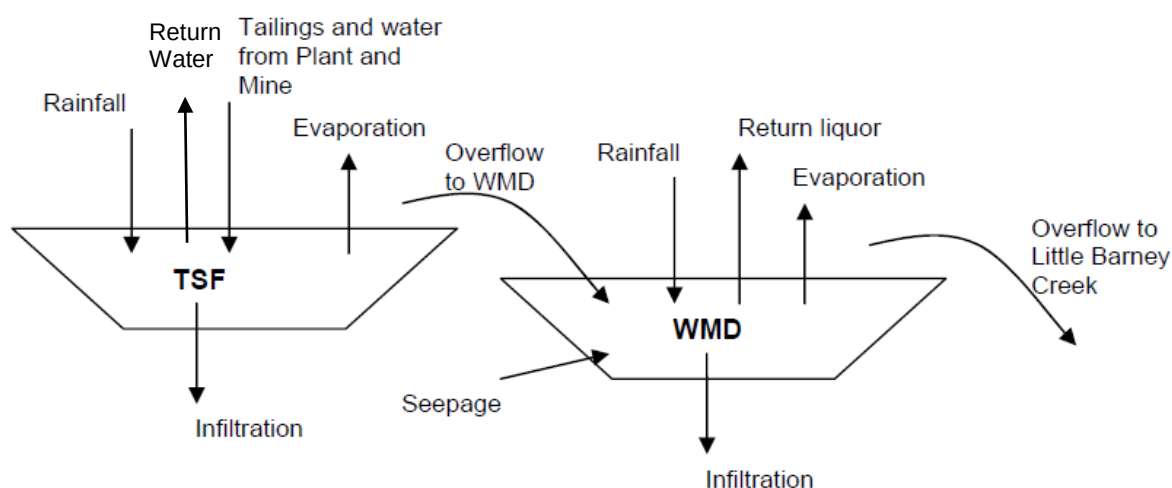
3.4 Water Management

TSF water management issues are included in the annual Sustainable Development Water Management Plan that is submitted to the Northern Territory Government. This includes the activities undertaken at the TSF within each reporting year.

Annual monitoring reports that detail the MRM environmental monitoring program, which includes groundwater and surface water monitoring results are also submitted.

3.4.1 TSF Water Management Schematic

A schematic of the existing TSF water management system is shown below.



3.4.2 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

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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.

Currently, the Cell 2 freeboard is based on Queensland Guidelines for water storage as they provide a greater (and more secure) freeboard criteria for mines located within high rainfall/wet season climates, which is applicable for the McArthur River site. In addition to the greater freeboard volume provided, the QLD guideline also has the trigger of requiring the freeboard to be available as at the 1st November of each year (i.e. prior to the wet season).

The freeboard storage capacity is designed to contain a 1:200 year 2 month wet season + 2 months of process inputs.

3.4.3 Existing Stormwater Management

3.4.3.1 Design Objective

The overall design objective of surface water management strategies is to limit erosion of the rehabilitated TSF surface in high intensity rainfall events. This will be achieved by ensuring that:

- drainage works are designed to convey flows safely from the TSF
- unlined catchment areas of the drainage system are limited
- drainage layout and drain types are compatible with their respective capacity to limit erosion and the slopes that the drains traverse.

Drainage works will cater for peak flow conditions, particularly for unlined components of the drainage system. In this respect the design criterion for unlined revegetated drains, rock lined drains, and rock chutes that form the permanent drainage system is for adequate erosion resistance for large storms with up to 1 in 100-year ARI rainfall intensity.

3.4.3.2 Contour Drains

Regularly spaced contour drains will be provided as the primary design mechanism against sheet flow causing rilling and gully erosion of the crest and outer slopes of the TSF. Across the crest of the TSF, the longitudinal gradient of contour drains will be no flatter than 1 in 200. As such, these contour drains may be susceptible to siltation, however, the general gradient of the crest of the TSF is expected to generate only minor quantities of sediment.

The contour drains will be formed by small embankments as opposed to drains cut into the slope as this ensures that adequate cap depth will remain beneath the drains. The drains will be V-shaped with relatively flat side slopes. Such drains have similar performance to wide drains in terms of limiting peak velocity, but are less prone to siltation when flow is less than the design capacity. It can be expected that the base of the V-shaped contour drains will eventually silt up and form a parabolic shaped cross-section. Such sediment will not be removed unless an excessive depth of sediment substantially reduces the flow capacity of the contour drain.

It is desirable to retain minor silt deposits (say up to 150 mm thick) in the drains as this greatly assists in maintaining moisture in the soil profile and maximising the success of vegetation growth along the contour drains.

In lesser storm events the deposition of silt promotes shallow flow hydraulics and assists in limiting flow energy. In more intense storm events, the silt deposits erode and consume flow energy.

The contour drains will be spaced to limit the velocity of sheet flow across the surface of the TSF. Under bare earth conditions, the surface of the TSF with an alluvial silt or silt loam cover should be able to resist sheet flow velocities up to 0.6 m/s (IEAust, 1996). Under revegetated conditions, the surface should be able to

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resist flow velocity up to 1.0 m/s depending on uniformity and condition of the vegetation.

The crest contour drains will discharge into rock-lined channels. Where the channel gradient needs to be steeper than 1 in 20 (5%), rock chute structures will be used. The channel design is discussed further below.

3.4.3.3 Rock-Lined Channels and Chutes

Rock-lined channels and rock chute drop structures will be provided to convey flow from the contour drains safely to the toe of the TSF. Unlined drains are not suitable, because the amount of flow discharging from the contour drains may result in flow velocities exceeding maximum permissible velocities during more intense rainfall events. Rock-lined channels will be used for drains where the longitudinal gradient is at 1 in 20 (5%) or less.

For steeper drains, the combination of flow forces and gravity forces acting to destabilise the rock armouring are too high to utilise simple rock lined channels, and engineered rock chute drop structures will be used.

The rock-lined channels will be sized as wide shallow V-shaped drains with 1 in 10 side slopes and armoured with 200 mm (D50) rock, laid 500 mm deep. The relatively shallow side slopes of the drain will ensure that flow velocities are adequately limited for the specified rock size, and will allow passage of off-road vehicles across the drains and hence eliminate the need to construct formal access road crossings.

The dimensions of the rock chute drop structures depend on peak flows, slope of the chute, height of the chute, and grading (size) of the rock. The rock chute drop structures are likely to use a rock grading (D50) of 300 mm. The flow down the rock chute drop structures will have high velocity and energy, and outlet aprons will be provided to dissipate flow energy at the toe of the chute. The rock chute drop structures will be constructed of durable NAF rock, as these structures are required for the long-term stability of the TSF.

3.4.4 Cell 2 Spillway Design Upgrade

As mentioned in Section 3.4.1, the WMD is used as an emergency storage facility if Cell 2 overtops, with the spillway on Cell 2 is directed to the WMD. The Cell 2 spillway was recently raised to RL 48.0 m as well as having major improvements in the spillway design including additional concrete batters, a clay core and concrete tie-ins (Figure 5).

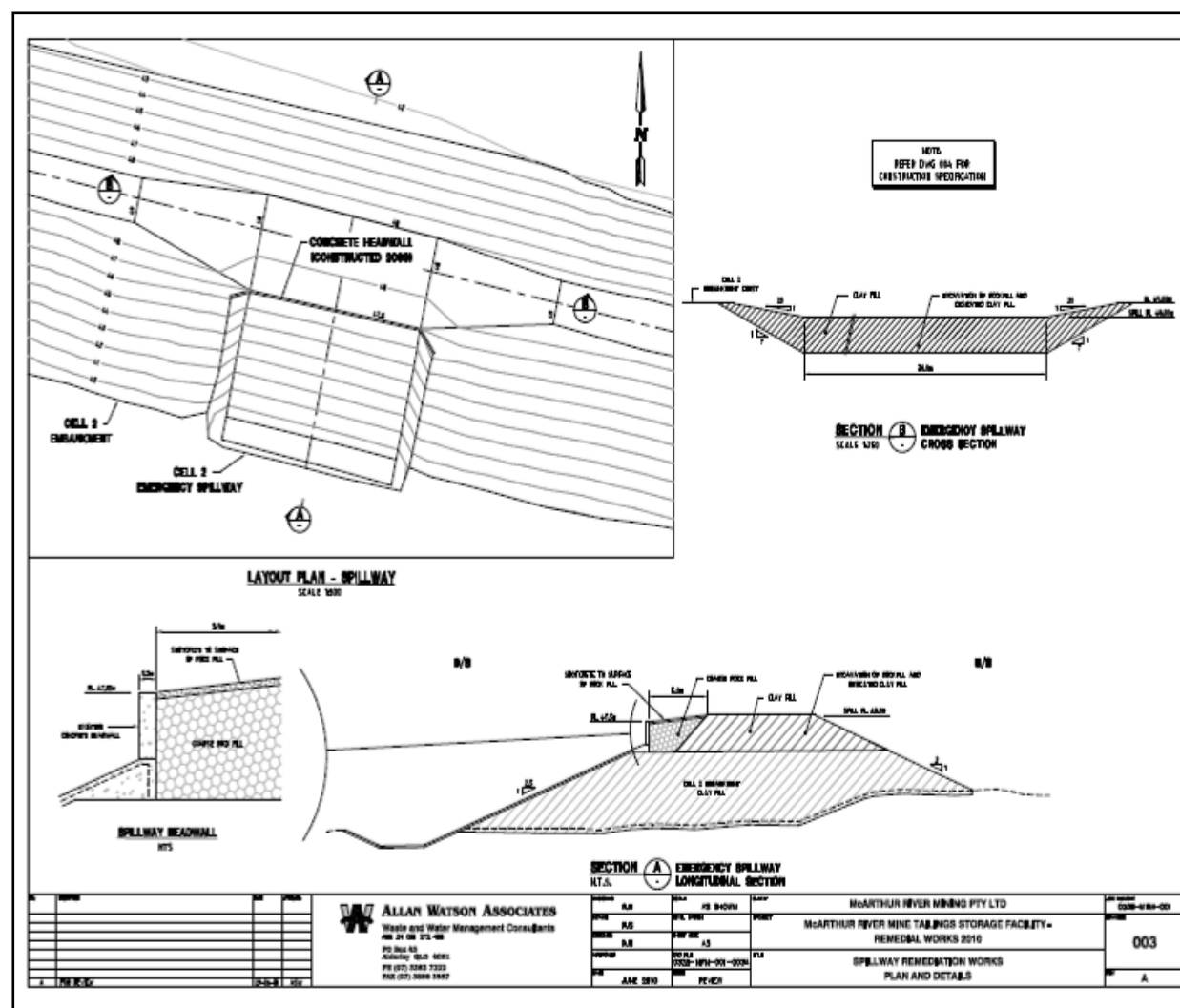


Figure 4 TSF Cell 2 Spillway Design Upgrade

Emergency spillways for the TSF development will be provided for each cell and stage and generally located such that spills will be directed into the WMD for Cells 2 and 3 and to Surprise Creek for Cell 4.

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 will be based on the worst of:

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

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3.4.5 Emergency Procedures – Extreme Rainfall Events

The most likely scenario for an emergency situation at the TSF is due to an excessive rainfall event. In this situation the following plan is to be put in place.

- during these major rainfall events 3 hourly monitoring of the TSF will be required
- stop water pumping from the mine to the TSF
- stop the plant i.e. stop the deposition of tailings (preventing surface froth from reporting to the WMD)
- increase the spillway height of Cell 2 to RL 48.5 m (using sand bags if necessary)
- once the level in Cell 2 is within 0.5 m of the maximum spillway height (RL48) start pumping clean water from the WMD to the little Barney creek spillway. Start water sampling and monitoring of this discharge
- water from Cell 2 can overflow into the WMD – this is part of the design
- additional spillway length has been excavated adjacent to the emergency spillway on the southern wall of the WMD to ensure the integrity of the WMD perimeter wall.

3.5 TSF Stability

3.5.1 Long-Term Stability

To ensure that the TSF remains stable in the long-term and will not pose an ongoing threat to the surrounding environment, particular attention has been given to the provision of a competent and long lasting embankment and cover to encapsulate the stored tailings against air or water intrusion.

The embankment design is described in Section 3.3, and engineering analysis of the rock-filled embankment has shown that it will be stable in the long-term.

3.5.2 Water Balance Modelling

The Visual HELP program, which is based on the Hydrologic Evaluation of Landfill Performance (HELP) program, was used to assess the water balance for a range of possible cover designs for maximum long-term performance (URS, 2006).

The HELP model was developed by the United States Environmental Protection Agency (USEPA) to assist landfill designers and regulators in evaluating the hydrologic performance of proposed landfill designs. The HELP model is a quasi-two-dimensional, deterministic, water-routing model for evaluating water balances. The water-balance method evaluates:

- water moving into the TSF (e.g. infiltrating rainfall)
- changes in the amount of water stored in the TSF elements (TSF cover and tailings material)
- water moving out of the TSF (e.g. evaporation from the TSF cover, drainage flows, or seepage from the base of the TSF).

The HELP model was used to simulate the performance of the cover design for the TSF, using the historic rainfall and evaporation records. Cover performance was assessed on the predicted long-term seepage rates. Each of the model runs simulated 100 years of climatic conditions, which were generated from Bureau of Meteorology data for the McArthur River site, localised to relevant climatic conditions using mean monthly rainfalls and temperatures.

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The average rainfall for the site area is about 760 mm (predominantly as summer rainfall), while mean annual pan evaporation is about 2,450 mm. This climatic setting results in minor recharge to groundwater through the soil profile.

The modelling results for the TSF cover showed the following features:

- the diversion of approximately 16% of rainfall as runoff
- interception and storage of about 76% of rainfall, which would be removed subsequently from the cap by evapo-transpiration
- approximately 8% of annual rainfall (65 mm) could infiltrate through the cap. This would assist in reducing the risk of cracking of the cover profile. In the event of extremely dry conditions, cracking could occur, but this is expected to be self-healing as summer rains rewet the cover profile.

The figure of 65 mm of annual seepage through the cap has been included in the long-term seepage modelling for the TSF.

Further modelling will be undertaken over the life of the mine to confirm the cover design performance based on new technologies and techniques.

3.5.3 Erosion Modelling

Consideration has been given to long-term erosion modelling of the TSF landform design to ensure that it provides adequate protection against erosion for long-term integrity after mine closure.

Erosion modelling, also known as landscape evolution modelling, is a newly-developing science that attempts to model the integrated processes and influences of rainfall, runoff, landform geometry and materials, cover protection, and sediment transport to estimate the long-term evolution of landforms due to erosion.

Application of erosion modelling (such as SIBERIA software) has been tested in some case studies in the Northern Territory on abandoned mine sites and requires extensive data collection on erosion, hydrology, and sediment transport to ensure adequate model calibration and accuracy in the long-term predictions.

To date, the application of erosion modelling has not been adequately tested on vegetated constructed landforms or on landforms with engineered drainage systems. Hence, the technological capabilities and accuracy of erosion-modelling science are not adequate at this stage to improve the proposed rehabilitation design for the TSF particularly as it includes added levels of erosion protection that are not present in the disturbed lands where erosion modelling has been tested to date.

MRM will continue to review the limitations and potential application of erosion modelling technology, and monitor new developments and improvements in the future. When erosion modelling science is sufficiently developed to provide reliable estimates of long-term erosion from engineered rehabilitation landforms, MRM will undertake erosion modelling with the monitoring data gained from early rehabilitation of the existing TSF Cell 1. The modelling results will be used to verify and adapt the future TSF rehabilitation strategy for the Life of Mine Completion Plan (URS, 2006).

3.5.4 Erosion Protection

The topsoil surface of the cover may be susceptible to erosion from wind and rain immediately after construction and during the vegetation establishment period. Erosion protection will be provided to minimise erosion and the loss of seed and fertiliser from the surface of the cover. A range of options is available to provide erosion protection including a number of proprietary surface mat products, straw mulching or hydro-mulching.

Hydro-mulching is a technique that involves mixing a slurry containing, for example, selected seed varieties, fertiliser, hay mulch, water and an adhesive. The slurry is pumped from a large tanker through a high-pressure spray, over the area to be treated. The seed generally adheres to the mulch, which improves the microclimate for germination and establishment.

Hay mulch in the slurry provides cover for the soil to improve pasture growth, modifies the soil surface to assist in erosion control, and improves moisture availability to establishing pasture. The mulch protects the soil surface against raindrop impact, improving the micro-environment for seed germination/establishment by reducing evaporation loss and assisting in the control of surface erosion caused by raindrop impact and overland water flow.

More information on cover design and erosion protection can be found in Section 3.4.4. Information on revegetation and rehabilitation is discussed in Section 6.

3.6 TSF Cover

3.6.1 Proposed TSF Cover Design

Decommissioning the TSF will involve placing a cover system over the facility, which should:

- reduce the net infiltration of water to levels that can be assimilated without adverse impact to the surrounding ecosystem
- provide a growth medium for the establishment of a sustainable vegetation canopy.

The design of a TSF cover can include a range of materials and different layers, depending upon the local site conditions and the potential environmental risks that are considered acceptable after rehabilitation. A review of selected literature on the design of covers indicates that the number of layers within a cover may vary from one to five. There is also a significant variation in the specified thickness of the various layers. A conceptual TSF cover design is shown in Figure 5.

A revegetation cover system generally involves the placement of a relatively thin layer (i.e. 0.3 m) of non-compacted native or barren waste material. The primary purpose of this cover system is to provide a medium for the establishment of sustainable vegetation communities. However, this simple cover system may also improve the quality of surface runoff water and reduce the entry of meteoric water and atmospheric oxygen compared to an uncovered or bare surface condition for a waste rock pile. Although this type of cover system is referred to as a “revegetation” cover system, revegetation is a key component to the success of TSF cover types from an erosion and net percolation perspective.

A moisture store-and-release cover system, also referred to as an evapotranspiration or ET cover system, generally consists of a thicker layer (as compared to the revegetation cover system) of non-compacted native or barren waste material. This cover system is an attempt to increase the ability of the cover to reduce net percolation of moisture to the underlying waste material by increasing the available moisture storage capacity.

A relatively homogeneous layer of a well-graded earthen material is best suited for this type of cover system. A moisture store-and-release cover system should also further reduce the ingress of atmospheric oxygen to the underlying waste material compared to the revegetation cover system.

The current conceptual design for the TSF cover at MRM includes a cap system, which is considered necessary to provide long-term stability in a tropical monsoonal climate with wet and dry seasons. However, this cap system will be trialled throughout the mine life when TSF areas are available for rehabilitation.

Potential sources for capping material have been identified, and these include material from the open pit, and borrow pits near the TSF and North OEF. More detailed specifications and material balances will occur once detailed planning commences.

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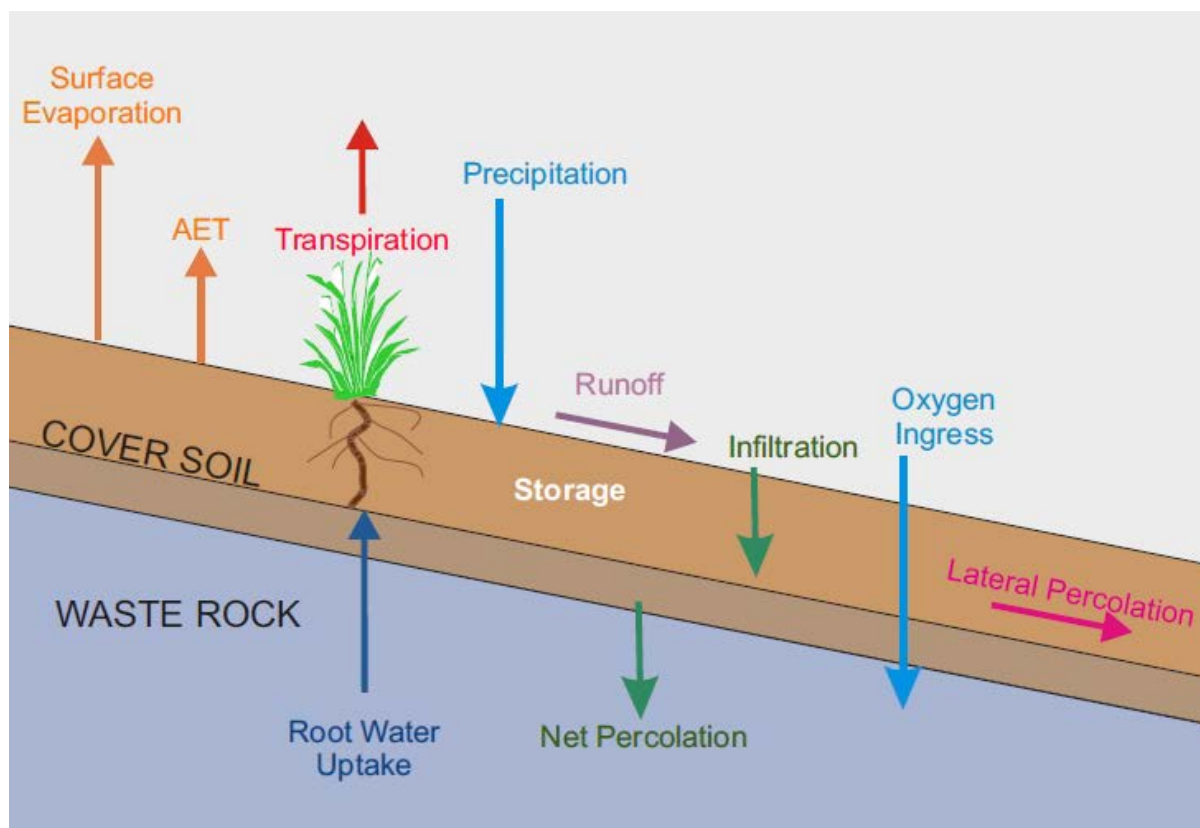


Figure 5 Conceptual TSF Cover Design

3.6.2 Previous TSF Cover Design Modelling

Soil-atmosphere numerical modelling was completed to evaluate the performance of alternate cover system designs for the MRM TSF by O’Kane Consultants (OKC) in 2006. One-dimensional (1-D) numeric simulations were completed to predict the performance of various cover system designs using VADOSE/W, a saturated-unsaturated numerical model that is fully coupled to the atmosphere.

The VADOSE/W model uses meteorological inputs such as air temperature, relative humidity, rainfall, and potential evaporation to define the flux to heat and moisture at the soil-atmosphere interface.

Net percolation was used as the indicator of cover system performance in the modelling program.

The following inputs were assumed for the modelling:

- a 42-year climate database was developed for the mine site based on the climate data collected from the McArthur River Mine and Borroloola Bureau of Meteorology stations
- the Particle Size Distributions (PSDs) of the tailings and potential cover materials were compared to materials within the OKC database. The soil-water characteristic curve (SWCC) and hydraulic conductivity function (k-function) of the database PSDs that best matched the PSDs from McArthur River Mine were selected for the modelling program. Five materials were developed for the soil-atmosphere modelling program (Tailings, Intermediate, Coarse, Fine-textured, and Compacted Fine-textured)
- the detailed modelling program examined both monolithic and multi-layered cover systems. The predicted annual average net percolation ranged from 79 mm (10% of average annual rainfall) to 118 mm (16% of average annual rainfall).

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The key findings of the soil-atmosphere modelling program are:

- the modelling program found there was relatively little difference in the performance of the cover systems containing monolithic intermediate material and multi-layer systems because the addition of a finer compacted layer did not significantly improve the performance of the cover system during the above average rainfall years. While the fine-textured or compacted fine-textured layers at the base of the cover systems did buffer the net percolation (reducing the maximum downward velocity of flow but increasing the length of time over which downward flow occurs) the total downward flow was only slightly reduced
- the modelling program found a substantial improvement in cover performance with the intermediate materials compared to the coarse cover material
- a sensitivity analysis was completed for a cover option (2.0 m intermediate/0.5 m fine-textured material) to evaluate the effect of key input parameters to the VADOSE/W model on predicted net percolation. The analysis included a number of vegetation, material properties, and climate parameters. The allowance for rainfall to either pool at the soil surface or runoff had the largest influence on the average predicted net percolation. The variance of the potential evaporation at the site also had a significant influence, as did the root depth of vegetation. The cover type and saturated hydraulic conductivity of the fine and intermediate cover materials had a moderate influence on the predicted net percolation. The length of the vegetation growing season and the surface coverage supplied by the vegetation or Leaf Area Index (LAI) had the least effect on the predicted net percolation
- the establishment of vegetation on the potential cover systems at MRM is important for stability against erosion, aesthetics, and to improve the performance of the cover systems. The available water holding capacity within the top 1.0 m of the intermediate material cover system was estimated to be 120 mm. Analysis of the detailed simulations showed that vegetation die-back is unlikely as there are few periods where the available water reaches the wilting point. The average annual water usage predicted by the VADOSE/W model was 470 mm/m²/yr. It is expected that vegetation will strongly contribute to the cover system water balance cycle through transpiration as well as providing improved stability against erosion and aesthetics to the final TSF landform
- contaminant transport modelling conducted showed little upward movement of oxidation products due to diffusion or advective transport. The limited upward movement of oxidation products suggests that vegetation is not likely to be adversely impacted at the MRM site
- the numerical simulations completed in the detailed modelling phase assumed that runoff water would pond on the cover surface during intense rainfall periods when the rainfall rate was greater than the surface infiltration rate. In some wet seasons, the size and frequency of cyclone events led to ponding up to 20 cm to 30 cm. The average net percolation decreased by 60% from 160 mm to 67 mm over the five-year simulation when surface runoff was assumed to exit the TSF cover system
- the probability of the cover systems exceeding given values of net percolation were derived from the results of the 42-year simulations. The probability function will allow the inclusion of risk-based analysis into the design of the final closure landform for the TSF.

This cover design modelling has shown that the TSF cap will be stable in the long term. However, future modelling and monitoring results will be assessed throughout the mine life to determine the final closure specifications.

3.7 TSF Seepage Mitigation

3.7.1 Background

Aquifers that underlie the TSF occur within superficial deposits and the underlying weathered and fresh bedrock. Groundwater appears to be hosted predominantly within the weathered bedrock and potentially in

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vugs or structures within the dolomitic siltstone. Groundwater levels prior to construction of the TSF were set at approximately RL 31 m or about 9 m (below the ground surface). Groundwater flow is towards the southeast and the McArthur River.

In June 1997, elevated sulphate attributed to seepage from the TSF was first detected in Surprise Creek. Zinc and lead concentrations do not currently exceed background levels.

Based on ANCOLD 1999 Guidelines, TSF seepage mitigation objectives are as follows:

- surface expression of seepage discharge from the TSF should not occur
- there should be no significant impact on the environmental quality of the receiving waters
- the potential beneficial use of either surface water or groundwater downstream of the TSF should not be compromised.

Since 2002 seepage water that has been identified outside the TSF impoundment walls has been recovered by a number of pumps in various locations including Surprise Creek. To date this water has not been a significant contributor to the site or TSF water balance.

Seepage Recovery Bores were installed during 2007 around the perimeter of Cell 1 and became operational during 2009. Several additional recovery bores were implemented in 2009 along with a small sump aiding in the recovery of contaminated water.

3.7.2 Existing Seepage

Groundwater accumulating in the existing open pit and abandoned underground workings, together with stormwater from the mine and plant area are transferred via a system of ponds to Cell 3 of the TSF. The liquor stored (a mixture of tailings liquor, groundwater and stormwater) in the TSF has infiltrated the aquifer under the TSF and is now evident at various locations outside of the TSF including Surprise Creek and the WMD. The extent of groundwater expression in Surprise Creek is such that it has become perennial in the reaches below the TSF.

Seepage from the TSF can migrate vertically through the deposited tailings, directly to the water table and laterally through embankments. Sandy alluvial profiles beneath the TSF will over time become saturated and propagate the seepage in a radial direction, outward from the source. Where these strata intersect watercourses, groundwater discharge will occur. Surprise Creek is a natural groundwater discharge zone during the wet season. The discharge rapidly diminishes after the wet season once the short-term bank storage is depleted and the water table falls below the base of the watercourse. When an artificial source of water creates a water table mound, prolonged discharge into Surprise Creek may occur.

Discrete surface expression seepage areas have been identified in the following areas of the TSF:

- Cell 1 North East Perimeter PW 3900 to PW 4700 expressing in old creek bed, which may be reaching Surprise Creek
- Cell 1 North West Perimeter PW 3100 to PW3900 expressing in Surprise Creek
- Cell 2 Western Perimeter expressing towards little Barney Creek
- Cell 2 South Eastern Corner PW 800 expressing adjacent to WMD Eastern Wall
- WMD Eastern perimeter expressing directly below water catchment pump station.

An updated conceptual water balance was derived by Allan Watson & Associates in 2011 and was used to determine the likely groundwater recharge from the existing cells of the TSF. The conservative estimate is based on the Cell 2 construction concept with a perimeter drain, saturated beach with a central pond due to spigoting around the perimeter of the cell.

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Tailings will liberate approximately 35% of the water to the pond, where it will be evaporated or decanted off for re-use in the mill. This leave the settled tails with an in-situ moisture content of around 48%. Over time, the tails will consolidate further to around 10-20% moisture, depending on its depth in the pile. This results in at most 27% of the water piped to the dam being available for seepage.

The seepage estimates through the perimeter wall of Cell 2 were estimated in the range of 90 L/day to 170 L/day per metre of wall. With a conservative assumption of seepage from all four walls, daily seepage losses would be in the order of 400 kL to 900 kL.

An Electromagnetic (EM) survey, undertaken in December 2007, measured high ground conductivities in areas of known or likely seepages, from the south-eastern and north-east areas of the TSF (URS, 2009). The survey was undertaken post injection of the geopolymer solution, with the primary objective of the survey being to monitor changes over time to gauge the geopolymer and recovery bore performance. In agreement with URS recommendations and the finding of the EM survey a network of groundwater recovery bores were commissioned in 2008, with groundwater being recovered to Cell 2 of the TSF for use in processing. The EM survey was repeated in October 2009 and 2010.

Monitoring of the seepage recovery bores is undertaken, however it is difficult to delineate water that has occurred from seepage, and that which is from the groundwater table.

Metals contained in the tailings mixture are currently being attenuated in the stratum below the TSF however, while the groundwater expressing outside the TSF has high levels of chlorides and sulphates, there is little evidence of metals being transported at this point in time. The capacity of the stratum under the TSF to attenuate the metals is limited by its physical characteristics and continued escape of liquor to the environment may be accompanied by increased levels of metals being detected in the monitoring bores.

Some seepage has flowed through the sandy soils on which the TSF is located and deep into the bedrock layers underground. At this level, seepage can run into groundwater systems. During the wet season, groundwater can be discharged into local watercourses like Surprise Creek.

The seepage that has found its way to Surprise Creek was minor and was a sulphate, similar to salt deposits. Close monitoring of this seepage has found that no heavy metals have entered Surprise Creek from the tailings.

Monitoring of flora and fauna in the area surrounding the tailings dam has also found there has been minimal impact from seepage. This is discussed more in Chapter 13 – Nature Conservation of this Draft EIS.

Surprise Creek pH values remained consistent upstream and downstream of the TSF with no significant difference found when comparing sites. Nor was there any significant difference for Copper (Cu) or Lead (Pb) and all concentrations have remained well below guideline limits for the reporting period (Metserve, 2011).

Filtered Zinc (Zn) concentrations at monitoring sites have remained below guideline levels and remained within the range of concentrations recorded over previous years. Reduced levels of Zn coincided with the initial stages (61%) of capping Cell 1 of the TSF.

The dolomite present underneath the TSF has the capacity to provide substantial ANC in the event of AMD occurring from the tailings, which has been supported by reactive ANC tests. Based on this, there may be ongoing buffering against potential acid generation for the long term. This is in addition to the tailings themselves which are comprised of 13 to 30% dolomite.

3.7.3 Previous Seepage Modelling

SEEP/W modelling was undertaken by URS in 2006 to assess the long-term performance of the TSF embankment design and seepage controls. The following comments are based on the results of this SEEP/W modelling:

- the recovery bores gradually lower the head of water within the TSF with time, and the volume of seepage pumped from the bores also decreases with time. Between 30 and 50 years after closure,

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the groundwater level will have reached the pre-TSF levels. By this time there will be no more TSF seepage as there will be no hydraulic head in the TSF. By then the recovery bore pumping can cease and seepage will no longer require management

- the rate of lowering of the head of water within the TSF and the volume of seepage pumped does not vary significantly for sandy clay or sandy soils in the upper horizons. This demonstrates that the seepage performance is controlled by the nature of the underlying dolomitic siltstone material
- a sensitivity analysis was carried out to assess the impact of a lower permeability base rock. Lowering the permeability of the base rock shows that the seepage rates are generally lower and the time taken to lower the head of water within the TSF is increased. However there is considerable evidence that the underlying dolomitic siltstone has a higher permeability than this 'worst case' scenario.

MODFLOW modelling of the seepage recovery bores was also undertaken to simulate the performance of the TSF with respect to impacts on the regional groundwater regime following its closure. The modelling has been undertaken assuming that a total of 32 recovery bores are installed around the perimeter of the TSF. The number and depth of bores actually installed may vary depending upon the results of further detailed design studies.

A summary of the MODFLOW modelling results is presented below.

- pumping the recovery bores over a 10 year period after TSF closure using flow rates of approximately 12 kL/day/bore is effective in drawing down the elevated groundwater levels that have built up during operations, with the seepage impacts confined typically to the immediate vicinity of the TSF footprint. The model results show a slight (1 to 2 m) mounding of groundwater levels to the south of the TSF. This mounding can be reduced by increasing the pumping rate beyond that assumed in the model for the bores along the southern boundary of the TSF
- pumping the recovery bores over a 25 year period after closure, using the same assumed flow rates, is effective in managing seepage impacts over the longer term. Seepage impacts are confined typically to the immediate vicinity of the TSF footprint, again with a slight mounding to the south.

The modelling has shown that judicious variation of the recovery bore pumping rates, which can be determined by using an observational approach, will result in no significant drawdown or mounding of groundwater levels surrounding the TSF following its closure.

Once the hydraulic head within the TSF is removed within 30 to 50 years after closure, no further seepage will be generated and no further pumping of the recovery bores will be required (URS, 2006b).

Seepage modelling will be undertaken throughout the life of the Project to verify potential seepage rates that will inform mine closure strategies. This will include predictions of quantity, quality and impacts of seepage, including cumulative risks from seepage. The existing groundwater and surface water monitoring program has already created a substantial database of information that will be sourced for further investigations.

3.7.4 Previous Seepage Control Measures

To date, the following seepage mitigation measures have been undertaken for the TSF:

- capping Cell 1 with an impermeable clay layer to prevent water infiltration
- installation of a soil reactive geopolymer injection to form a seepage barrier around 2,300 m of the Cell 1 toe (completed in 2005)
- the geopolymer cut off was extended along the entire length of the eastern embankment of the TSF in line with commitments made in the 2006 PER document (URS, 2006 – see Figure 6)
- construction of the Cell 2 embankment raise included the installation of a clay core cut off key which was extended downward until it intercepted suitably impermeable clays. This operation varied in

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depth from approximately 2 m to as deep as 6 m in sections

- a shallow seepage cut off spoon drain was installed on the eastern side of Cell 2 from which water is pumped back to the TSF
- the placement of the tailings was altered to a spigot outpour arrangement to minimise pooling of water against the perimeter embankments of the TSF (see Section 3.2)
- recovery bore holes, drilled and located around Cell 1, are monitored for recovery rates weekly
- a project is currently being undertaken on further strategies to minimise or alleviate seepage issues from the TSF. A combination of recovery bores, trenches and further geopolymer application may be required
- the addition of further piezometers in Cell 1 and the perimeter wall as a result of both Independent Auditor findings and the replacement of ones damaged during the rehabilitation of Cell 1.

The location of the geopolymer barrier at the TSF is shown in Figure 6.

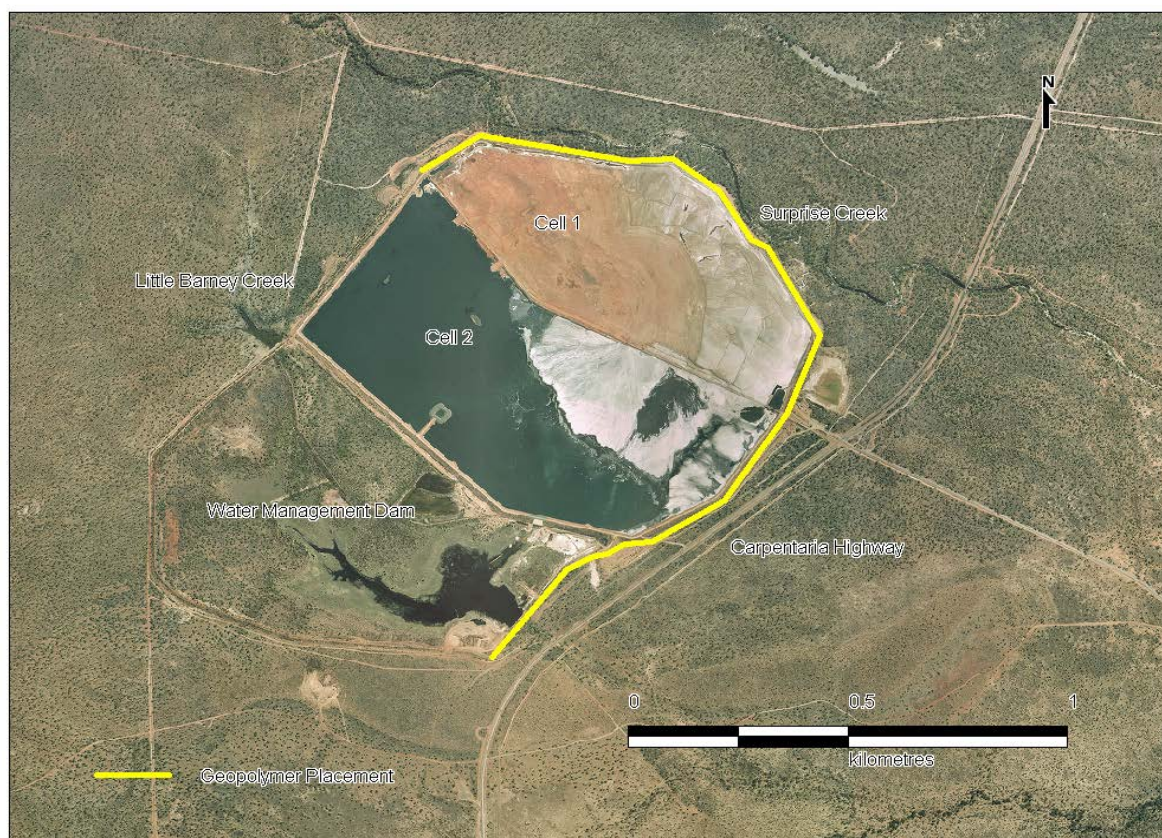


Figure 6 Existing TSF with Geopolymer Barrier Placement

The primary purpose of the barrier wall is to provide an additional line of defence to cut-off seepage through the upper sand and gravel soils, as well as the upper fractured zones of the dolomitic siltstone. Preliminary observations showed that previously wet zones around the TSF and seepage to Surprise Creek have dried out. Monitoring will continue to confirm the work was successful in the longer term.

Modelling of the seepage predicts that the cut-off barrier will reduce surface expression of seepage. However, this modelling also indicates that an elevated groundwater mound would extend outside the footprint of the TSF, which may, in the latter period of mine life (25 years), express in localised depressions such as old borrow pits, drainage channels and creek systems (URS, 2006). The groundwater recovery bores

were installed as a further measure to mitigate against the risk of an elevated groundwater mound developing in the long-term outside of the footprint of the TSF. While there have been a number of measures taken to control seepage from Cell 1, decommissioning of the cell was considered the best option to control seepage in the long term, with tailings placement to Cell 1 ceasing in 2007.

As a result of these measures, the existing plume of seepage is expected to be recovered. The precautions in place will make sure there is unlikely to be future potential contamination of groundwater beyond the TSF footprint, subject to the studies mentioned in Section 3.3.2.

3.8 Previous MRM TSF Investments and Upgrades

MRM has invested more than \$10 million since 2006 in TSF upgrades to protect the environment, including:

- decommissioning and commencement of rehabilitation of Cell 1 to minimise risk of seepage into the waterway, including a geochemical assessment of tailings
- installation of a sump to intercept surface leachate draining toward Surprise Creek
- installation of a geo-polymer fill as a physical barrier to prevent further seepage
- installation of piezometers within the TSF embankments for monitoring
- ongoing monitoring of Surprise Creek, that checks average zinc, lead, copper and cadmium concentrations at monitoring locations remain within stipulated guidelines
- undertaking electromagnetic surveys to locate and manage potential seepage points
- upgrading the Cell 2 spillway into the WMD
- developing additional protection with emergency spillways
- continuing the monitoring program to assess tailings content, seepage, and integrity of the embankment walls, pipe and infrastructure.

4 Proposed TSF Expansion – Cell 4

4.1 Location

The new Cell 4 area comprises a gently inclined and broadly undulating pediplain with mostly 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 1.0 m and in excess of 2.0 m. Elsewhere, red to yellow gravelly silty clay underlain by weathered dolomitic shale/siltstone bedrock (around 2 m depth) occurs locally on low rises.

MRM considered alternative sites to contain Project tailings. However, all alternative sites within the region have similar soils and therefore provide no benefit in terms of seepage control. The current site was found to offer the best environmental performance based on its existing disturbance footprint, technical performance, seepage control, vegetation presence, cultural heritage areas and lowest long-term risks.

4.2 Hydrogeology

The geology beneath the TSF comprises of 0.1 to 0.6 m of superficial alluvial and abandoned watercourse deposits, a 0.8 to 4.5 m thick middle succession of sandy clay and silty clay and a lower succession of weathered siltstone, sandstone, and dolomite that extends to approximately 12 m below the ground surface.

Based on previous TSF design works and the available data within the TSF area, comprising geological structure, groundwater intersection depths and in-situ 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 Project area. The groundwater surface within the TSF area is at a depth of some 10 to 12 m
- the regional groundwater system is 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 sub-cropping structures (generally coincident with creek lines/drainages)
- with a limited groundwater surface gradient and moderate aquifer permeabilities, the inferred rate of groundwater flow is low to moderate. (AWA, 2011).

4.3 TSF Cell 4 Embankment Design

The Cell 2 design of the TSF was amended to include a clay core cut-off key, effective from the construction of Cell 2 onwards. The cut-off key provides a barrier to seepage flows in the upper, higher permeability material.

The addition of Cell 4 to the TSF is required to accommodate tailings that will result from the Project. The Cell 4 placement area was selected based on the demonstrated properties of the existing TSF, the presence of existing TSF infrastructure, and to minimise disturbance to other areas.

Adjoining Cell 4 to Cells 2 and 3 also has the advantage of sharing an established embankment wall that includes the clay cut off key. Cell 4 will also include an engineered liner (such as HDPE, bentonite or clay) to further limit potential seepage from the TSF.

Stage 1 of Cell 4 will have an embankment crest level of RL 55 m and capacity of 4,300 ML for use as a water storage dam, providing additional evaporation surface area sufficient to remove 1,410 ML of water from the TSF annually. Stage 2 is planned for 2029 and the embankment height will be raised to RL 61 m,

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capable of holding 8,400 ML. This concept is illustrated in Figure 7.

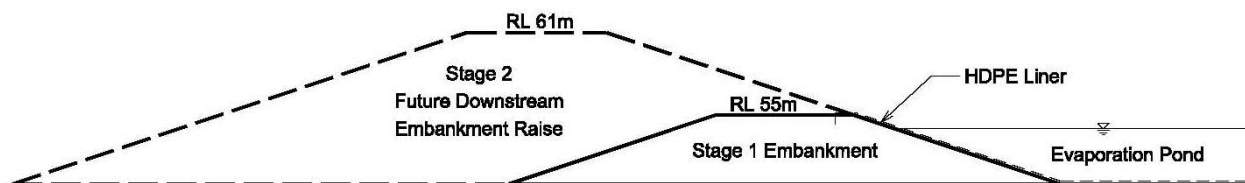


Figure 7 TSF Cell 4 – Conceptual Stage Construction

The materials for Cell 4 will be sourced from the open pit, rehandled from the overburden emplacement facilities or local borrow pits.

The initial design specifications for Cell 4 are shown below in Table 3.

Table 3 TSF Cell 4 – Design Specifications

Cell 4 Characteristic	Design Specification
Height	61 m RL
Footprint	68 ha
Capacity	8,400 ML
Spillway	Emergency spillway channel on embankment batter
Contour drains	Yes, see Section 3.4.3
Cap design	See Section 3.5
Seepage drains	Yes, perimeter seepage drains.
Liner	Yes, engineered liner such as HDP, bentonite or clay
Erosion protection	Yes, see Section 3.5.4
Sediment capture	Sediment Ponds, if required
Engineering standards	Guidelines on Tailings Dam Design, Construction and Operation (ANCOLD, 1999),
Monitoring	Survey monuments and embankment piezometers

TSF embankment stability analyses for the Project were conducted by Allan Watson Associates (AWA, 2011). Stability was modelled using the General Equilibrium method and slope stability analyses used the SLOPE/W software package with the Bishop Simplified method of analysis.

Two scenarios of embankment condition were analysed; Starter Embankment and Ultimate Embankment. Modelling considered material parameters, hydrostatic conditions and seismic effects. Results indicated that both the Starter and Ultimate Embankments will be stable.

4.4 Inferred Tailings Behaviour

Based on the tailings characteristics as defined in Section 3.3 and by correlation with available literature and previous experience with tailings of similar properties, the following potential behaviour related to tailings slurry deposition in Cell 4 has been interpreted (AWA, 2011):

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4.4.1 Tailings Dam Densities

Due to the relatively high specific gravity 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 (Table 4):

Table 4 Tailings Dam Densities

Settled Condition	Condition Description	Achievable Settled Density (t/m)
Undrained	- Initial beaching on a low permeability foundation. - Settlement around the decant (supernatant water pond)	1.25
Drained	Beaching on a previously air-dried layer of tailings (or a permeable foundation).	1.3

Assuming controlled thin layer, sub-aerial beaching of tailings based on a nominal rate of tailings surface rise of 3 m/annum, it is anticipated that a lower-bound average dry density for tailings will be of the order of 1.6 t/m³. This is consistent with estimates within the initial MRM design studies. Depending on the standard of storage management throughout the life of the facility, it is expected that average densities as high as 1.9 t/m³ are achievable and is comparable with currently achieved densities as advised by MRM. The beach slopes expected to be achieved, subject to sub-aerial deposition methods, would be of the order of 0.75 to 1.0%.

4.4.2 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.

More information on water balance is available in Chapter 10 – Water Resources.

4.4.3 Tailings Permeabilities

The measured permeability for the tailings subject to drained settlement of 5x10⁻⁷ 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.

4.5 Geotechnical Review and Implications

A geotechnical review of the TSF was undertaken by AWA 2011 and reported in previous geotechnical investigations (AWA 2003.) The implications of site geotechnical conditions on the TSF expansion design (Cell 4), 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 1.0 m to 2.0 m thick. These soils comprise generally colluvial and outwash fan deposits and floodplain alluvium. The underlying basement sequences comprise predominantly dolomite and dolomitic siltstone
- the engineering properties of the soil profile are as follows:

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- soils occurring within the site can generally be described as a sandy/gravelly clay of medium plasticity
- the soil profile below any topsoil horizon is generally of high strength (inferred undrained shear strength of 100 kPa)
- the in-situ permeability of the soil profile is moderate (in the range of 5×10^{-6} m/s to 10^{-6}), m/s however subject to re-engineering, permeability decreases to around 5×10^{-8} m/s
- 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 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.

The permeability of the geological strata has influenced the design of Cell 4, hence the need for an engineered liner.

4.6 Project Seepage Modelling

Steady-state seepage analyses (AWA, 2011) have been undertaken to model the expanded TSF (including Cell 4) to:

- estimate potential tailings water seepage losses from the TSF
- estimate potential hydrostatic heads developed within the TSF embankments, so as to assess embankment stability.

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.

Assuming Cell 4 was not lined, two embankment conditions were analysed:

- Condition 1: Starter (External) Embankment
- Condition 2: Ultimate Embankment Configuration.

In each condition, the tailings beach was assumed formed to the maximum impoundment level (i.e. 1 m 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 are provided in Table 5.

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Table 5 Permeability Values Adopted in Seepage Analysis

Zone Description	Adopted Saturated Permeability (m/s)
<i>In-situ Materials</i>	
Upper profile-soils	1×10^{-6}
Lower profile-basement	9×10^{-6}
<i>Engineered/Tailings Materials</i>	
Earth Fill/Tailings Fill	1×10^{-6}
Rock Fill	1×10^{-6}
Deposited Tailings	1×10^{-6}

The results of the seepage analyses for Conditions 1 and 2 indicate the following:

- 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
- 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.

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

- Condition 1: 255L/day/m of embankment length
- Condition 2: 230L/day/m of embankment length.

The modelling confirmed the decision to line Cell 4 with a geopolymer barrier (or similar) to minimise the seepage potential (see Section 4.1).

AMD potential from the tailings will be limited based on the deposition method currently used, which is described in Section 3.2.

4.7 Future Seepage Quality and Control Measures

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

- 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
- monitoring of surface water and groundwater quality around the TSF to detect excessive seepage migration
- implementation of effective rehabilitation works to minimise the potential seepage footprint.

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 down gradient, likely towards the east. The time taken for

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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 completed seepage analysis, 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. A network of under-drains to collect any seepage and channel it to sumps for collection will be investigated during detailed design.

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 down-gradient 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 surface water retained within the system.

MRM will initially utilise the Cell 4 area as a water management dam. MRM propose to install an engineered liner (such as polyethylene, bentonite or clay) for the Cell 4 area up to the crest level of the starter embankment. It is considered that such a liner will significantly improve the seepage performance of the cell when utilised as water storage facility (AWA, 2011). In conjunction with the management controls already in place (Section 3.7.3), seepage from the TSF will be minimised.

As mentioned in Section 3.7, predictions of seepage volumes, quality and impact will occur throughout the life of mine to determine the effect of the six lines of defence outlined in Section 2.2. The evidence provided by the environmental monitoring program has shown that there has not been a significant environmental impact from TSF seepage to date.

5 TSF Monitoring and Inspection

Research and monitoring into the potential impacts of TSF seepage at MRM will continue throughout the Project's life, as is the current case. MRM is aware of the potential impacts of the TSF operations and intends closing the site to ensure no significant off-site impacts occur. Appendix E4 – Mine Closure Plan provides further information on TSF issues and risks.

5.1 Monitoring Objectives

The TSF is monitored for structural integrity as well geochemistry. The environmental monitoring program also includes groundwater and surface water monitoring to assess any potential impacts from the TSF. Monitoring bores are located around the TSF and the frequency and results of monitoring are contained in the Annual MRM Water Management Plan.

Monitoring the performance of the TSF is an important component of demonstrating that the design assumptions and mitigation measures are effective in controlling the potential environmental impacts from the TSF, both during operations and after closure. Monitoring data will be compiled and assessed at regular intervals and reported as part of the mine's annual environmental monitoring report, which is submitted as part of MRM's obligations under its Mining Management Plan.

5.2 TSF Inspection and Reporting Schedule

The following inspections, reports and plans for the TSF are currently conducted and prepared:

- production shift inspections – every six to 12 hours
- TSF infrastructure inspections - monthly or after 50 mm rainfall events
- geotechnical inspections - annual
- TSF monthly operating report - monthly
- TSF annual operating report - annual
- life of mine tailings management plan - annual.

This will be continued for the Project and amended where necessary.

5.3 TSF Structural Monitoring

Structural surveillance of the TSF and associated infrastructure is conducted regularly, in accordance with site procedure MET-GEN-GDL-2800-0001. Any potential major abnormalities are reported immediately to the Production Superintendent for assessment and subsequent remedial action if required.

Particular attention during TSF inspections is paid to:

- the efficiency of the decant system
- embankment integrity
- any erosion of the rock face
- evidence of seepage.

5.4 Geochemical Monitoring

Geochemical testing of the final tailings provides evaluation of the potential acid generating capacity of the tailings and changes in the geochemistry of the tailings over time. The analysis of tailings allows for increased accuracy in relation to emissions reported through the National Pollution Inventory (NPI). Monitoring of the

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product also underpins management of waste material and mitigation measures for potential environmental incidents (MRM, 2010).

Tailings are analysed monthly for their oxidation characteristics. Geochemical testing of the fine tails material is undertaken monthly to characterise the potential acid generating nature of the tailings. The analysis includes:

- Net Acid Production Potential (NAPP)
- Maximum Potential Acidity (MPA)
- Net Acid Generation (NAG)
- Acid Neutralising Capacity (ANC)
- Total Sulphur (S)
- Fluorine (F)
- soluble hexavalent chromium (Cr6+)
- major cations including calcium (Ca), magnesium (Mg), potassium (K), sodium (Na)
- metals including arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn).

Results from the 2010-2011 Sustainable Development Mining Management Plan indicate consistent levels of sulphur (16.2%) with variable NAG pH. NAPP values are shown to have risen over time due to improvements in the metallurgical processes leading to a reduction of pyrite material in the tailings.

Kinetic leach tests are underway both on-site and in laboratory conditions on tailings samples. The final events of the current program were completed in October 2011, and a report will be produced incorporating and comparing the 2010-2011 and the 2009-2010 wet season samples. It is intended that Kinetic leach tests will continue and will form a part of the annual monitoring program for tailings.

5.5 Future Environmental Monitoring

Monitoring data will be collected as per current schedules and reported as part of the mine's Water Management Plan, which is submitted to the Department of Resources on an annual basis as a part of MRM's obligations under the Mining Management Plan.

It is proposed that the TSF environmental monitoring program will include the following components:

- groundwater quality
- dust monitoring
- seepage recovery rates and quality
- surface water in Surprise Creek
- artificial sites in and surrounding the TSF
- annual Electromagnetic Surveys.

5.6 Extreme Weather Events Monitoring

An emergency monitoring procedure is in place for excessive rainfall events comprising the following:

- three hourly monitoring of the TSF

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- ceasing water pumping from the mine to the TSF
- ceasing tailings deposition by halting plant operations
- increasing the spillway height of active tailings cells if required (by sandbagging if necessary).

Should the water level in an active tailings cell reach within 0.5 m of the maximum spillway, clean water can be pumped from the Water Management Dam to Little Barney Creek (contingent on regulatory approval) allowing overflow of tailings cells into the Water Management Dam. This process would necessitate immediate monitoring, including sampling, of discharge.

5.7 TSF Reporting Schedule

The current TSF reporting schedule on management of the TSF is:

- TSF Monthly Operating Report
- TSF Annual Operating Report
- Annual Life of Mine Tailing Management Plan.

This will continue and be revised throughout the life of the Project.

6 Rehabilitation and Decommissioning

Rehabilitation and decommissioning objectives at the Project are outlined in Chapter 5 – Rehabilitation and Decommissioning of the Draft EIS.

Rehabilitation of the TSF will occur progressively as cells reach their planned tailings storage capacity. This approach allows regular review and reassessment of the TSF rehabilitation plans that can be applied to subsequently decommissioned cells.

6.1 TSF Decommissioning Objectives

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

- stable and sustainable
- compatible with the surrounding landform
- consistent with the post-mine land use
- of minimum long term environmental impact (i.e. non-polluting).

The main rehabilitation and decommissioning objectives of the TSF are:

- cessation of tailings deposition
- profiling of the final tailings surface to prevent ponding and facilitate surface runoff
- construction of a low-permeability cap across the TSF to limit infiltration and prevent oxidation of Potential Acid Forming (PAF) material
- collect clean rainwater that falls within the TSF and discharge it to the environment without erosion of the TSF
- monitor and maintain seepage recovery pumping post-closure until the potentiometric head of the TSF is sufficiently reduced to prevent seepage into the environment
- further monitor groundwater levels for five years after the seepage recovery systems have been decommissioned to confirm the mitigation of seepage from the TSF.

6.2 TSF Rehabilitation Strategy

At the completion of mining activities, the TSF will be decommissioned. This will include the following management methods:

- re-profiling the surface to ensure incident rainfall runs off the TSF rather than seeps into the tailings
- placement of a capillary layer over the re-profiled surface to limit the capillary rise of salts into the cover layer
- placement of a low permeability cover over the capillary layer to prevent the oxidation of tailings, minimise the potential for seepage into the tailings, to stabilise the surface, and to provide a medium for vegetation growth.

The effect of this rehabilitation strategy will be to eliminate as far as possible additional water input into the tailings. In this way the head of water available to influence the seepage will be limited to what is in the tailings and will reduce over time as the seepage water is removed by the recovery bores.

Based on the TSF Rehabilitation objectives, a closure concept for the TSF, including Cell 4, is as follows:

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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 targeted 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

At this stage, the planned surface cover of the TSF will be 2,100 mm thick. A tailings surface cap (TSF capping and cover design are outlined in Section 3.4.4) would serve the following purposes:

- facilitate ongoing surface water drainage and prevent ponding
- stabilise the surface to mitigate against potential ongoing erosion; prevent oxidation of PAF tailings material
- limit water infiltration to the TSF thereby reducing seepage from the TSF
- reduce potential rainfall infiltration into the tailings as recharge to seepage.

The three layers of the TSF currently consist of:

- 500 mm of low-permeability clay to limit infiltration and capillary rise of salts into the cover layer
- 1,500 mm of NAF rocks
- 100 mm of topsoil (minimum thickness).

Revegetation

The TSF will be revegetated with native grasses and shallow-rooted shrubs that will stabilise the surface against erosion and reduce water stored within the cover. Water management systems will be reassessed following the establishment of vegetation. The TSF will remain fenced post-mining to prevent ingress of cattle should the surrounding land be returned to light grazing use. Permanent fire breaks will be constructed around the perimeter.

The vegetation established across the capped surface of the TSF will comprise a mixture of native and shallow-rooted grass, shrub and tree species such as suitable Acacias. The exotic grasses will be used to quickly establish a vegetation cover while the slower growing native species become established. The recommended grass species for the revegetation program are outlined in below:

- | | |
|----------------|-----------------------|
| • Silk Sorghum | • Purple Pigeon Grass |
| • Rhodes Grass | • Bambasti Panic |
| • Buffel Grass | • Siratro |
| • Indian Couch | • Stylo. |

Silk Sorghum is proposed as the dominant initial cover crop species, because it is suitable for rapid and aggressive establishment for erosion control, and mulching of perennial species in the pasture mix.

Once no longer required to transport potential seepage from the TSF, the pipeline corridor will be stripped of potentially contaminated material which will be encapsulated in either the PAF cells in the North OEF or in one of two 3 m deep bunded pits at the southern end of the Water Management Dam (Cell 3). The corridor will be seeded to facilitate revegetation.

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Seepage Recovery Bores

Seepage recovery bores will continue to function post-closure to mitigate the environmental impacts of seepage. It is currently estimated that seepage reclamation will occur for at least 30 years after decommissioning before the potentiometric head in the TSF is reduced sufficiently that seepage will not be expressed at the surface. However, further seepage studies will be undertaken to verify and predict future seepage rates.

There are a number of variables that may affect the period that the recovery bores will need to be operated following decommissioning and an observational approach is proposed. This would include a series of monitoring bores that would be installed within the TSF, the perimeter embankment and the area down-gradient of the TSF to monitor the level and quality of groundwater.

The operation of the recovery bores for the period following site closure when power is no longer readily available will be undertaken using renewable energy sources that could include either solar or wind powered pumps. The groundwater monitoring data collected during the operation of the TSF will be used to evaluate which system is most suitable. The recovery well system will be designed to have a much greater pumping capacity than theoretically required and it may be acceptable to have intermittent pumping from the bores particularly as the volume of seepage flows reduce with time. Monitoring of the performance of the recovery bores using alternate power sources will be undertaken to confirm that satisfactory performance can be provided.

After mining activities have ceased, seepage water collected from the recovery bores will no longer be able to be reused in the concentrator. Instead it will be pumped to the open pit void. Based on previous modelling results, the volume of seepage that will be collected in a typical year after the TSF is decommissioned is of the order of 73,000 m³ (200 m³ per day) (URS 2005).

As discussed in Chapter 5 – Rehabilitation and Decommissioning and Appendix E4 – Mine Closure Plan, after site closure the open pit void will be allowed to fill with groundwater inflow and surface water drainage. Discharging the TSF seepage water into the open pit will increase the depth of water in the pit over a year by less than 10 cm which will be insignificant in an open pit that will be over 400 m deep.

6.3 Final TSF Land Use

The final land use for the top of the TSF will be confirmed in the Life of Mine Completion Plan which will include rehabilitation strategies developed from experience to be gained from the closure of the existing TSF cell.

The current expectation is that it will be retained as an area of stable self-sustaining native vegetation. It is not expected that the area will be used for cattle grazing due to the difficulty in providing access for cattle and potential for disturbance and erosion.

6.4 TSF Rehabilitation Monitoring

Undertaking rehabilitation trials and monitoring of the early rehabilitation works for the existing TSF cell will include the performance of capping materials and depth (such as using lysimeters), topsoil cover (i.e. evidence of topsoil erosion and loss), vegetation cover species and resilience, integrity of constructed drainage, erosion and silt accumulation in constructed drainages, net sediment loss rates (tonnes/ha/year), sediment quality and runoff quality.

These monitoring data will be used to review the performance of the rehabilitation works implemented for the existing cell and any deficiencies will be remediated including all relevant aspects and causes of poor performance. For example, if erosion is identified due to insufficient vegetation growth indirectly caused by inadequate topsoil cover, topsoil replenishment and protection against topsoil depletion would be key requirements to remediate the TSF rehabilitation.

Progressive rehabilitation monitoring is a key requirement to adapt and implement remedial and contingency works to achieve the objective of a stable and sustainable landform. The knowledge and experience gained

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from performance monitoring of the early rehabilitation works will then be applied and adapted to the overall rehabilitation design for closure of the remainder of the TSF.

At the end of mine life, and prior to relinquishment of the mine lease, MRM will provide detailed post-rehabilitation monitoring reports to the Northern Territory Government to demonstrate that the rehabilitated landform is stable and that performance criteria agreed in the Life of Mine Completion Plan have been achieved.

6.5 TSF Closure Monitoring

An “observational” approach will be taken in determining how long the seepage recovery bores need to be operated following mine closure. Groundwater levels will be monitored within the TSF, the perimeter embankment, and the area down-gradient of the TSF. During operation of the mine, personnel will be on site to oversee the groundwater and seepage monitoring program. After mining activities have ceased, an automated monitoring system will be installed. The automated monitoring system will store data at the site, which will be downloaded at regular intervals, either by personnel visiting the site or by a dial up connection.

The Mine Management Plan also outlines a closure and rehabilitation plan for the tailings. This is at least 25 years away and so the final plan, when the time comes, will include emerging best practice and new technology as relevant.

MRM has made a commitment to the long term management of the tailings, even after the mine has closed, until such time that the monitoring and maintenance is assessed by the Northern Territory Government to be no longer required. The aim is to ensure the tailings has no lasting legacy on the environment or for future owners of the land.

The cost of an unplanned closure of the mine site is used to estimate the security that is held by the Northern Territory Government as required by the *Mining Management Act 2001*. The security is based on the costs of implementing the environmental requirements to achieve the agreed closure criteria and is presented annually in the Mining Management Plan.

6.6 TSF Rehabilitation Reporting

Rehabilitation status and requirements for the TSF are reviewed annually. Updated calculations of closure costs are included in the annual Sustainable Development Mining Management Plans and provide the basis for the Financial Security Bond. Maintenance of the seepage recovery bores, including considerations for future electricity requirements have been included in the calculated mine closure costs.

The TSF rehabilitation design is consistent with current best practice and provides multiple levels of protection against erosion. Continual improvement in the TSF rehabilitation design will be developed during the life of the mine. Furthermore, data from the performance monitoring of the early rehabilitation of the existing Cell 1 will be used to adapt the rehabilitation design and to confirm the integrity of the rehabilitation works prior to mine closure.

MRM will use the monitoring data and erosion modelling to verify that the rehabilitation design has adequate protection to sustain the integrity of the TSF against erosion in the long term.

Progressive results will be reported to the Northern Territory Government during the mine life through the Mine Management Plan process and agreed measurable mine closure criteria will be defined in the Life of Mine Closure Plan.

This approach ensures that adequate objectives and prescriptive rehabilitation processes are provided as commitments for project approval, whilst ensuring mechanisms and commitments are in place for continual improvement and implementation of best practice during the mine life and prior to mine closure.

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6.7 Closure Personnel

Specific personnel would stay in the event of closure and would include environmental personnel for monitoring purposes.

Consultants would also be utilised to have input into any of the pre-determined plans for rehabilitation and to also assess the implementation of them.

7 Previous TSF Commitments

MRM have made a number of commitments in regards to TSF via previous environmental assessments and Mining Management Plans. MRM will continue these commitments for the life of the Project and refine them where appropriate.

7.1 Draft EIS Commitments (August 2005) for Major Open Cut 25 Year Mine Life

The Draft Environmental Impact Statement August 2005 lists the following commitments in relation to the TSF and water systems;

Extract Section 7 Waste Management

- 7.4.1 The existing tailings storage facility (TSF) footprint will be utilised for the open cut operations. No additional land disturbances will be necessary.
- 7.4.2 The general operational philosophy for the new TSF will be based on the use of sub-aerial techniques for tailings deposition. Sub aerial deposition involves the discharge of tailings from multiple locations around the perimeter of the active cell.

As the head of water in the TSF is a key driver of seepage, the volume of water in the decant pond will be kept as small as possible and water will not be stored across the tailings surface.

Maintaining a minimum moisture condition within the beach to inhibit the formation of oxidation products from drying tailings beaches and to prevent dust generation.

- 7.4.3 The TSF embankment will be coincident with the existing embankments. Their integrity will be confirmed by detailed investigations and depending on the results they will be either incorporated into the new embankments or removed for the new construction.

The embankments will be designed to meet the minimum factors of safety. A factor of safety for any structure needs to be greater than one before it can be considered safe.

Condition	Factor of Safety	Design
Steady State (at maximum storage level)	1.5	1.8
Seismic condition	1.1	1.2
At Closure	1.3	1.3
Rapid drawdown	1.2	-

Water management design will be based on the requirements of the Australian National Committee on Large Dams (ANCOLD, 1999). Using this criteria, the hazard category of the TSF is rated as high given the potential impacts from an uncontrolled release or embankment failure.

Any external draining spillway will be based on ANCOLD (1999) design conditions for a high hazard category and will incorporate the worst of the following:

- Probable maximum flood (PMF) on the highest pond level in normal year; or
- Worst wet season on record less water returned to the plant, plus 100 year average recurrence interval (ARI) storm plus waves.

Appendix E1 – TSF Management Plan

- 7.4.4 The site water balance indicates that the Water Management Dam (WMD) requires a capacity of 2,500 MI

An emergency spillway will be provided. It will be designed to accommodate at least a 1:500 year event.

- 7.4.5 Maintaining a large enough decant pond to enable sufficient residence time for the settlement of suspended solids prior to recovery.

Maintaining an appropriate tailings deposition regime so that the potential for tailings to oxidise and release oxidation products is limited. Levels of saturation/moisture within the beach will be defined and maintained to inhibit oxidation. This practice will significantly reduce the dusting potential of the tailings

- 7.4.7 The design objective of the TSF will be to prevent seepage from occurring. On the basis of ANCOLD (1999), the following design objectives have been adopted for seepage at the new TSF:

- Surface expression of seepage discharge downstream of the TSF should not occur
- No significant impact should occur on the environmental quality of receiving waters
- The potential beneficial uses of surface and ground water downstream of the TSF should not be compromised.

Water from recovery bores will be pumped to the concentrator for reuse.

7.2 Supplement to Draft EIS December 2005

The water management system will be designed such that spillway discharge from the TSF will be extremely unlikely (1 in 500 year probability) which is more stringent than ANCOLD guideline requirements which require containment for 1 in 200 year wet season rainfall. The possibility of discharges from the TSF to Surprise Creek will be extremely rare and in excess of the 1 in 500 year probability.

7.3 Public Environmental Report July 2006

7.3.1 Section 7.0 Tailings Storage Facility

7.3.1.1 Summary

The overall strategy to manage the risk of environmental harm from the TSF, in particular seepage, comprises a multiple lines of defence strategy that has been developed for the three key stages of the life of the TSF as follows:

1. Design Stage

- Decommission the existing Cell 1
- Incorporate seepage control measures in the design of the perimeter TSF embankment, including a compacted low permeability clay cut-off into the foundation and a low permeability clay core to the embankment.
- Incorporating additional seepage control measures, including a low permeability geopolymer cut-off wall below the embankment to the eastern wall downgradient of the regional groundwater flow, as well as recovery bores downstream of the embankment for the full perimeter of the TSF, to intersect and capture seepage flows.
- Modify the current tailings and water management practices to keep ponded water away from the perimeter embankment.

Appendix E1 – TSF Management Plan

2. Operations Stage

- Modify the current tailings and water management practices, to minimise the risk of tailings oxidising and generating acidic runoff.
- Monitoring the performance of the TSF to measure the actual seepage control performance against the predicted performance as a part of an observational approach.
- Managing a network of seepage recovery bores so that while seepage from the TSF is recovered, regional groundwater levels surrounding the TSF are not affected.

3. Closure and Rehabilitation Stage

- Tailings placement to the TSF ceases
- Re-profile the tailings surface to provide a well graded surface that promotes surface runoff and prevents ponding.
- Construct a low permeability cap across the final landform surface (500mm of clay).
- Construct a surface water management system across the TSF to collect rainfall and discharge this clean water to the surrounding environment in a controlled manner. Monitoring data and erosion modelling will be used to verify the rehabilitation design provides adequate protection against erosion.
- Maintain the recovery bores until the seepage head within the TSF has been lowered to the design level.
- Monitor the groundwater levels around the perimeter of the TSF for a period of five years after the recovery bores have been decommissioned, to ensure that the ongoing seepage performance meets the design expectations, with limited impacts to the regional groundwater regime.

The approach to managing the TSF so that it will not impact on the receiving environment has been summarised in Section 2.

7.4 MRM Mine Management Plans

Mine Management Plans are submitted on an annual basis and contain the commitments for the site that will occur in the upcoming year. These plans will have specific requirements for TSF management and will be different between years.

8 References

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