PROGRESSIVE REHABILITATION AND CLOSURE PLAN

DUGALD RIVER MINE

PREPARED BY: WULGURU TECHNICAL SERVICES
DOCUMENT ID: 2024.07003
VERSION: 4.0
DATE OF SUBMISSION: 6 March 2026
TENURE: MDL79, ML2467, ML2468, ML469, ML2470, ML2471, ML2477, ML2478, ML2479, ML2480, ML2481, ML2482, ML2496, ML2497, ML2498, ML2499, ML2500, ML2501, ML2502, ML2556, ML2557, ML2558, ML2559, ML2596, ML2599, ML2601, ML2638, ML2684, ML2685, ML7496, ML90047, ML90049, ML90050, ML90051, ML90211, ML90212, ML90213, ML90218, ML90220, ML90230, ML90237, ML100383, ML100359, ML100382
ENVIRONMENTAL AUTHORITY: EPML00731213
EA HOLDER: MMG DUGALD RIVER PTY LTD
EA HOLDER CONTACT DETAILS: LEVEL 23, 28 FRESHWATER PLACE SOUTHBANK VIC 3006

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Document Control and History

Version	Date	Description	Prepared By	Reviewed By
1.0	2/10/2022	Final	Madison Jackson	Scott Hayes-Stanley
2.0	23/10/2024	Final – Approval of October 2024 EAA	Madison Jackson	Madison Jackson
2.1	18/03/2025	Draft – April 2025 EAA	Taysha Hall	Madison Jackson
3.0	17/04/2025	Final – April 2025 EAA	Taysha Hall	Madison Jackson
3.1	30/05/2025	Response to NPM	Madison Jackson	Madison Jackson
4.0	5/03/2026	Response to Information Request	Taysha Hall	Madison Jackson

Citation

Wulguru Technical Services, 2026, *Progressive Rehabilitation and Closure Plan*, Prepared by Wulguru Technical Services Pty Ltd for MMG Dugald River Pty Ltd.

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1. Introduction

Dugald River Mine (the Project) is owned and operated by MMG Dugald River Pty Ltd. The Project operates under Environmental Authority EPML00731213 (the EA) and Progressive Rehabilitation and Closure Plan (PRCP) schedule PRCP-EPML00731213-V2. Wulguru Technical Services Pty Ltd (WTS) was engaged by MMG to revise the existing PRCP for activities proposed by an EA amendment application, submitted for assessment in April 2025.

This document summarises the technical components and supporting information relating to the rehabilitation and closure of the Project and has considered the following Department of Environment, Tourism, Science and Innovation (DETSI) guideline:

- Guideline ESR/2019/4964 – *Progressive rehabilitation and closure plans (PRC plans)*, Version 3.01 – 16 September 2024.

The PRCP outlines the Project planning and post-closure requirements, community consultation, post-mining land use, rehabilitation methods, risk assessment, monitoring and maintenance, and rehabilitation schedule. A summary of proposed changes is provided in Appendix O.

2. Purpose of Plan

The purpose of this document is to assess the existing environmental values and provide for rehabilitation and closure planning based on approved activities. This PRCP will:

- Outline how MMG will meet landholder expectations for final land use;
- Outline how MMG will achieve a decommissioned site that is safe, fit for purpose, and non-polluting;
- Outline how MMG will minimise residual impact or liability for community and future land holders following rehabilitation; and
- Outline how MMG will return the landform to an agreed or pre-mine condition.

2.1. Requirements of the Plan

The PRCP is required to provide the information stated in the Guideline ESR/2019/4964 – Progressive rehabilitation and closure plans as well as sections 126C and 126D of the Environmental Protection Act 1994 (EP Act). Table 1 details how each requirement has been met to achieve a 'properly made' PRCP application.

Table 1. Requirements of a PRCP

PRCP Requirement	PRCP Reference
Project description	
Describe each resource tenure, including the area of each tenure, to which the application relates.	Section 3.1.2

PRCP Requirement	PRCP Reference
Describe the relevant activities to which the application relates.	Section 3.1.4
Describe the likely duration of the relevant activities.	Section 3.1.9
Include a detailed description, including maps, of how and where relevant activities are carried out.	Section 3.1.1, Section 3.1.4
Consultation	
Include details of the consultation undertaken by the applicant in developing the proposed PRCP.	Section 3.2
Include details of how the applicant will undertake ongoing consultation in relation to the rehabilitation to be carried out under the plan.	Section 3.2.2
Post-mining land use	
State the extent to which each proposed post – mining land use identified in the proposed PRCP schedule for the plan is consistent with the outcome of consultation with the community in developing the PRCP.	Section 3.3.3.1
State the extent to which each proposed post-mining land use identified in the proposed PRCP schedule for the plan is consistent with any strategies or plans for the land of a local government, the State or the Commonwealth.	Section 3.3.3.2
Non-use management area	
State the extent to which each proposed non-use management area identified in the PRCP schedule for the plan is consistent with the outcome of consultation with the community developing the PRCP.	N/A – No NUMAs proposed
State the extent to which each non-use management area identified in the PRCP schedule for the plan is consistent with any strategies or plans for the land of a local government, the State or the Commonwealth.	N/A – No NUMAs proposed
For each proposed non-use management area, state the reasons the applicant considers the area cannot be rehabilitated to a stable condition because of a matter mentioned in section 126D(2). Note for transitional PRCPs: The holder is not required to comply with the requirements under section 126C(1)(g) or 126D(2) or (3) for the propose PRCP schedule for the plan in relation to land if a land outcome document identified the outcomes for the land as the same, or substantially similar to, the outcome for the land if it were a non-use management area.	N/A – No NUMAs proposed
For each matter mentioned in the requirement above, include copies of reports or other evidence relied on by the proposed for each proposed non-use management area. Note for transitional PRCPs: The holder is not required to comply with the requirements under section 126C(1)(g) or 126D(2) or (3) for the propose PRCP schedule for the plan	N/A – No NUMAs proposed

PRCP Requirement	PRCP Reference
in relation to land if a land outcome document identified if the outcomes for the land are the same, or substantially similar to, the outcome for the land if it were a non-use management area.	
Rehabilitation and management methodology	
For each post-mining land use, state the applicants' proposed methods or techniques for rehabilitating the land to a stable condition in a way that supports the rehabilitation milestones under the proposed PRCP schedule.	Section 3.5
For each non-use management area, state the applicant's proposed methodology for achieving best practice management of the area to support the management milestones under the proposed PRCP schedule for the area.	N/A – No NUMAs proposed
Risk assessment	
Identify the risk of a stable condition for land described as a post-mining land use not being achieved, and how the applicant intends to manage or minimise the risks.	Section 3.6
PRCP Guideline	
Include any other information prescribed by the administering authority in the Guideline - Progressive rehabilitation and closure plans.	Appendix B – Appendix H
Include the spatial information referred to in the Guideline - Progressive rehabilitation and closure plans.	Spatial submission
Other information	
Include the other information the administering authority reasonably considers necessary to decide whether to approve the PRCP schedule.	Appendix B – Appendix H
PRCP Schedule	
Include a PRCP scheduled prepared using the PRCP schedule template (ESR/2019/5103)	Appendix A
Include all maps showing all of the land mentioned in the PRCP schedule, as it relates to being progressively rehabilitated.	Figure 12 and Figure 14

2.2. Amendments to the Current Schedule

Rehabilitation of currently approved activities are scheduled to be carried out in accordance with the PRC Plan and approved PRCP Schedule (P-PRCP-100846032). An EA amendment application has been prepared, seeking approval of the following:

- Downstream raise of the Tailings Storage Facility (TSF);
- Construction of a borrow pit to access suitable material for the construction of the TSF raise;
- An expansion to the Potentially Acid Forming (PAF) Waste Pad;
- Construction of a borrow pit to access suitable material for the expansion of the PAF Pad;

- Replacing the groundwater contaminant limit for Fluoride with a site-specific value;
- Addition of Mining Lease (ML) 100383, 100359, and 100382 to the Project area; and
- Alternative air quality monitoring locations.

This PRC Plan and Schedule have been submitted in consideration of the proposed EA amendments detailed above. This amended PRC Plan and Schedule is submitted in accordance with Section 226AA (2) of the EP Act. Specific amendments to the PRCP Schedule are detailed in Appendix O.

Overall, the revisions to the timing within the PRCP Schedule have been made to reflect the current technical information available and are not necessarily a result of a reduced LoM. Future mine planning is still in progress, with potential extensions being considered.

2.2.1. Condition PRCP5

This application proposes amendment of PRCP Schedule Condition PRCP5.

PRCP5 – *'Within 3 years of approval of the PRCP Schedule P-PRCP-100846032, the PRCP holder must commence field trials to demonstrate the construction and performance of the alternative cover system…'.*

In accordance with the current conditioning, within 3 years of approval of the PRCP Schedule would necessitate rehabilitation trials to commence in 2026. The current approvals timeframe and project scheduling estimates construction of the tailings storage facility (TSF) stage 3 embankment raise, subject of the EA amendment application, to be completed in 2029. As such, the TSF area will not become available to conduct rehabilitation trials by 2026. The conditioning of PRCP5 is proposed to be amended to allow the commencement of rehabilitation trials following the TSF stage 3 embankment raise, as proposed by the following conditioning:

PRCP5 – '*The PRCP holder must commence field trials within 12 months of the completion of the tailings storage facility (TSF) stage 3 embankment raise to demonstrate the construction and performance of the alternative cover system…'*.

3. Rehabilitation Planning

3.1. Project Planning

3.1.1. Project Description

DRM is located approximately 63 km northwest of Cloncurry, in north-western Queensland (Figure 1).

The DRM ore body was discovered in the late 1900s following early small-scale mining and prospecting. The explorers identified gossanous zinc/ lead/ silver outcropping between two main drainage features on the plains below the Knapdale Range. Evidence of the outcropping is still visible within a demarcated area of the mines surface features. The surrounding area is littered with surficial copper oxide deposits as well as historic small scale mining features including waste dumps, collapsed shafts and rusted infrastructure (WTS, 2021).

Systematic exploration of the deposit began in the 1950s. Zinifex Australia Limited started the most recent phase of exploration in 2004 who subsequently began the process of gaining State and Federal approvals. During this period, the Project was purchased by Minerals and Metals Group (MMG) with approval being granted in 2012 and the first phase of construction (earth works, waste rock pads and dams and underground development) following in 2013. After a brief pause mid-construction to more thoroughly investigate the mining methodology, the Project was completed early 2017. MMG shipped the first parcel of zinc concentrate later that year (WTS, 2021).

Since 2017, the Project has continued to operate as an underground mine and processing facility. Approximately 13 million tonnes have been processed to date.

409700E

412700E

7762855N

7759855N

Mmg Dugald River Mine Access Road

Dugald River

Clayton Creek

100 0 100 200 km

Sources:
ESRI
QLD Department of Resources (2023, 2024)

LEGEND

Mining Lease
- Application
- Granted

Key features

Road and track

Watercourse
- 1
- 2
- 3
- 5

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MMG DUGALD RIVER MINE

FIGURE 1. PROJECT LOCATION

0.8 0 0.8 1.6 km

CRS: GDA2020 / MGA zone 54
Scale: 1:30,000 @A3

Date: 12 February 2025

Author: H. Robb

WULGURU TECHNICAL SERVICES

Project Number: 2024.07003

Client: MMG Dugald River Pty Ltd

Version: 0.04

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3.1.2. Mining Tenements

The project encompasses 40 mining leases and one mineral development lease, as detailed in Table 2. An additional three mining leases are proposed within the related EA amendment application, submitted April 2025.

Table 2. Granted tenures for the Dugald River Mine

Permit	Permit Name	Area (ha)	Land Tenure
MDL 79	NA	227.59	59TG40; 36AP23793; 92SP303378
ML 2467	DUGALD 1	16.21	27B15753; 36AP23793
ML 2468	DUGALD 2	16.21	27B15753; 35B15753; 36AP23793
ML 2469	DUGALD 3	16.2	35B15753; 36AP23793; 36B15753
ML 2470	DUGALD 4	16.19	36AP23793; 36B15753
ML 2471	DUGALD 5	16.19	36AP23793
ML 2477	DUGALD 6	32.51	36AP23793
ML 2478	DUGALD 7	129.49	36AP23793; 92SP303378
ML 2479	DUGALD 8	32.37	36AP23793; 92SP303378
ML 2480	DUGALD 9	32.37	36AP23793; 92SP303378
ML 2481	DUGALD 10	129.49	36AP23793; 92SP303378
ML 2482	DUGALD 11	32.37	36AP23793
ML 2496	DUGALD RIVER NO 6	129.49	36AP23793
ML 2497	DUGALD RIVER NO 7	8.09	36AP23793
ML 2498	DUGALD RIVER 8	29.06	36AP23793; 36B15753
ML 2499	DUGALD RIVER 9	28.08	36AP23793
ML 2500	DUGALD RIVER 10	28.35	36AP23793
ML 2501	DUGALD RIVER 11	30.4	36AP23793
ML 2502	DUGALD RIVER 12	31.63	36AP23793
ML 2556	CLANDESTINE 7	127.72	36AP23793; 92SP303378
ML 2557	CLANDESTINE 8	129.14	36AP23793
ML 2558	CLANDESTINE 13	128.5	36AP23793; 92SP303378
ML 2559	CLANDESTINE 14	98.7	36AP23793; 92SP303378
ML 2596	DUGALD RIVER 51	19	36AP23793
ML 2599	DUGALD RIVER 57	44.77	36AP23793; 92SP303378
ML 2601	DUGALD RIVER 61	28.5	36AP23793
ML 2638	KNAPDALE	122.51	36AP23793; 92SP303378
ML 2684	DUGALD NO 12	1.05	36AP23793
ML 2685	DUGALD NO 13	2.45	36AP23793
ML 7496	DUGULD	24.76	27B15753; 35B15753; 36AP23793
ML 90047	KNAPDALE NO 2	8.36	36AP23793
ML 90049	DUGALD SOUTH NO 7	0.31	36AP23793
ML 90050	DUGALD SOUTH NO 8	0.22	36AP23793
ML 90051	SCANLAN NO 6	9.59	36AP23793
ML 90211	DUGALD TSF	642.67	36AP23793; 92SP303378
ML 90212	DUGALD TXS1	100.48	36AP23793; 92SP303378
ML 90213	DUGALD TXS2	31.7	36AP23793; 92SP303378

Permit	Permit Name	Area (ha)	Land Tenure
ML 90218	DUGALD WPIPE	43.49	5AP23793; 36AP23793
ML 90220	DUGALD PLINE	507.93	2BD56; 3635SP274652; 36AP23793; 3AP23793; 4144SP256851; 521CP905413; 7CP905412; 91SP303378; 92SP303378
ML 90230	DACCESS	120.32	2577PH139; 36AP23793; 92SP303378; 211SP136468
ML 90237	DUGALD TXS3	20.5	36AP23793; 92SP303378
ML100383*	Dugald River Southwest	1075.4	36AP23793, 211SP136468, 2577PH139, 35B15753, 36AP23793, 92SP303378
ML 100359*	Dugald River Northwest	21.13	36AP23793, 211SP136468, 2577PH139, 35B15753, 36AP23793, 92SP303378
ML 100382*	Dugald River Northeast	43.53	36AP23793, 211SP136468, 2577PH139, 35B15753, 36AP23793, 92SP303378

**Subject to EA approval*

3.1.3. Underlying Landholders

The underlying landholders are shown in Table 3.

Table 3. Underlying landholder

Permit	Lot	Plan	Landholder
MDL 79, ML 2467, ML 2468, ML 2469, ML 2470, ML 2471, ML 2477, ML 2478, ML 2479, ML 2480, ML 2481, ML 2482, ML 2496, ML 2497, ML 2498, ML 2499, ML 2500, ML 2501, ML 2502, ML 2556, ML 2557, ML 2558, ML 2559, ML 2596, ML 2599, ML 2601, ML 2638, ML 2684, ML 2685, ML 7496, ML 90047, ML 90049, ML 90050, ML 90051, ML 90211, ML 90212, ML 90213, ML 90218, ML 90220, ML 90230, ML 90237	36	AP23793	Unallocated State Land
MDL 79, ML 2478, ML 2479, ML 2480, ML 2481, ML 2556, ML 2558, ML 2559, ML 2599, ML 2638, ML 90211, ML 90212, ML 90213, ML 90220, ML 90230, ML 90237, ML 100383, ML 100359, ML 100382	92	SP303378	Harold Henry McMillan
MDL 79, ML 90211	59	TG40	North Australian Pastoral Co Pty Ltd
ML 7496	27	B15753	MMG Australia Limited
ML 7496	35	B15753	MMG Australia Limited
ML 7496	36	B15753	MMG Australia Limited
ML 90230	211	SP136468	Queensland Rail

Permit	Lot	Plan	Landholder
ML 90220	521	CP05413	Jersey Plains Pastoral Company
ML 90220	3635	PH2175	Cameron Creek Pastoral Co Pty Ltd

3.1.4. Primary Mine Features and Infrastructure On-Site

The approved mine features, including proposed additional disturbances, are defined in Table 4.

Table 4. Mine features

Mine Domain	Mine Feature Name	Maximum Disturbance Area (hectares)
Ancillary Infrastructure and Services	Accommodation Village and sewage treatment plant	13.60
	Pipeline and Accommodation Village Road	6
	Communications tower	0.06
	Powerline	65.72
	Raw water pipeline	5.44
	Roads and Tracks	47.98
	Groundwater infrastructure	0.54
	Emergency response training area	0.5
	Tailing pipeline catch dam	0.16
Borrow Pits & Stockpiles	Topsoil Stockpile A	8.23
	Borrow Pit A	2.96
	Access Road Borrow Pit(s)	4.72
	TSF Borrow Pit A, TSF Borrow Pit B, TSF Stockpile	4.1
	TSF Borrow Pit C	9.23
	Topsoil Stockpile B	9.60
	Borrow Pit D	2.06
	Borrow Pit E	2.95
Dams and Diversion Structures	Diversion Drains	2.39
	Stage 2 PAF PAD Run Off Dam	11.60
	Underground Mine Water Collection Dam	0.65
	STP Dam Stage 1	0.9

Mine Domain	Mine Feature Name	Maximum Disturbance Area (hectares)
	STP Dam Stage 2	4
	ROM Area Run Off Dam	3.7
	Raw Water Dam	1.8
	Sediment Dam A	1.1
	Process Plant Run Off Dam	1.5
	Containment Dam	0.6
	Mine Workshop Run Off Dam	0.6
	Sediment Dam C	0.30
	Sediment Dam D	0.35
	Sediment Dam F	1.4
	Sediment Dam G	1.4
Exploration	Drill Pads*	10*
Mineralised Waste	NAF waste rock dump	8
	NAF waste rock dump bund	
	PAF waste rock dump (Stage 4)	14.56
Mining and Processing Area	West Laydown Area	10.3
	Waste Transfer Station	0.25
	Explosives magazine	0.6
	Fuel Storage	0.2
	Temporary Waste Laydown	1
	Construction Laydown, Warehouse, Mobile Equipment Laydown and Core Shed	6.8
	North decline	1
	South decline	1
	Ventilation shaft 1	0.05
	Ventilation shaft 2	0.05
	Ventilation shaft 3	0.05
	Ventilation shaft 4	0.05
	Ventilation shaft 5	0.05

Mine Domain	Mine Feature Name	Maximum Disturbance Area (hectares)
	Ventilation shaft 6	0.05
	Ventilation shaft 7	0.05
	Ventilation shaft 8	0.05
	Ventilation shaft 9	0.54
	Run of Mine (ROM) Pad	3.8
	ROM Haul Roads	3.53
	Processing Plant and Conveyor Area	13.53
	Switchyard 1	1.04
	Switchyard 2	0.99
	Exploration Camp and Camp Expansion Works	2.41
	Sewage Treatment Plants	0.16
	Workshop, Vehicle Washdown and Maintenance Area	3.8
	Office & Administration Buildings	2.72
	Laydown east	6.47
Tailings Storage Facility (TSF)	TSF and Seepage Collection Pond	103.51
	TSF Pipelines and Roads	6.37
Renewables	Wind Farm and Ancillary Infrastructure	27.86
	Laydown west	6.13
	Access Roads	33.08

*Exploration disturbance is conditioned by PRCP4 and not included in the total area defined in the PRCP Schedule

3.1.5. Pre-mining Land Use

The DRM is located on Roseby Station pastoral leases. Prior to the development of the operation, the area was used for cattle grazing. The site also contained several small, abandoned mine workings and previous exploration disturbance.

3.1.6. Communities

The nearest residential area is the McMillan family residence at Roseby Station, approximately 6 km from the operational area.

The DRM is located within the Mount Isa Mineral Province. This region is characterised by mineral exploration, mining and pastoral activities. Cloncurry is located 65 km southeast of the Project. Cloncurry's population is approximately 3,000 with the primary industries being cattle grazing and mining. The nearest regional centre is Mount Isa, located 80 km southwest of DRM. Mount Isa has a population of over 18,000 and is the administrative, commercial and industrial centre for north-western Queensland.

The Project ML area does not contain areas of regional interest (priority living areas, priority agricultural areas, strategic cropping land and strategic environmental areas) protected under the *Regional Planning Interests Act 2014* (DPI, 2024).

3.1.7. Native Title

The Kalkadoon Native Title Aboriginal Corporation (the Kalkadoon People) are the Registered Native Title Claimants of the land in and surrounding the Project.

Part of the southern section of the powerline to site is in the Mitakoodi and Mayi People's Native Title claim. The Mitakoodi and Mayi people have not achieved formal Native Title determination, however they are generally recognised to have ties to the areas directly surrounding the Cloncurry township.

A Cultural Heritage Management Agreement is in place for each group.

3.1.8. Type of Operations

The zinc/lead/silver ore is mined from underground by conventional mechanised methods (long hole open stoping and down hole benching methods). Ore and waste are drilled and blasted prior to excavation. The mine is accessed by twin declines that are also used to haul ore and waste from the mine.

The ore is processed onsite, then transported by rail to the Port of Townsville. Any tailings that are not transferred to the paste plant (to be used as paste fill underground) are disposed to the Tailings Storage Facility (TSF) via a 4 km pipeline.

Exploration drilling also occurs within the mining leases and on the mineral development lease. There is no other activity conducted on the mineral development lease.

3.1.9. Duration Of Operation

The Project began in 2018 and has a current Life of Mine (LoM) of 25 years (i.e. 2043). It is noted that this LoM has been revised from a previous date of 2047. The rehabilitation schedule has been amended to reflect the new LoM.

An approved rehabilitation schedule is provided in Appendix A, with works scheduled to commence in 2044. Where land becomes available for rehabilitation earlier than the nominated date, progressive rehabilitation will commence as soon as practical. A third-party review will be undertaken by an independent, appropriately qualified and experienced person annually, to review all authorised areas and assess availability for progressive rehabilitation. This review will be submitted to the administering authority within 10 business days of being requested. Within 90 days of the land becoming available for

rehabilitation, MMG will apply to the administering authority to amend the PRCP schedule in a way that maximises the progressive rehabilitation of the land to a stable condition, including bringing forward achievement of relevant milestones and criteria in the approved schedule.

Where progressive rehabilitation occurs, it is expected that at least one wet season will be needed to establish vegetation. As such each rehabilitation campaign is to be completed, at the latest, by October of each year to allow for vegetation establishment prior to the wet season and to minimise erosion potential.

3.1.10. Existing Environmental Context

3.1.10.1. Climate

3.1.10.1.1. Rainfall and Temperature

The Project is situated within the northwest highlands biogeographic region. The bioregion is characterised by distinctive wet and dry seasons with hot conditions and periods of rainfall between November to April, and relatively dry and mild conditions between May to October.

Statistics from the nearest Bureau of Meteorology weather station at the Cloncurry Airport (BOM Station ID 29141) generalise a 14°C spread of the mean monthly minimum and maximum daily temperatures during summer while increasing to 15°C in winter (Figure 2). The highest mean monthly temperatures are recorded in December and the lowest in July.

Most rainfall measured at the Cloncurry Airport is received between January and February with an annual average rainfall of 505 mm. With only 35 days where rainfall is ≥ 1mm, short and intense storm events are common (Table 5).

The predominant wind direction is south-southeast (Figure 3).

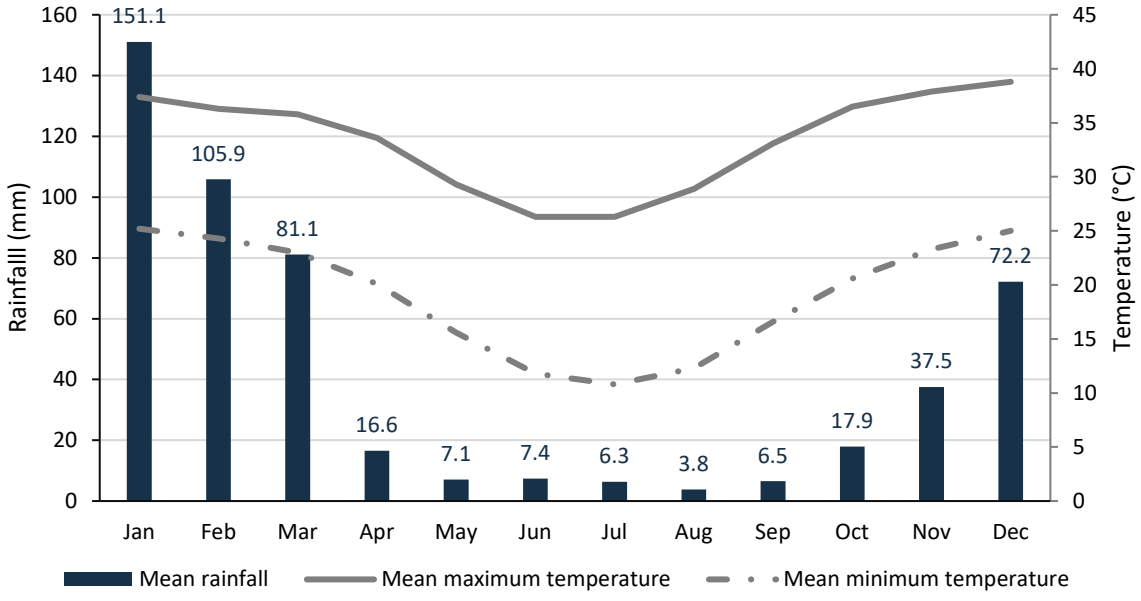


Figure 2. Climate statistics recorded at the Cloncurry Airport (BOM, 2024)

Table 5. Mean monthly rainfall recorded at the Cloncurry Airport (BOM, 2024)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (mm)	151.1	105.9	74.1	15.1	7.1	7.4	6.3	3.8	6.5	17.9	37.5	72.2	502.3
Days ≥ 1mm	8.3	6.4	4.0	1.4	0.8	0.7	0.5	0.4	1.2	1.9	3.7	5.3	34.8

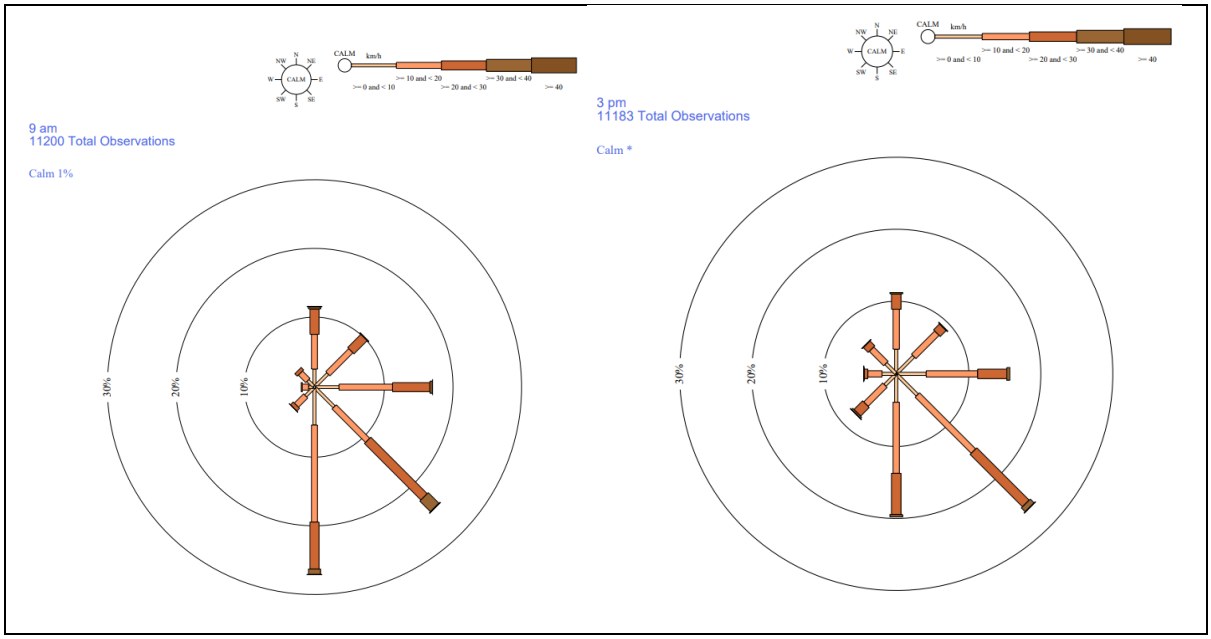


Figure 3. Cloncurry Airport 9am and 3pm wind rose (BOM, 2024)

3.1.10.1.2. Long-term Climate Projections

The 2024 State of the Climate Report (CSIRO & BOM, 2024) has predicted a continued increase in air temperatures, with more heat extremes and fewer cold extremes. There is a continued decrease, on average, in cool season rainfall across many regions of southern and eastern Australia, which will likely lead to more time in drought. Collectively, these contribute to an increase in the number of dangerous fire weather days and a longer fire season across eastern Australia. More intense short-duration heavy rainfall events even in regions where the average rainfall decreases or stays the same will contribute to increased flooding risk. Flooding risk may exacerbate erosion, impacting upon exposed or freshly rehabilitated surfaces.

3.1.10.2. Topography and Hydrology

3.1.10.2.1. Topography

The topography of the DRM is dominated by the Knapdale Range (Knapdales) as the topographical high (~310m Australian Height Datum (AHD)). The Knapdales is a north south orientated formation

~14km long and ~2.5km wide sharply transitioning to undulating country east to the Dugald River and west to Cabbage Tree Creek at ~200mAHD (Figure 4).

The mining and processing infrastructure is located on the eastern slope of the Knapdale Range with the Tailings Storage Facility (TSF) sited within the centre valley of the range, formerly draining to the west.

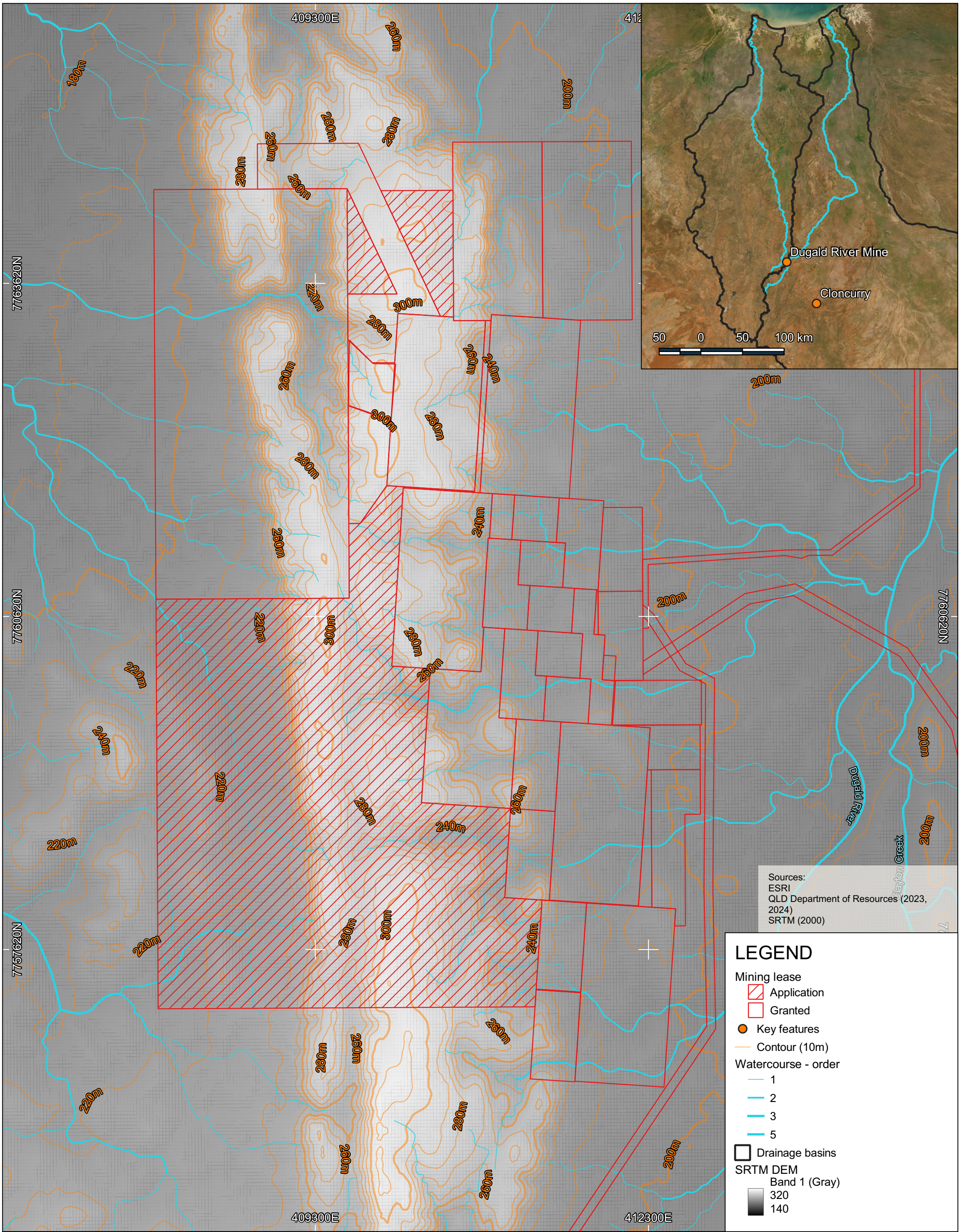
3.1.10.2.2. Hydrology

Regionally, DRM is situated in the Leichardt and Flinders drainage basins with the Knapdale Range providing the drainage divide between the two catchments (WRM, 2010). Both the Leichardt and Flinders Rivers drain north into the Gulf of Carpentaria ~400 km from the Project (Figure 4).

Locally, the Project area is dominated by stream order 1 and 2 ephemeral drainage features that only flow intermittently during wet season rains. To the north and west of the Knapdales, these features drain to Vieuex Rose Creek and Cabbage Tree Creek which flow into Pinnacle Creek, a tributary of the Leichardt River. Drainage to the east and south of the Knapdales enters the Flinders River via Dugald River, a tributary of the Cloncurry River (WTS, 2021). The catchments associated with the predominant mine features are listed in Table 6.

Table 6. Local catchments and mine features

Local catchment	Mine features
Silvermine Creek	Mining, processing, mineral waste storage, administration, mine access, village, and logistics
Vieuex Rose Creek	Village
Cabbage Tree Creek	Tailings storage facility



MMG DUGALD RIVER MINE

FIG 4. TOPOGRAPHY AND HYDROLOGY

0.8 0 0.8 1.6 km CRS: GDA2020 / MGA zone 54 Scale: 1:30,000 @A3	Date: 12 February 2025 Author: H. Robb	WULGURU TECHNICAL SERVICES
Project Number: 2024.07003	Client: MMG Dugald River Pty Ltd	Version: 0.03

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3.1.10.3. Surface Water

3.1.10.3.1. Environmental Values

The Environmental Protection Policy (Water and Wetland Biodiversity) (EPP Water) details the scheduled water quality basins and their specific management intent. DRM is situated between the Leichardt and Flinders drainage basins with the Knapdale Range providing the drainage divide between the two catchments. No Environmental Values are listed in the EPP Water for either the Leichardt or Flinders drainage basins. In the absence of EVs for either catchment, the following EVs have been adopted from the EPP Water Part 3:

- For high ecological value waters—the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued; or
- For slightly disturbed waters—the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators; or
- For moderately disturbed waters—the biological integrity of an aquatic ecosystem that is adversely affected by human activity to a relatively small but measurable degree; or
- For highly disturbed waters—the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned in paragraphs (a) to (c); or
- For waters from which aquatic foods intended for human consumption are taken—the suitability of the water for producing the foods for human consumption; or
- For waters that may be used for aquaculture—the suitability of the water for aquacultural use; or
- For waters that may be used for agricultural purposes—the suitability of the water for agricultural purposes; or
- For waters that may be used for recreation or aesthetic purposes—the suitability of the water for—
    - Primary recreational use; or
    - Secondary recreational use; or
    - Visual recreational use; or
- For waters that may be used for drinking water—the suitability of the water for supply as drinking water having regard to the level of treatment of the water; or
- For waters that may be used for industrial purposes—the suitability of the water for industrial use; or
- The cultural and spiritual values of the water (The State of Queensland, 2023).

3.1.10.3.2. Water Quality Trigger Limits

The EA provides receiving water reference sites and downstream monitoring locations (Schedule C – Table 4 of the EA) (Figure 5). Each site is monitored and sampled in accordance with Schedule C Table 5 of the EA, presented below in Table 7.

Table 7 Receiving waters trigger levels and contaminant limits (Schedule C - Table 5 of the EA)

Quality Characteristic[1]	Unit	Trigger Level [1, 10]	Contaminant Limit[1, 10, 12]	Monitoring Frequency
Hardness ($CaCO_3$)	mg/L	For interpretation purposes		Sites on tributaries of Dugald River: Sample daily for the first two days when releases or stream flows commence at interpretative sites. If releases or flows at interpretative sites persist, sample weekly until flow ceases. Dugald River Sites: Sample Dugald River sites daily while there is flows at DR-14, and daily for one week after cessation of flows at SC-38 and SN-23. Sample monthly if flows are present in Dugald River during the wet season. Cabbage Tree Creek sites: Sample CT3-08, CC-05 and CC-15 daily when flows are present at CT3-08 and sample CC-05 and CC-15 daily for two days after flows at CT3-08 cease.
pH	pH Units	6.0 (minimum) 8.6[13] (maximum)	5.5 (minimum) 9.0[13] (maximum)	
Electrical Conductivity	µS/cm	435 or 80th percentile of reference whichever is higher	1000	
Total Suspended Solids	mg/L	For interpretation purposes		
Sulfate	mg/L	77 [Duglad River] or 80th percentile of reference whichever is higher	400[4]	
Fluoride	mg/L	80th percentile of reference	2[3] or 95th percentile of reference[10] whichever is lower	
Aluminium (dissolved)	mg/L	0.055[2] or 80th percentile of reference whichever is higher	95th percentile of reference[10]	
Aluminium (total)	mg/L	For interpretation purposes		
Arsenic[8] (dissolved)	mg/L	0.013[2] or 80th percentile of reference whichever is higher	95th percentile of reference	
Arsenic (total)	mg/L	-	0.5[3]	

Quality Characteristic[1]	Unit	Trigger Level [1, 10]	Contaminant Limit[1, 10, 12]	Monitoring Frequency
Cadmium (dissolved)	mg/L	0.0002[2] or 80th percentile of reference whichever is higher	95th percentile of reference[10]	Sample CC-05 and CC-15 weekly if flows are present.
Cadmium (total)	mg/L	-	0.005[4]	
Copper (dissolved)	mg/L	0.0014[2] or 80th percentile of reference whichever is higher	95th percentile of reference[10]	
Copper (total)	mg/L	-	1[4]	
Lead (dissolved)	mg/L	0.0034[2] or 80th percentile of reference whichever is higher	95th percentile of reference[10]	
Lead (total)	mg/L	-	0.05[4]	
Manganese (dissolved)	mg/L	1.9[2] or 80th percentile of reference whichever is higher	95th percentile of reference[10]	
Manganese (total)	mg/L	For interpretation purposes		
Nickel (dissolved)	mg/L	0.011[2] or 80th percentile of reference whichever is higher	95th percentile of reference[10]	
Nickel (total)	mg/L	-	1[3]	
Zinc (dissolved)	mg/L	0.008[2] or 80th percentile of reference whichever is higher	95th percentile of reference[10]	
Zinc (total)	mg/L	-	20[3]	

[1] All metals and metalloids must be measured as both 'total' (from analysis of an unfiltered sample) and 'dissolved' (from analysis of a field filtered sample). All trigger levels are based on dissolved metal concentrations.

- Metals concentrations may be adjusted to the site-specific hardness in accordance with ANZECC 2000 (Section 3.4.3 and Table 3.4.3) as appropriate.

- If a filterable result exceeds the applicable trigger value, further analysis may be performed to quantify the dissolved component of the filtrate.

[2] Based on ANZG (2018).

[3] Based on ANZECC/ARMCANZ (2000) Table 4.3.2 for livestock drinking water.

[4] Based on ANZECC/ARMCANZ (2000) Table 5.2.3 for recreational purposes.

[8] Speciated arsenic concentrations for As (III) and As (V) only required if 13 mg/L is exceeded - note that the sample bottle requirements for As (total species) and As (speciated) may differ.

[9] Site-specific trigger levels and contaminant limits for water quality (80th and 95th percentile of reference site concentration) must be calculated in accordance with QWQG (2009) and ANZECC (2000) methodology if sufficient monitoring data is available. The environmental authority holder must maintain a database documenting all relevant water quality monitoring data and calculation of 80th/95th percentiles adopted as water quality trigger levels and contaminant limits.

[10] The contaminant limit '95th percentile of reference' is not applicable where the 95th percentile of reference site concentration is below the specified trigger level for the respective Quality Characteristic.

[11] Reference site concentration determined from reference sites specified in Schedule C – Table 6 (Receiving Water and Stream Sediment Reference Sites and Downstream Monitoring Points).

[12] Compliance at DR-18 and DR-22 is assessed when surface flows are present at either interpretive site SC-38 or SN-23

[13] Based on TropWATER Technical Memo – Recommended amendments to Dugald River Mine Environmental Authority EPML00731213 dated January 2020

3.1.10.3.3. Receiving Environment Monitoring Program

DRM implements a receiving environment monitoring program (REMP), that encompasses event-based surface water sampling, stream sediment sampling and macroinvertebrate and fish sampling.

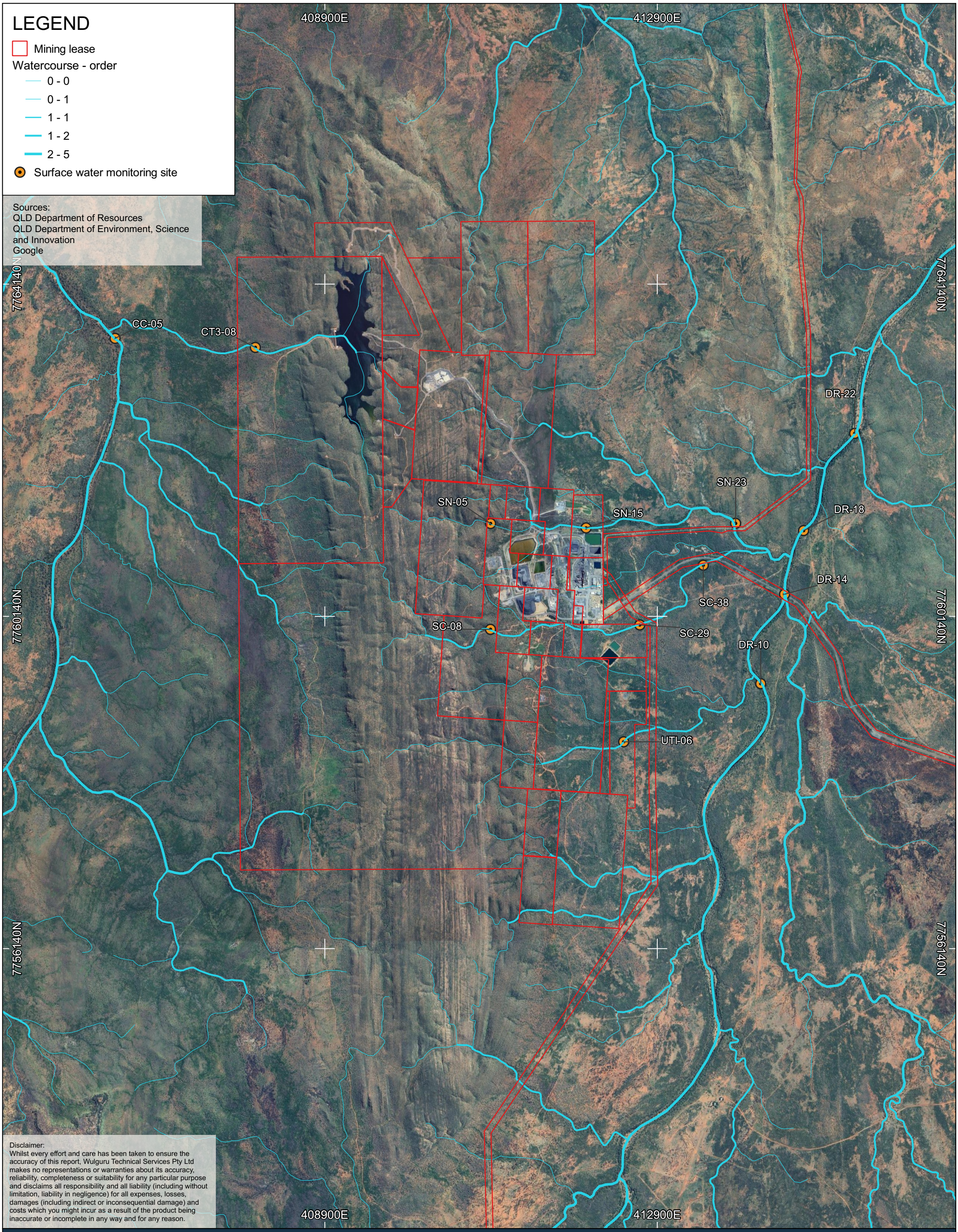
REMP data collected to date indicates that the ephemeral sites on Silvermine Creek and Cabbage Tree Creek provide limited habitat opportunities for most aquatic organisms. Waterholes dry out too quickly to allow the establishment of sustained aquatic plant, macroinvertebrate or freshwater fish communities (TropWATER, 2020). The ephemeral waterholes are also too small and transient to have recreational value or provide watering points for terrestrial fauna.

The waterholes that form along the main channel of Dugald River are larger and semi-permanent. The waterholes periodically provide refugia for freshwater biological communities and provide a drinking water source for livestock and terrestrial fauna.

Overall, the waterholes assessed in the REMP are defined as being slightly to moderately disturbed, typical of waterways in free grazing areas (TropWATER, 2020).

3.1.10.3.4. Surface Water Quality

A summary of surface water chemistry is provided in Table 8.



MMG DUGALD RIVER MINE

FIGURE 5. SURFACE WATER MONITORING

1 0 1 2 km CRS: GDA2020 / MGA zone 54 Scale: 1:40,000 @A3	Date: 23 April 2025 Author: H. Robb	WULGURU TECHNICAL SERVICES
Project Number: 2024.07003	Client: MMG Dugald River Pty Ltd	Version: 0.02

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Table 8: Surface water chemistry 2020-2024

1		Hardness (mg/l)	pH	EC µS/cm	TSS (mg/l)	Sulphate (mg/l)	Fluoride (mg/l)	Total Metals (mg/l)								Filtered Metals (mg/l)							
								Al	As	Cd	Cu	Pb	Mn	Ni	Zn	Al	As	Cd	Cu	Pb	Mn	Ni	Zn
SC-08	Count	83	83	83	84	57	84	84	84	83	84	84	84	84	83	83	83	82	83	83	83	83	83
	Minimum	0.5	6.09	27	2.5	1	0.05	0.04	<0.001	<0.0001	0.001	0.001	0.00005	0.001	0.001	0.03	<0.001	<0.0001	0.001	0.001	0.001	0.001	0.003
	Maximum	48	8.6	365	78	26	0.5	4.17	<0.001	<0.0001	0.130	0.039	0.189	0.004	0.001	0.64	<0.001	<0.0001	0.003	0.016	0.067	0.001	0.019
	Mean	8.44	7.27	56.7	6.3	2.16	0.06	0.65	<0.001	<0.0001	0.004	0.002	0.02	0.001	0.001	0.15	<0.001	<0.0001	0.001	0.001	0.005	0.001	0.003
	Median	7.00	7.18	46.5	2.5	2.00	0.05	0.44	<0.001	<0.0001	0.002	0.001	0.01	0.001	0.001	0.11	<0.001	<0.0001	0.001	0.001	0.002	0.001	0.003
SN-05	Count	57	54	54	57	57	57	58	58	58	58	58	58	58	58	57	58	58	58	58	58	58	58
	Minimum	0.5	6.32	29.2	2.5	0.5	0.05	0.03	0.0005	0.00005	0.0005	0.0005	0.001	<0.001	0.0025	0.01	<0.001	0.00005	0.0005	0.0005	0.0005	0.0005	0.0025
	Maximum	47	8.38	172.6	20	17	0.5	1.24	0.002	0.0002	0.003	0.015	0.029	<0.001	0.082	0.89	<0.001	0.0002	0.002	0.006	0.026	0.003	0.048
	Mean	10.54	7.31	62	3.7	2.55	0.06	0.33	0.0005	0.0001	0.0008	0.001	0.006	<0.001	0.0087	0.13	<0.001	0.0001	0.0006	0.0007	0.004	0.0005	0.007
	Median	7	7.275	55.7	2.5	2	0.05	0.21	0.0005	0.00005	0.0005	0.0005	0.006	<0.001	0.0065	0.06	<0.001	0.00005	0.0005	0.0005	0.002	0.0005	0.0025
CT3-08	Count	47	44	44	48	48	48	49	49	49	49	49	49	49	49	48	48	48	48	48	48	49	48
	Minimum	9	6.28	49.7	2.5	0.5	0.05	0.005	0.0005	<0.0001	0.0005	0.0005	0.002	0.0005	0.0025	0.005	0.0005	<0.0001	0.0005	0.0005	0.0005	<0.001	0.0025
	Maximum	143	9.46	349.7	21	120	0.3	1.33	0.001	<0.0001	0.006	0.022	0.661	0.001	0.012	0.27	0.001	<0.0001	0.003	0.004	0.142	<0.001	0.009
	Mean	30	7.76	111.8	4.8	10.5	0.066	0.364	0.0006	<0.0001	0.0018	0.0015	0.056	0.0005	0.0036	0.0679	0.0005	<0.0001	0.0009	0.0007	0.0186	<0.001	0.0027
	Median	24	7.57	91.85	2.5	6	0.05	0.3	0.0005	<0.0001	0.002	0.0005	0.037	0.0005	0.0025	0.04	0.0005	<0.0001	0.001	0.0005	0.006	<0.001	0.0025
MS5	Count	15																					
	Minimum	7.00	6.56	39.00	2.50	1.00	<0.1	0.09	0.0005	0.0001	0.0010	0.0005	0.0080	0.0005	0.0025	0.0600	0.0005	0.0001	0.0005	0.0005	0.0005	0.0005	0.0025
	Maximum	45.00	7.66	126.00	107.00	20.00	<0.1	3.96	0.0040	0.0003	0.0360	0.0430	0.2030	0.0050	0.1590	0.6400	0.0020	0.0002	0.0110	0.0050	0.1490	0.0010	0.0350
	Mean	27.60	6.99	88.20	19.23	10.00	<0.1	0.94	0.0013	0.0001	0.0079	0.0084	0.0542	0.0014	0.0438	0.2636	0.0007	0.0001	0.0032	0.0017	0.0316	0.0005	0.0149
	Median	28.00	6.97	89.00	5.00	11.00	<0.1	0.49	0.0010	0.0001	0.0030	0.0040	0.0280	0.0005	0.0280	0.2100	0.0005	0.0001	0.0020	0.0010	0.0160	0.0005	0.0120
UT1-06	Count	12			13																		
	Minimum	9.00	6.43	39.00	2.50	0.50	0.05	0.06	<0.001	<0.0001	0.0005	<0.001	0.0020	0.0005	0.0025	0.0400	0.0005	<0.0001	0.0010	0.0005	0.0010	<0.001	<0.005
	Maximum	32.00	7.72	103.00	21.00	2.00	0.20	0.75	<0.001	<0.0001	0.0080	<0.001	0.0770	0.0010	0.0060	0.5000	0.0010	<0.0001	0.0060	0.0010	0.0700	<0.001	<0.005
	Mean	17.3	7.02	61.83	4.92	0.92	0.06	0.30	<0.001	<0.0001	0.0037	<0.001	0.0145	0.0005	0.0028	0.2200	0.0006	<0.0001	0.0028	0.0005	0.0111	<0.001	<0.005
	Median	17.00	7.04	56.50	2.50	1.00	0.05	0.19	<0.001	<0.0001	0.0030	<0.001	0.0070	0.0005	0.0025	0.2000	0.0005	<0.0001	0.0020	0.0005	0.0060	<0.001	<0.005
SN-15	Count	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
	Minimum	2	6.75	43.35	2.5	2	0.05	0.01	0.0005	0.00005	0.0005	0.0005	0.004	0.0005	0.0025	0.005	0.0005	0.00005	0.0005	0.0005	0.0005	<0.001	0.0025
	Maximum	119	9.01	319.1	136	68	0.5	6.03	0.007	0.0004	0.019	0.046	0.291	0.006	0.291	0.48	0.002	0.0002	0.008	0.02	0.064	<0.001	0.07
	Mean	43.8	7.67	130.1	12.21	15	0.085	0.755	0.001	0.0001	0.003	0.007	0.034	0.0009	0.044	0.09	0.0006	0.0001	0.001	0.0018	0.010	<0.001	0.017
	Median	36.5	7.58	121.25	2.5	10	0.05	0.28	0.0005	0.00005	0.002	0.004	0.012	0.0005	0.023	0.03	0.0005	0.00005	0.001	0.0005	0.006	<0.001	0.01
SN-23	Count	40	39	39	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
	Minimum	7	6.87	42.4	2.5	0.5	0.05	0.005	0.0005	0.00005	0.0005	0.0005	0.004	0.0005	0.0025	0.005	<0.001	0.00005	0.0005	0.0005	0.0005	<0.001	0.0025

1		Hardness (mg/l)	pH	EC µS/cm	TSS (mg/l)	Sulphate (mg/l)	Fluoride (mg/l)	Total Metals (mg/l)								Filtered Metals (mg/l)							
								Al	As	Cd	Cu	Pb	Mn	Ni	Zn	Al	As	Cd	Cu	Pb	Mn	Ni	Zn
	Maximum	73	9.73	224	30	32	0.1	1.28	0.001	0.0002	0.024	0.035	0.175	0.001	0.102	0.4	<0.001	0.0001	0.009	0.011	0.1	<0.001	0.033
	Mean	48.6	7.56	135.49	7.67	12.76	0.053	0.44	0.0005	0.00007	0.0053	0.0034	0.0345	0.0006	0.018	0.063	<0.001	0.0001	0.0024	0.001	0.0159	<0.001	0.0069
	Median	50	7.5	139.5	2.5	13	0.05	0.42	0.0005	0.00005	0.003	0.002	0.0195	0.0005	0.01	0.0075	<0.001	0.00005	0.002	0.0005	0.003	<0.001	0.0025
SC-38	Count	54	52	52	54	53	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
	Minimum	7.0	7.04	44	2.5	2	0.050	0.005	0.001	0.0001	0.001	0.001	0.005	0.001	0.003	0.005	0.001	0.0001	0.001	0.001	0.001	<0.001	0.003
	Maximum	156	8.20	404	88	109	0.100	3.49	0.008	0.0008	0.028	0.043	0.219	0.004	0.568	0.720	0.002	0.0006	0.010	0.005	0.157	<0.001	0.438
	Mean	43.6	7.43	132	8.65	20.6	0.056	0.756	0.001	0.0001	0.005	0.005	0.039	0.001	0.081	0.078	0.001	0.0001	0.002	0.001	0.011	<0.001	0.045
	Median	34	7.36	103	2.5	12	0.050	0.525	0.001	0.0001	0.003	0.003	0.028	0.001	0.036	0.020	0.001	0.0001	0.002	0.001	0.002	<0.001	0.013
DR-10	Count	215	195	194	215	216	216	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217
	Minimum	0.5	6.4	5.92	2.5	0.5	0.05	0.005	0.0005	0.00005	0.0005	0.0005	0.00005	0.0005	0.0025	0.005	0.0003	0.00005	0.0005	0.00005	0.0005	0.0005	0.0014
	Maximum	381	8.7	1000	702	104	0.9	38.4	0.005	0.0013	0.119	0.041	2.43	0.039	0.207	0.57	0.002	0.0003	0.006	0.005	0.122	0.019	0.102
	Mean	79.5	7.73	235	54	6.15	0.16	3.18	0.0008	0.0001	0.0094	0.0019	0.1706	0.0031	0.0084	0.0616	0.0005	0.0001	0.0018	0.0005	0.0109	0.0006	0.0032
	Median	61	7.72	170	11	3	0.2	1.14	0.0005	0.00005	0.004	0.0005	0.107	0.001	0.0025	0.005	0.0005	0.00005	0.002	0.0005	0.001	0.0005	0.0025
DR-14	Count	259	236	235	261	260	261	262	262	262	262	262	262	262	261	262	262	262	262	262	262	262	262
	Minimum	0.5	6.2	41.9	2.5	0.15	0.05	0.005	0.0005	0.00005	0.0005	0.0005	0.00005	0.0005	0.0025	0.0025	0.0005	0.00005	0.0005	0.00005	0.0005	0.0005	0.0025
	Maximum	297	8.93	1027	1030	46	0.5	41.9	0.004	0.0007	0.121	0.021	1.99	0.043	0.09	0.64	0.001	0.0001	0.01	0.005	0.69	0.019	0.1
	Mean	80.02	7.72	250.50	60.53	6.13	0.16	3.05	0.0007	0.0001	0.0092	0.0018	0.1758	0.0028	0.0068	0.0756	0.0005	0.0001	0.0020	0.0005	0.0227	0.0006	0.0034
	Median	60	7.7	171.4	14	3	0.2	1.195	0.0005	0.00005	0.00445	0.0005	0.1305	0.001	0.0025	0.005	0.0005	0.00005	0.002	0.0005	0.004	0.0005	0.0025
CC-05	Count	51	48	48	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
	Minimum	7	7.06	84.4	2.5	0.5	0.05	0.005	0.0005	0.00005	0.0005	0.0005	0.003	0.0005	0.0025	0.005	<0.001	<0.0001	0.0005	<0.001	0.0005	0.0005	0.0025
	Maximum	181	8.95	541	545	27	0.6	15.3	0.002	0.0001	0.03	0.012	0.99	0.018	0.038	1.02	<0.001	<0.0001	0.003	<0.001	0.11	0.001	0.008
	Mean	84.59	7.94	279.76	27.79	4.65	0.26	1.25	0.0005	0.0001	0.0035	0.0010	0.0852	0.0017	0.0057	0.0570	<0.001	<0.0001	0.0012	<0.001	0.0126	0.0005	0.0026
	Median	78	7.95	262.7	7	4	0.2	0.38	0.0005	0.00005	0.002	0.0005	0.05	0.0005	0.0025	0.005	<0.001	<0.0001	0.001	<0.001	0.003	0.0005	0.0025
DR-18	Count	244	221	220	245	244	245	245	245	245	245	245	245	245	245	245	245	245	245	245	245	245	245
	Minimum	14	7.09	52.9	2.5	0.15	0.05	0.005	0.0005	0.00005	0.0005	0.00034	0.00005	0.0005	0.0025	0.0025	0.0005	<0.0001	0.0005	0.00005	0.0005	0.0005	0.0025
	Maximum	332	8.85	1103	638	51	1.2	29.9	0.005	0.0012	0.089	0.026	1.12	0.024	0.212	0.7	0.002	<0.0001	0.006	0.002	0.47	0.002	0.08
	Mean	84.44	7.75	256.27	58.09	7.15	0.17	2.78	0.0008	0.0001	0.0084	0.0017	0.1773	0.0026	0.0073	0.0655	0.0005	<0.0001	0.0018	0.0005	0.0197	0.0005	0.0033
	Median	64.5	7.71	178.4	18	4	0.2	1.1	0.0005	0.00005	0.004	0.0005	0.136	0.001	0.0025	0.005	0.0005	<0.0001	0.002	0.0005	0.003	0.0005	0.0025
DR-22	Count	243	220	219	244	243	244	245	245	245	245	245	245	245	244	245	245	245	245	245	245	245	245
	Minimum	0.5	6.77	52.9	2.5	0.15	0.05	0.005	0.0005	0.00005	0.0005	0.0005	0.00005	0.0005	0.0025	0.0025	0.0005	0.00005	0.0005	0.00005	0.0005	0.0005	0.0005
	Maximum	318	8.91	1010	573	42	0.7	25.3	0.004	0.0003	0.4	0.02	1.53	0.022	0.065	0.61	0.002	0.0002	0.005	0.005	4	0.004	0.1

1		Hardness (mg/l)	pH	EC µS/cm	TSS (mg/l)	Sulphate (mg/l)	Fluoride (mg/l)	Total Metals (mg/l)								Filtered Metals (mg/l)							
								Al	As	Cd	Cu	Pb	Mn	Ni	Zn	Al	As	Cd	Cu	Pb	Mn	Ni	Zn
	Mean	76.63	7.72	229.26	51.06	5.75	0.156	2.768	0.00075	0.00005	0.01	0.0017	0.173	0.003	0.007	0.072	0.0005	0.0001	0.0018	0.0005	0.031	0.0005	0.003
	Median	56	7.69	161.5	15	3	0.1	1.06	0.0005	0.00005	0.004	0.0005	0.121	0.001	0.0025	0.01	0.0005	0.00005	0.002	0.0005	0.003	0.0005	0.0025
CC-15	Count	61	55	55	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
	Minimum	24	7.12	54.1	2.5	0.5	0.05	0.005	0.0005	0.00005	0.0005	0.0005	0.02	0.0005	0.0025	0.005	0.0005	0.00005	0.0005	<0.001	0.0005	0.0005	0.0025
	Maximum	240	8.71	534	1520	13	0.6	45.7	0.002	0.0001	0.081	0.022	1.51	0.046	0.061	0.38	0.001	0.0001	0.005	<0.001	0.537	0.001	0.005
	Mean	93.62	7.94	258.75	52.33	4.37	0.23	2.06	0.0005	0.0001	0.0049	0.0013	0.1157	0.0025	0.0056	0.0317	0.0005	0.0001	0.0011	<0.001	0.0323	0.0005	0.0025
	Median	77	7.9	236.3	7	3	0.2	0.44	0.0005	0.00005	0.002	0.0005	0.049	0.0005	0.0025	0.005	0.0005	0.00005	0.001	<0.001	0.001	0.0005	0.0025

3.1.10.4. Groundwaters

3.1.10.4.1. Groundwater Occurrence and Hydrostratigraphy

Groundwater storage and flow at the DRM primarily occur within the fractured zone of unweathered metasedimentary rocks, predominantly through secondary porosity features such as fractures and joints. The Mount Roseby Schist is the prime aquifer, with fracturing extending to approximately 70 m deep and up to 200 m deep in some locations.

The hydrostratigraphic units of the Project are described in Table 9.

Table 9. Hydrostratigraphic units (CDM Smith, 2024)

Hydrostratigraphic Unit	Location	Hydrogeological Behaviour
Unconsolidated sediments	In patchy coverage, mostly found in the lower landscape such as along the courses of Dugald River and Cabbage Tree Creek.	May host aquifers where present and saturated; however with limited distribution and likely to be unsaturated
Mount Roseby Schist	To the east of the Knapdale Range, around the mine area.	Relative aquifer – fractured rock aquifer, with heterogenous behaviour. Fracturing typically down to 70 m below ground. Note that the calc-silicate facies is most likely to permit groundwater storage and flow
Coocerina Formation and Lady Clayre Formation	To the west of the Knapdale Range, at Cabbage Tree Creek.	Unknown behaviour, presume similar to the Mount Roseby Schist.
Knapdale Quartzite	In the Knapdale Range, including underlying the TSF.	Largely tight aquitard, with some fractured rock groundwater occurrences. Fracturing mostly within the upper 10 m.
Corella Formation	Deep underlying the constituent units of the Mount Albert Group.	Limited information, but presumed to be the hydrogeological basement as it occurs at great depth in the Project area.

3.1.10.4.2. Groundwater Recharge and Discharge

Evaporation at the Project exceeds rainfall, however recharge allows water levels to rise. Mount Roseby Schist groundwater monitoring bores experience seasonal variations in water levels which are consistent with rainfall patterns of the region. Recharge occurs primarily via diffuse recharge from rainfall, however during flow events of ephemeral creeks, enhanced recharge occurs along these watercourses with infiltration through creek beds. Recharge from rainfall predominantly occurs in the Knapdale Ranges and other elevated areas, and where rainfall exceeds evaporation. The preferential recharge zone of the Project is anticipated at the base of the ridge at the Knapdale Range and close to

the geologic contact with the Mount Roseby Schist. Recharge rates at the Project are estimated as low, comprising approximately 2% of rainfall received, or 10 mm/year (CDM Smith, 2024).

As groundwater is deeper than 4 m below ground level, baseflow is unlikely to occur and natural groundwater discharge does not occur in the vicinity of the DRM. Seasonal fluctuations in water levels may allow baseflow discharges to lower reaches of unnamed tributary creeks. During unusually wet years, groundwater levels may rise sufficiently to provide baseflow, such as through bank storage processes, to allow creeks to persist for several weeks. Outside of these rare occurrences, groundwater discharge is expected to only occur downstream after very long flow paths and residence times (given the low permeability) to Dugald River and Cabbage Tree Creek (CDM Smith, 2024).

3.1.10.4.3. Groundwater Flow

In the vicinity of the DRM, groundwater flows in the topographic direction from west to east towards and along tributaries of the Dugald River, namely North Creek and Silvermine Creek. To the west of the DRM, groundwater is also expected to flow in the topographic direction from east to west towards Cabbage Tree Creek. The elevated terrain in the Knapdale Ranges forms a groundwater divide, estimated to be along the topographic divide, with the TSF located west of the divide and only permitting seepage towards the west. It is likely that to the north of the TSF, groundwater flows in northernly/northeasterly directions towards other tributaries of Cabbage Tree Creek. The conceptual hydrogeological model at the DRM is presented in Figure 6 (CDM Smith, 2024).

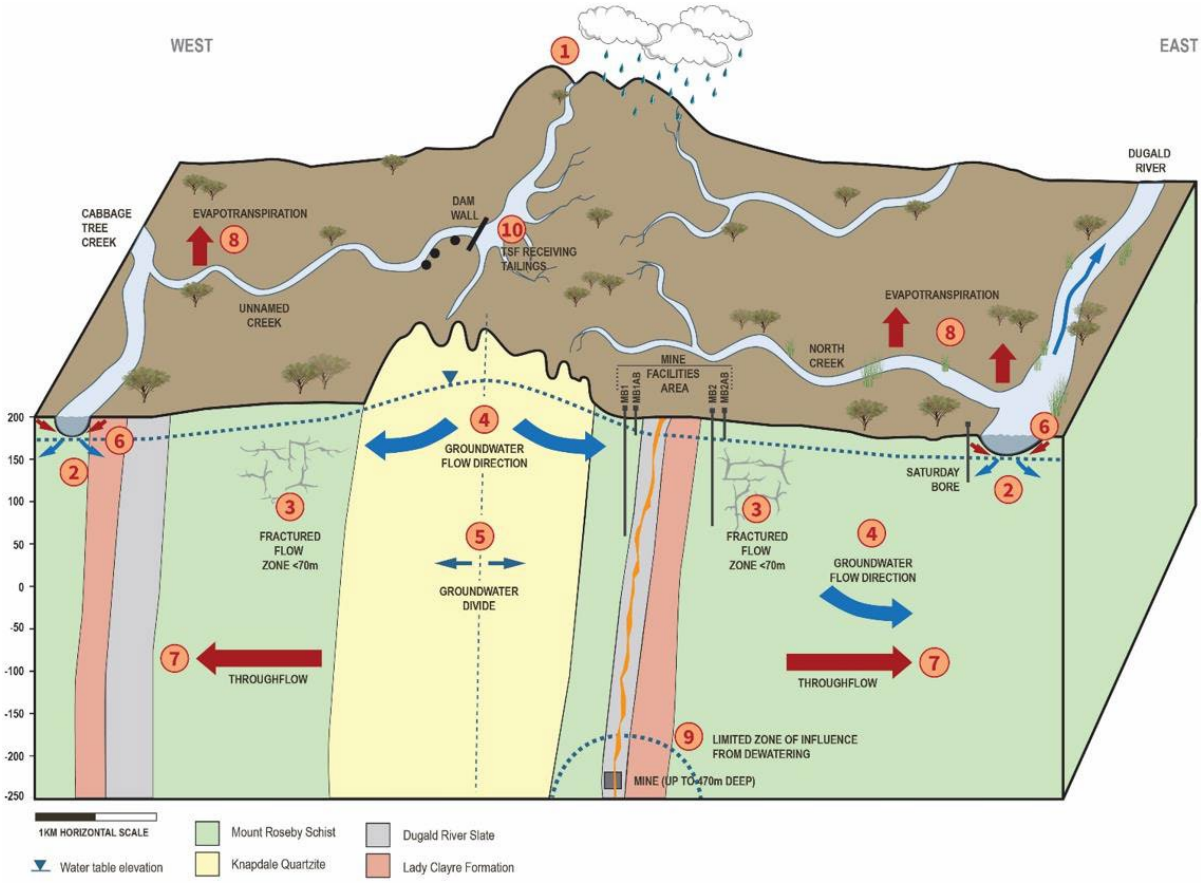


Figure 6. Conceptual hydrogeological model (CDM Smith, 2024)

3.1.10.4.4. Groundwater Users

There are no groundwater users within vicinity of the DRM TSF; registered bores within this area are monitoring bores associated with the DRM and its TSF. MMG do not extract groundwater for use on-site, rather raw water is sourced from Lake Julius.

Groundwater is not used for stock and domestic bores in the area of the DRM. Approximately 8 km to the north of the TSF, groundwater bores in alluvial deposits are used to supply water for cattle grazing. After excluding the bores associated with DRM, the nearest registered bores are over 3 km to the northeast and northwest, and well outside the DRM tenement areas. The registered bores beyond DRM operations may be associated with both industrial and agricultural activities (CDM Smith, 2024).

3.1.10.4.5. Groundwater – Surface Water Interaction

When ephemeral creeks are flowing, they become sites for enhanced recharge via infiltration through creek beds. Groundwater discharge in the form of temporary baseflow is possible in lower reaches of the watercourses when groundwater levels have sufficiently risen. Bank storage processes may operate, allowing ephemeral watercourses to temporarily persist following rain events. As such, there is only a short duration of groundwater-surface water interaction, consisting of a phase of recharge followed by a phase of discharge. During standard conditions, there is no groundwater-surface water interaction (CDM Smith, 2024).

3.1.10.4.6. Groundwater Dependent Ecosystems

The Bureau of Meteorology (BOM) Groundwater Dependent Ecosystem (GDE) Atlas indicates a low to moderate potential for terrestrial GDEs to be present across the Project area. This suggests that vegetation may access shallow groundwater. This may occur when the groundwater is close to the surface, such as in the Cabbage Tree Creek valley. In the Knapdale Range, water that infiltrates into fractures may be absorbed by vegetation; minimal volumes may be intercepted and therefore do not percolate deep enough to reach elevations beneath the topographic ridge (CDM Smith, 2024).

There is a low potential for aquatic GDEs within Cabbage Tree Creek and Dugald River; GDEs are not identified in tributaries. The highly ephemeral waterways do not support specialised riparian vegetation nor habitat for aquatic fauna, as the hydraulic habitats are too transient. Given that watercourses are non-perennial, and there is only a low potential for aquatic GDEs to be present, it is likely that any aquatic ecosystems would only be fed by groundwater when the water table is temporarily elevated to allow groundwater discharge. This suggests it is unlikely for aquatic ecosystems to be GDEs within vicinity of the Project (CDM Smith, 2024).

3.1.10.4.7. Environmental Values

The most relevant EVs were derived from the EPP (Water and Wetland Biodiversity) 2019 which include:

- For waters that may be used for agricultural purposes – the suitability of the water for agricultural purposes;
- For waters that may be used for recreation or aesthetic purposes – the suitability of water for:

- Primary recreational use; or
- Secondary recreational use; or
- Visual recreational use

- For water that may be used for drinking water – the suitability of the water for supply as drinking water having regard to the level of treatment of the water;
- For waters that may be used for industrial purposes – the suitability of the water for industrial use; or
- The cultural and spiritual values of the waters.

3.1.10.4.8. Groundwater Monitoring Network

The groundwater monitoring network is described in Table 10 and in Figure 7. The groundwater monitoring program focusses on risk associated with the mine infrastructure area. Several bores are located to the west of the Knapdale Range (MB5, MB6, MB9S and MB9D) to monitor for potential impacts from the TSF.

Table 10. Groundwater bore details

Bore	Formation	EA classification	Permeability
MB1	Mount Roseby Schist	Background	7.53×10^{-6}
MB3	Mount Roseby Schist	Background	2.60×10^{-1}
MB5	Mount Roseby Schist	Compliance	9.21×10^{-2}
MB6	Mount Roseby Schist	Compliance	2.23×10^{-3}
MB9S	Knapdale Quartzite	Compliance	No data
MB9D	Knapdale Quartzite	Compliance	No data
MB2	Mount Roseby Schist	Compliance	4.08×10^{-1}
MB4	Mount Roseby Schist	Compliance	7.52×10^{-2}
GWBFAB	Dugald River Slate	Interpretation	No data
MB1AB	Mount Roseby Schist	Interpretation	No data
MB2AB	Mount Roseby Schist	Interpretation	No data
MB3AB	Mount Roseby Schist	Interpretation	No data
MB4AB	Mount Roseby Schist	Interpretation	No data
SHALL6AB	Mount Roseby Schist	Interpretation	No data

3.1.10.4.9. Groundwater Trigger Limits

EA Schedule C – Table 8 specifies the groundwater quality trigger levels and contaminant limits for DRM. This is replicated in Table 11. Summary statistics of the groundwater monitoring bores at the Project from 2009 to 2024 are detailed in Table 12.

Table 11. Groundwater trigger levels and contaminant limits (EPML00731213)

Quality Characteristic[1]	Unit	Trigger Level[1]	Contaminant limit[2]
pH	pH unit	6.0 (minimum) 8.0 (maximum	6.0 (minimum) 9.0 (maximum)
Electrical Conductivity	µS/cm	1500[6]	2000[6]
Hardness (as $CaCO_3$)	mg/L	For interpretation purposes	
Total Dissolved Solids (TDS)	mg/L	For interpretation purposes	
Major ions	mg/L	For interpretation purposes	
Sulphate (mg/L)	mg/L	150[6]	1000[5]
Fluoride (mg/L)	mg/L	-	2[4]
Aluminium	mg/L	0.055[3, 11]	5[4]
Arsenic[7]	mg/L	0.013[3, 11]	0.5[4]
Cadmium (mg/L)	mg/L	0.0002[3, 11]	0.01[4]
Copper (mg/L)	mg/L	0.0014[3]	1[4]
Lead (mg/L)	mg/L	0.0034[3, 11]	0.1[4]
Manganese (mg/L)	mg/L	1.9[3, 11]	-
Nickel (mg/L)	mg/L	0.011[3, 11]	1[4]
Zinc (mg/L)	mg/L	0.008[3, 11]	20[4]

[1] All metals and metalloids must be measured as filtered with the exception of fluoride.

[2] All metals and metalloids must be measured as total (unfiltered).

[3] Based on ANZG (2018)..

[4] Based on ANZECC/ARMCANZ (2000) Table 4.3.2 for livestock drinking water.

[5] Based on ANZECC/ARMCANZ (2000) Section 4.3.3.4;

[6] MMG Dugald River - site specific value

[7] Speciated arsenic concentrations for As (III) and As (V) only required if 13 mg/L is exceeded - note that the sample bottle requirements for As (total species) and As (speciated) may differ.

[11] Where appropriate, the default trigger values may be hardness adjusted in accordance with ANZG (2018).

3.1.10.4.10. Groundwater Quality

A groundwater impact assessment (CDM Smith, 2025) was recently undertaken to review groundwater quality across the Project. Groundwater chemistry is summarised as follows:

- Most groundwater has a close to neutral pH ranging between 6.03 and 8.4.
- Salinity ranges from <100 mg/l to approximately 12,000 mg/l. The variable salinity occurs through change over time. The median salinity for each bore is generally between 400–1,900 mg/l.

- The ionic composition is bicarbonate dominant except for MB3 which is sulfate dominant. The water quality is described as suitable for stock watering and marginally potable at some locations.
- The average concentration of most metals are below trigger levels, with exception of copper and zinc. All average concentrations of metals are below the contaminant limits.

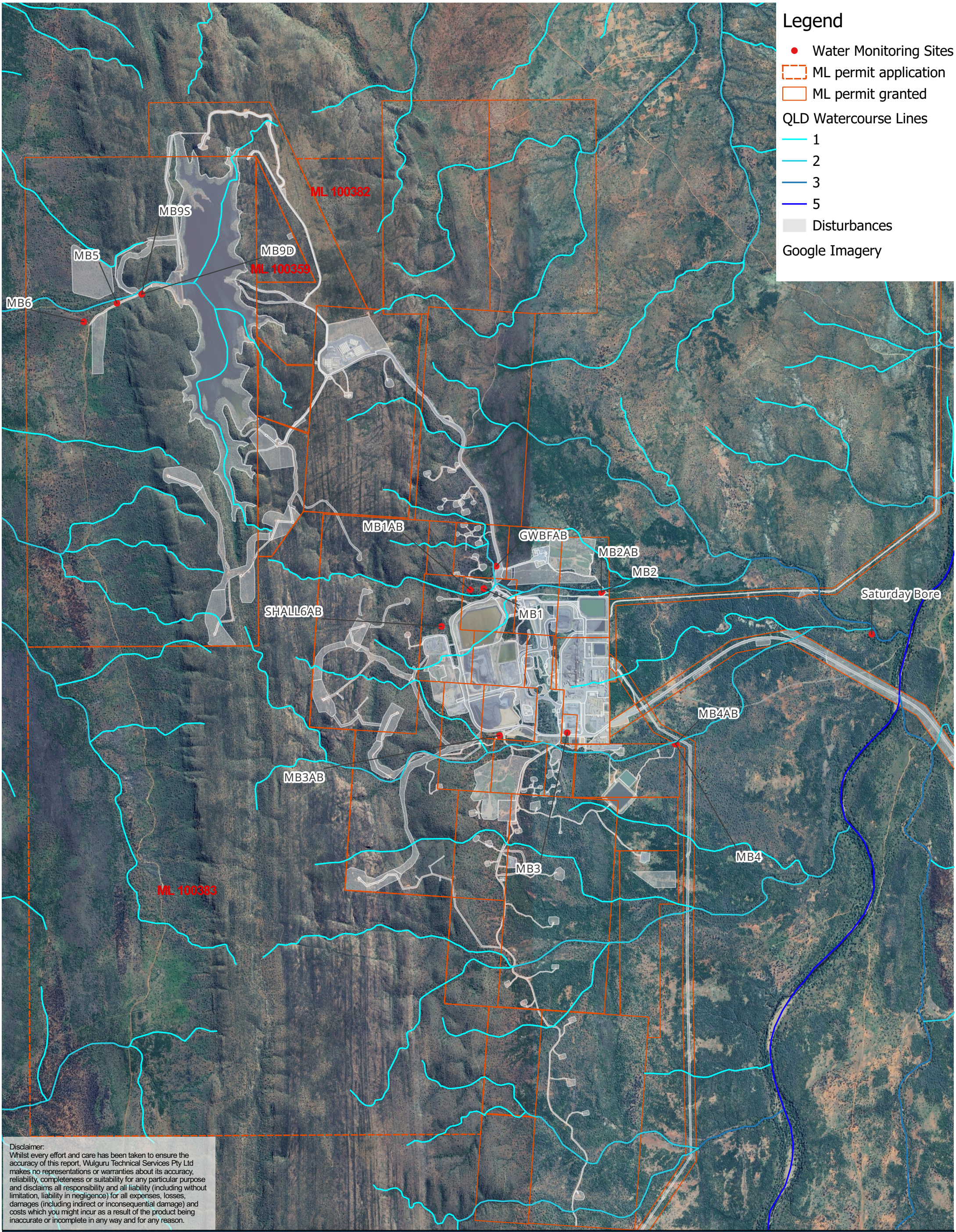


FIGURE 7. GROUNDWATER MONITORING NETWORK

0.7 0 0.7 1.4 km

CRS: GDA94 / MGA zone 54
Scale: 1:25,000 @A3

Date: 19 February 2026
Author: M. Kaminski
Version: 0.01

WULGURU TECHNICAL SERVICES

Project Number: 2024.07003
Client: MMG

C:\Users\MichaelKaminski\OneDrive - Wulguru Tech Services\DugaldRiver\Dugald_Process.qgz

Table 12. Groundwater chemistry (2009-2024)

Analytes	pH	Electrical Conductivity	Sulphate as SO4	Fluoride	Aluminium		Arsenic		Cadmium		Copper		Lead		Manganese		Nickel		Zinc	
					Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Units	pH units	µS/cm	mg/L	mg/L	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
Limit of Reporting	0.01	1	1	0.1	0.01		0.001		0.0001		0.001		0.001		0.001		0.001		0.005	
Trigger Level	6.0 (Min.) 8.0 (Max.)	1500	150	-	0.055 (Dissolved)		0.013 (Dissolved)		0.0002 (Dissolved)		0.01 (Dissolved)		0.0014 (Dissolved)		1.9 (Dissolved)		0.011 (Dissolved)		0.008 (Dissolved)	
EA Contaminant Limit	6.0 (Min.) 9.0 (Max.)	2000	1000	2	5 (Total)		0.5 (Total)		0.01 (Total)		1 (Total)		0.1 (Total)		-		1 (Total)		20 (Total)	
Interpretation Bores - Depth																				
MB1AB																				
Number of samples	5	6	19	19	19	17	19	17	19	17	19	17	19	17	17	17	19	17	19	17
Minimum	7.52	966	10	1.6	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001	0.00	0.0005	0.0025	0.0025
Maximum	7.88	1460	37	4.6	0.03	2.93	0.0005	0.002	0.0002	0.0007	0.007	0.019	0.006	0.042	0.071	0.175	0.00	0.004	0.223	0.556
Median	7.7	1190	12	3.5	0.005	0.06	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.0005	0.002	0.006	0.00	0.0005	0.0025	0.0025
80th percentile	7.77	1300	13	3.74	0.005	0.342	0.0005	0.0005	0.00005	0.00005	0.0005	0.003	0.0005	0.005	0.01	0.0418	0.00	0.0005	0.0051	0.0248
95th percentile	7.85	1420	17.2	3.97	0.0075	2.13	0.0005	0.0012	0.000065	0.00038	0.0034	0.0142	0.0024	0.0252	0.035	0.171	0.00	0.0024	0.0556	0.1824
MB2AB																				
Number of samples	16	15	30	30	30	28	30	28	30	28	30	28	30	28	27	27	30	28	30	28
Minimum	7	913	20	0.4	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.0005	0.001	0.002	0.00	0.0005	0.0025	0.0025
Maximum	8	1140	175	1.2	0.04	3.34	0.001	0.01	0.0005	0.0013	0.003	0.025	0.008	0.164	0.142	0.159	0.00	0.006	0.168	0.383
Median	7.46	1030	92	0.8	0.005	0.12	0.0005	0.0005	0.00005	0.00005	0.0005	0.001	0.0005	0.0005	0.007	0.013	0.00	0.0005	0.0025	0.0025
80th percentile	7.72	1062	143.2	1	0.005	0.23	0.0005	0.0016	0.00006	0.00026	0.0006	0.004	0.0006	0.0098	0.0118	0.0516	0.00	0.0008	0.0248	0.073
95th percentile	7.87	1133	149.55	1.055	0.01325	2.3595	0.0005	0.0033	0.0004	0.00076	0.00255	0.01615	0.00255	0.0487	0.0548	0.1349	0.00	0.0053	0.0697	0.25645
MB3AB																				
Number of samples	14	13	28	28	28	26	28	26	28	26	28	26	28	26	25	25	28	26	28	26
Minimum	7.73	1370	46	1.5	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.001	0.0005	0.0005	0.0005	0.004	0.00	0.0005	0.0025	0.0025
Maximum	8.11	2630	392	3.5	0.01	20.5	0.002	0.005	0.0001	0.0009	0.004	0.04	0.002	0.045	0.04	1.16	0.01	0.13	0.034	0.297
Median	7.92	2160	67	2.6	0.005	0.815	0.001	0.001	0.00005	0.00005	0.002	0.005	0.0005	0.0005	0.002	0.111	0.00	0.002	0.0025	0.00425
80th percentile	8.04	2356	226	2.86	0.005	2.32	0.001	0.002	0.00005	0.00005	0.0026	0.011	0.0005	0.002	0.007	0.2262	0.00	0.005	0.0025	0.016
95th percentile	8.10	2570	368.55	3.265	0.005	10.17	0.001	0.002	0.00005	0.00005	0.003	0.0315	0.000825	0.00575	0.0104	0.8158	0.00	0.031	0.02525	0.05575
MB4AB																				

Analytes	pH	Electrical Conductivity	Sulphate as SO4	Fluoride	Aluminium		Arsenic		Cadmium		Copper		Lead		Manganese		Nickel		Zinc	
					Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Number of samples	4	4	14	14	13	12	13	12	14	11	14	12	14	12	11	11	14	12	14	12
Minimum	7.14	2300	464	0.7	0.005	1.28	0.0005	0.0005	0.00005	0.00005	0.0005	0.002	0.0005	0.0005	0.023	0.187	0.0005	0.003	0.0025	0.01
Maximum	7.58	15000	4200	1.4	0.005	154	0.003	0.025	0.00005	0.0008	0.01	0.194	0.003	0.062	1.43	6.94	0.008	0.313	0.159	0.477
Median	7.46	2515	1855	1	0.005	5.93	0.0005	0.002	0.00005	0.00005	0.0005	0.0085	0.0005	0.004	0.242	1.2	0.0025	0.014	0.0115	0.0385
80th percentile	7.51	7596	3612	1.2	0.005	17.24	0.0014	0.004	0.00005	0.00005	0.0032	0.0254	0.0005	0.0058	1.3	1.76	0.0048	0.0324	0.052	0.0602
95th percentile	7.56	13149	4187	1.4	0.005	81.29	0.0024	0.01565	0.00005	0.0006	0.0087	0.1104	0.0017	0.0466	1.375	4.525	0.0067	0.16285	0.11675	0.3219
Compliance Bores – Depth and Quality																				
MB2																				
Number of samples	97	93	115	114	110	110	115	115	114	115	115	115	115	115	115	115	115	115	115	115
Minimum	7	753	4	0.6	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.00011	0.00012	0.0005	0.001	0.00	0.0005	0.0014	0.0025
Maximum	8.31	1580	530	6.5	0.02	0.23	0.002	0.002	0.0003	0.0004	0.094	0.102	0.011	0.006	0.404	0.422	0.03	0.029	0.078	0.085
Median	7.56	1120	144	1.7	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.006	0.014	0.0005	0.0005	0.037	0.039	0.00	0.0005	0.0025	0.0025
80th percentile	7.82	1426	404	2.5	0.005	0.02	0.0005	0.0005	0.00005	0.00005	0.0368	0.0444	0.0005	0.00144	0.0672	0.0704	0.00	0.0005	0.00818	0.00852
95th percentile	8.03	1490	483.9	2.8	0.005	0.05	0.0005	0.001	0.00005	0.00005	0.0545	0.065	0.00203	0.00321	0.0989	0.1133	0.00	0.00149	0.0238	0.0352
MB4																				
Number of samples	57	61	78	77	73	73	78	78	77	78	78	78	78	78	78	78	78	78	78	78
Minimum	7	0	16	0.4	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.00	0.0005	0.0025	0.0025
Maximum	8.18	1390	146	2	0.03	0.91	0.002	0.002	0.0002	0.001	0.007	0.014	0.006	0.017	0.302	0.332	0.01	0.011	0.062	0.106
Median	7.72	763	71.5	1	0.005	0.01	0.0005	0.0005	0.00005	0.00005	0.0005	0.001	0.0005	0.0005	0.0085	0.0265	0.00	0.0005	0.0025	0.008
80th percentile	7.93	1298	93.6	1.4	0.005	0.06	0.0005	0.0005	0.00005	0.00005	0.002	0.003	0.0005	0.002	0.0614	0.1034	0.00	0.000788	0.012	0.0292
95th percentile	8.16	1362	106	1.7	0.005	0.1745	0.001	0.001	0.00005	0.000115	0.0052	0.012	0.004	0.0062	0.1597	0.2331	0.00	0.00215	0.0388	0.0524
MB5																				
Number of samples	51	53	67	66	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
Minimum	6.88	784	4	0.05	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.00	0.0005	0.0025	0.0025
Maximum	8.01	1220	134	1.4	0.03	3.5	0.008	0.008	0.0002	0.0002	0.004	0.025	0.007	0.016	0.798	2.67	0.01	0.02	0.24	0.354
Median	7.48	1150	90	0.4	0.005	0.02	0.0005	0.0005	0.00005	0.00005	0.0005	0.002	0.0005	0.0005	0.529	0.616	0.00	0.0005	0.0025	0.007
80th percentile	7.79	1170	96	1	0.005	0.06	0.001	0.002	0.00005	0.00005	0.001	0.006	0.0005	0.004	0.6208	0.6598	0.00	0.00116	0.0088	0.019
95th percentile	7.93	1190	100	1.2	0.005	0.245	0.0057	0.0057	0.00005	0.0001	0.003	0.01075	0.003	0.0075	0.683	0.8139	0.00	0.0068	0.0412	0.06925
MB6																				
Number of samples	53	55	68	67	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68

Analytes	pH	Electrical Conductivity	Sulphate as SO4	Fluoride	Aluminium		Arsenic		Cadmium		Copper		Lead		Manganese		Nickel		Zinc	
					Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Minimum	7	365	1	0.05	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.00017	0.00018	0.0005	0.053	0.00	0.0005	0.0025	0.0025
Maximum	7.92	1610	191	1.4	0.03	0.41	0.005	0.006	0.0005	0.0009	0.017	0.052	0.008	0.021	0.916	0.973	0.00	0.008	0.485	0.581
Median	7.4	936	16	1.1	0.005	0.02	0.003	0.003	0.00005	0.00005	0.0005	0.003	0.0005	0.0005	0.3955	0.446	0.00	0.0005	0.0025	0.011
80th percentile	7.64	1250	104	1.2	0.005	0.078	0.004	0.004	0.00005	0.00005	0.00206	0.0066	0.0005	0.0026	0.5532	0.5972	0.00	0.001	0.0206	0.038
95th percentile	7.84	1480	135.6	1.3	0.005	0.224	0.00465	0.00565	0.00005	0.0001	0.00665	0.01765	0.003	0.01065	0.78555	0.8572	0.00	0.002195	0.0533	0.11425
MB9D																				
Number of samples	29	29	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
Minimum	6.99	1060	39	0.05	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.0005	0.003	0.227	0.00	0.0005	0.0011	0.0025
Maximum	8.4	1630	111	0.7	0.01	10.2	0.0005	0.011	0.0002	0.0017	0.004	0.143	0.002	0.125	1.12	14.6	0.00	0.038	0.053	0.492
Median	7.49	1130	46	0.5	0.005	0.08	0.0005	0.0005	0.00005	0.00005	0.0005	0.002	0.0005	0.0005	0.494	0.552	0.00	0.0015	0.0025	0.0025
80th percentile	7.69	1174	48	0.5	0.005	0.418	0.0005	0.0009	0.00005	0.0002	0.0005	0.0088	0.0005	0.006	0.6164	1.0644	0.00	0.004	0.0186	0.0516
95th percentile	7.97	1318	67.6	0.6	0.005	2.914	0.0005	0.0049	0.0002	0.0008	0.00145	0.03485	0.0005	0.0559	0.9326	1.9	0.00	0.0182	0.0432	0.3272
MB9S																				
Number of samples	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Minimum	6.36	92	2	0.05	0.005	2.57	0.0005	0.001	0.00005	0.00005	0.0005	0.016	0.0005	0.001	0.003	0.022	0.00	0.004	0.0025	0.008
Maximum	7.01	118	4	0.1	0.21	10.7	0.0005	0.002	0.00005	0.00005	0.001	0.069	0.0005	0.005	0.028	0.31	0.00	0.014	0.015	0.044
Median	6.61	99	2.5	0.1	0.03	5.605	0.0005	0.0015	0.00005	0.00005	0.00075	0.0255	0.0005	0.0035	0.015	0.117	0.00	0.004	0.0025	0.022
80th percentile	6.85	110.4	3.4	0.1	0.108	8.966	0.0005	0.002	0.00005	0.00005	0.001	0.0444	0.0005	0.0044	0.0238	0.2056	0.00	0.008	0.0075	0.035
95th percentile	6.97	116.1	3.85	0.1	0.1845	10.2665	0.0005	0.002	0.00005	0.00005	0.001	0.06285	0.0005	0.00485	0.02695	0.2839	0.00	0.0125	0.013125	0.04175
Background Bores – Depth and Quality																				
MB1																				
Number of samples	59	56	75	73	71	71	75	75	74	75	75	75	75	75	75	75	75	75	75	75
Minimum	7	794	18	0.8	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.0005	0.00014	0.0005	0.0005	0.0535	0.0005	0.0025	0.0025
Maximum	8.29	1200	41	2.2	0.01	0.24	0.002	0.002	0.0002	0.0001	0.008	0.015	0.006	0.008	0.132	0.304	0.0005	0.028	0.038	0.061
Median	7.7	1095	24	1.6	0.005	0.015	0.0005	0.0005	0.00005	0.00005	0.0005	0.001	0.0005	0.0005	0.037	0.042	0.004	0.0005	0.0025	0.007
80th percentile	7.93	1140	29.2	1.8	0.005	0.05	0.0005	0.0005	0.00005	0.00005	0.001	0.0034	0.0005	0.002	0.0622	0.068	0.0005	0.0005	0.0074	0.015
95th percentile	8.08	1172.5	33.3	1.94	0.005	0.1	0.001	0.001	0.00005	0.00005	0.003	0.009	0.002	0.0053	0.1066	0.1184	0.0005	0.0023	0.0223	0.0441
MB3																				
Number of samples	56	60	76	75	71	71	76	76	75	76	76	76	76	76	75	76	76	76	76	76
Minimum	7	1120	43	1.2	0.005	0.005	0.0005	0.0005	0.00005	0.00005	0.0005	0.0005	0.00011	0.00015	0.0005	0.0005	0.00	0.0005	0.0025	0.001
Maximum	8.27	6140	1930	4.1	0.05	0.26	0.004	0.007	0.0011	0.0014	0.028	0.041	0.059	0.023	0.046	0.086	0.03	0.04	0.11	0.04

Analytes	pH	Electrical Conductivity	Sulphate as SO4	Fluoride	Aluminium		Arsenic		Cadmium		Copper		Lead		Manganese		Nickel		Zinc	
					Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Median	7.65	4660	155.5	2.5	0.005	0.015	0.001	0.001	0.00005	0.00005	0.0005	0.001	0.0005	0.0005	0.002	0.004	0.00	0.0005	0.0025	0.002
80th percentile	7.86	5260	952	2.9	0.005	0.044	0.001	0.001	0.00005	0.00005	0.003	0.004	0.002	0.004	0.004	0.014	0.00	0.002	0.012	0.0072
95th percentile	8.07	5645	1562.5	3.13	0.01325	0.1865	0.002	0.002	0.00005	0.00005	0.0076	0.0189	0.00875	0.01425	0.0216	0.075	0.00	0.01475	0.03525	0.0294

3.1.10.5. Soils

3.1.10.5.1. Soil Types

The soils of DRM area were described in AustralAsian Resource Consultants (AARC 2010a) and were dominated by Rudosols with minor areas of Calcarosols. The Australian Soil Classification (Isbell, 2016) define Rudosols as being soil with negligible pedology, minimal development of an A1 horizon or the presence of less than 10% of B horizon material (including pedogenic carbonate) in fissures in the parent rock or saprolite. The soils are apedal or only weakly structured in the A1 horizon and show no pedological colour changes apart from the darkening of an A1 horizon. There is little or no texture or colour change with depth unless stratified or buried soils are present.

Specifically, six soil types were described by AARC (2010a) in SGM Environmental Pty Limited (SGM (2021) (Table 13). All soil management units are dominated by features that severely limit their productive use in grazing or copping due to very low plant-available water, erosion potential and limited nutrient availability. Subsequent to the AARC (2010a) soil surveys, several pockets of dispersive red clays were identified during construction.

Table 13. DRM soil types (AARC 2010a)

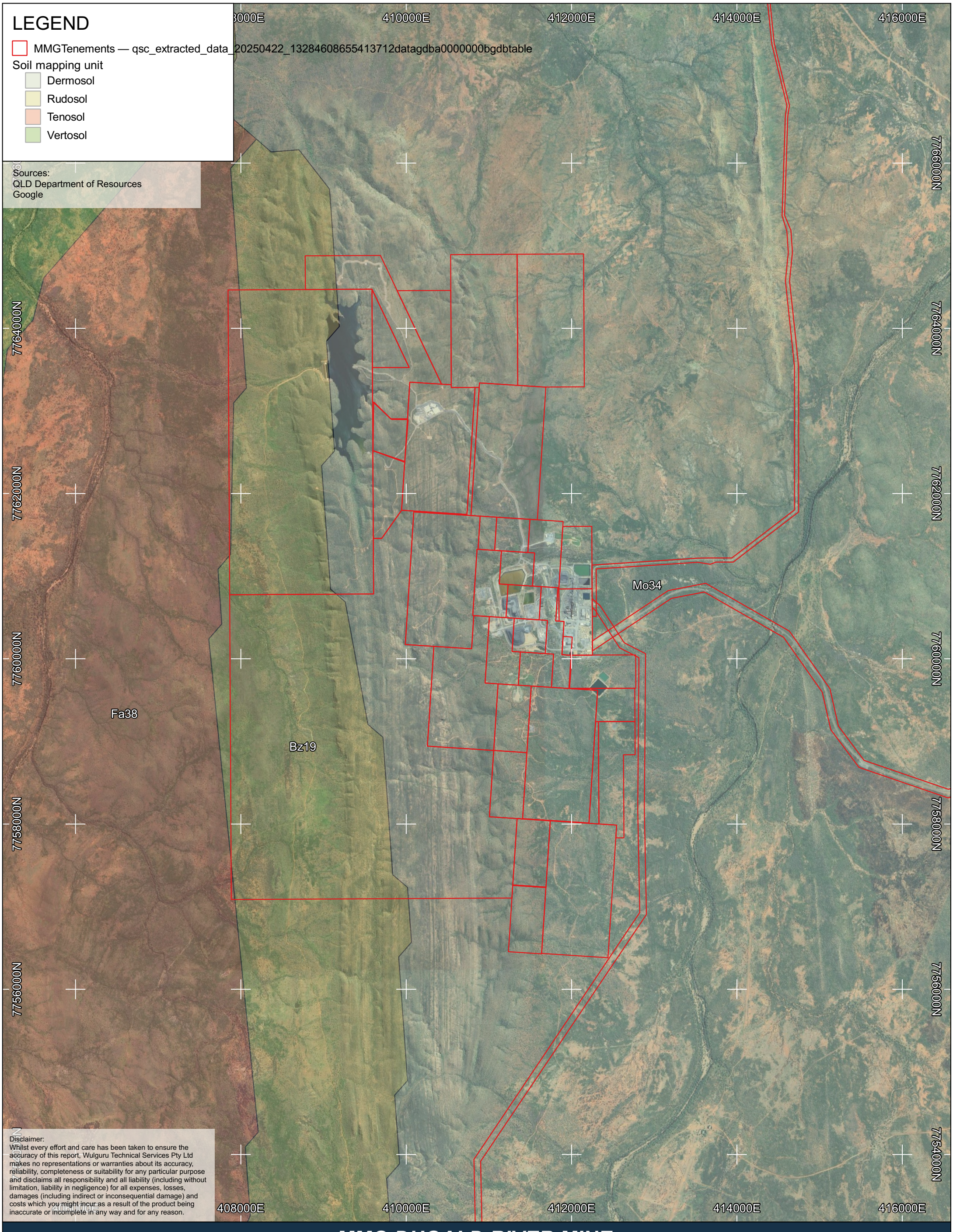
Soil Type	Description
Red Plains	The Red Plains SMU consists of red sandy loams to sandy clay loams with a neutral to slightly acidic pH. These soils are Rudosols with weak pedality and a maximum depth of 0.5 m.
Knapdale	The Knapdale SMU consists of brown skeletal sandy clay loams with a neutral to slightly acidic pH. These soils are Rudosols and very shallow (less than (<)0.2 m thick). They are mostly found on the eastern and western slopes of the Knapdale Range.
Dale	The Dale SMU consists of brown to reddish sandy loams with a slightly acidic pH increasing down the profile. Pedality ranges from weak to moderate with a depth of between 0.5-0.7 m. These soils are Rudosols and are generally found in depressions such as valley floors or plateaus in the Knapdale Range.
Miners	The Miners SMU consists of dark yellowish-brown sandy clay loams to silty loams with a slightly alkaline pH. Pedality is weak with a maximum depth of 0.2 m. These soils are Rudosols and are found on and immediately supporting the outcropping of the Dugald River deposit lode on the eastern side of the Knapdale Range.
Prospectors	The Prospectors SMU consists of dark yellowish-brown clay loams with a slightly acidic pH. Pedality is weak with a maximum depth of 0.2 m. These soils are Rudosols and are found on the toe slope of the western side of the Knapdale Range.
Pocket	The Pocket SMU consists of brown-grey sandy clay loams with an alkaline pH due to elevated levels of calcium carbonate. Pedality is weak. These soils are Calcarosols and are found in small pockets on the eastern and northern side of the Knapdale Range.

3.1.10.5.2. Soil Properties

Laboratory analysis of several soil parameters is summarised in Table 14. The soil types currently support native vegetation communities and there are no detrimental elements in the soil expected to limit that capacity in future (AARC, 2010).

Table 14. Rehabilitation related chemical properties

Soil Type	pH	EC (ds/cm)	Organic Carbon (%w/w)	CEC (meq/100mg)	ESP (%)
Red Plains	6.5	0.06	0.5	5.88	0.6
Knapdale	6.41	0.02	0.4	4.20	1.75
Dale	5.74	0.03	0.3	2.74	1.7
Miners	7.56	0.04	0.5	10.65	0.9
Prospectors	6.51	0.02	0.7	5.34	1.3
Pocket	8.8	0.08	0.5	22.89	0.5



MMG DUGALD RIVER MINE

FIGURE 8. PROJECT SOILS

1 0 1 2 km

CRS: GDA2020 / MGA zone 54
Scale: 1:40,000 @A3

Date: 23 April 2025
Author: H. Robb
Version: 0.02

WULGURU TECHNICAL SERVICES

Project Number: 2024.07003

Client: MMG Dugald River Pty Ltd

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3.1.10.5.3. Agricultural Land Classes

The soil management units have been classified into land classes according to the *Planning Guideline -The Identification of Good Quality Agricultural Land* published by the Department of Infrastructure and Planning (DIP), 1993. Agricultural land classes are described in Table 15.

Table 15. Agricultural land classes

Class	Description	
A	Crop Land	Land that is suitable for current and potential crops with limitations to production which range from non to moderate levels.
B	Limited Crop Land	Land that is marginal for current and potential crops due to severe limitations: and suitable for pastures. Engineering and/or agronomic improvements may be required before the land is considered for cropping.
C	Pasture Land	Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for crop production; but some areas may tolerate short period of ground disturbance for pasture establishment.
D	Non-Agricultural Land	Land not suitable for agricultural uses due to extreme limitations. This may be undisturbed land with significant habitat, conservation and/or catchment values or land that may be unsuitable because of very steep slopes, shallow soils, rock outcrops and poor drainage.

Table 16 details the agricultural land class of each soil management unit based on the descriptions provided in Table 15. No soil management unit on the site was found to be good quality agricultural land due to limiting factors, such as water availability, low nutrient levels, shallow soils, steep slopes and rocky outcrops (AARC, 2010).

Table 16. Agricultural land class of the Project soils from AARC (2010)

Soil Management Unit	Limiting features	Agricultural Land Class
Red Plains	No available water, relatively shallow soil, low nutrient levels.	D
Knapdale	No available water, shallow rocky soil, low nutrient levels and steep slopes.	D
Dale	This soil type may be suitable as pasture land as it is found up to 50-70 cm however it still has low nutrient levels and it is very inaccessible as it is surrounded by steep slopes.	D
Miners	Shallow and rocky, high levels of lead, rocky outcrops, no available water and low nutrients.	D
Prospectors	No available water, shallow soil, low nutrient levels.	D
Pocket	No available water, relatively shallow soil, low nutrient levels, slightly alkaline.	D

3.1.10.5.4. Land Suitability Assessment

AARC (2010) conducted a land suitability assessment during the initial EIS for the project. Land suitability was assessed using the methods and criteria provided in the *Planning Guideline – The Identification of Good Quality Agricultural Land (*DIP, 1993) and the *Land Suitability Assessment Techniques Guideline* (DME, 1995).

The Land Suitability assessment uses a five-class system, where Class 1 indicates that the land is most suitable for the enterprise and Class 5 the least suitable. The overall land suitability ranking for each specific soil unit is determined by the most severe limitation, or a combination of the varying limitations. Land is considered less suitable as the severity of limitations for a land use increase. The increasing limitations may reflect any combination of:

- Reduced potential for production;
- Increased inputs to achieve an acceptable level of production; and/or
- Increased inputs required to prevent land degradation.

The Land Suitability Classes are described in Table 17.

Table 17. Land suitability classes

Class	Suitability	Limitations	Description
1	Suitable	Negligible	Highly productive land requiring only simple management practices to maintain economic production.
2	Suitable	Minor	Land with limitations that either constrain production, or require more than the simple management practices of class 1 land to maintain economic production.
3	Suitable	Moderate	Land with limitations that either further constrain production, or require more than those management practices of class 2 land to maintain economic production.
4	Unsuitable	Severe	Currently unsuitable land. The limitations are so severe that the sustainable use of the land in the proposed manner is precluded. In some circumstances, the limitations may be surmountable with changes to knowledge, economics or technology.
5	Unsuitable	Extreme	Land with extreme limitations that preclude any possibility of successful sustained use of the land in the proposed manner.

The pre-mining land use suitability for these six soil types are summarised in Table 18.

Table 18. Land suitability assessment for Project soils

Soil Type	Beef Cattle Grazing	Broadacre Cropping	Conservation	Limitations	Area (ha)
Red Plains	4	5	4	Severe to Extreme Limitations in plant available water capacity (PAWC). Extreme Limitation in Slope, Topography, Rockiness.	1327
Knapdale	5	5	4	Extreme Limitation in Slope, Rockiness, PAWC and Topography.	1623
Dale	4	5	4	Severe to Extreme Limitation in PAWC and access.	38
Miners	5	5	4	Extreme Limitation in Rockiness, and PAWC.	166
Prospectors	5	5	4	Extreme Limitation in Rockiness, and PAWC.	165
Pocket	4	5	4	Extreme Limitation in Rockiness, and PAWC.	48

3.1.10.5.5. Land Stability

3.1.10.5.5.1. Soil Erosion Susceptibility

An assessment of soil erosion susceptibility is given in Table 19, which lists influencing factors for each soil type.

Table 19. Soil erosion susceptibility

Soil Type	Sodicity	Texture	Landform	Vegetation cover	Erosion Susceptibility
Red Plains	Non- Sodic	Sandy loam to sandy clay loam	Flatter plain areas	Cloncurry Box and Snappy Gum Open Woodland	Nondispersive
Knapdale	Non- Sodic	Sandy clay loam	Slopes of The Knapdale Range (30-40°)	Snappy Gum Open Woodland and Spinifex grass	Nondispersive
Dale	Non- Sodic	Sandy loam	Valley floors or plateaus in the Knapdale Range	Snappy Gum Open Woodland	Nondispersive
Miners	Non-Sodic	Sandy clay loam	Outcropping of the deposit lode	Cloncurry Box Open Woodland	Nondispersive
Prospectors	Non- Sodic	Clay loam	Toe slope of The Knapdale Range	Snappy Gum Open Woodland	Nondispersive

Soil Type	Sodicity	Texture	Landform	Vegetation cover	Erosion Susceptibility
Pocket	Non- Sodic	Sandy clay loam	Areas of low relief pockets (<5°)	Snappy Gum and Cloncurry Box Open Woodland	Nondispersive

3.1.10.5.5.2. Erosion Hazard (Average Rainfall)

The International Erosion Control Association's (IECA) Best Practice Erosion and Sediment Control Guidelines (IECA 2008) sets erosion hazard based on average rainfalls for regions around Australia. IECA erosion hazard for the Mt Isa region is detailed in Table 20.

A detailed erosion assessment has been completed for the TSF, the only mine structure to be retained, post closure (Section 3.5.10.2.10).

Table 20. Erosion hazard (IECA, 2008)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
High	High	Medium	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Medium

3.1.10.6. Geology

The DRM is located within a north to south trending feature named the Mt Roseby Corridor, within the Eastern Fold Belt of the Mount Isa Inlier. The Mount Roseby Corridor is bordered to the west by the Knapdale Quartzite and to the east by the Mt Rosebee Fault. The Knapdale Quartzite forms the Knapdale Range, a local topographic high. The Mount Roseby corridor is comprised of the Mount Roseby Schist Formation which includes the Dugald River Slate Sequence of hanging wall calc-silicates, Dugald River slate (host of the ore body) and the footwall limestone (SGM, 2021).

The geology of the rock units mined at the Project were described in EGi (2011). The units are calc-silicate, white mica schist, mafic feldspar porphyry, hanging wall slate, mineralized lode waste, footwall slate, and footwall limestone. Waste mined was found to be predominately non-acid forming (NAF) but areas of potentially acid forming (PAF) rock may be encountered proximal to the ore body and minor volumes within the hanging and foot wall slate. Table 21 describes the four dominant geological units at DRM. A cross section of the geology is provided in Figure 9.

Table 21. Mapped geology for the Project area

Geological Unit	Description	Age
Lady Clayre Dolomite	Dolomitic, locally pyrrhotitic siltstone, silty to sandy dolostone and fine-grained, variably dolomitic sandstone	Paleoproterozoic
Knapdale Quartzite	Pink, fine-grained, feldspathic to quartzose, locally micaceous sandstone	Paleoproterozoic
Dugald River Slate Sequence	Dark grey, carbonaceous shale and siltstone and grey mica schist;	Paleoproterozoic

Geological Unit	Description	Age
	Ore body; and Dark grey silty, dolomitic limestone and siltstone	
Mount Roseby Schist	Grey muscovite-biotite-quartz schist (psammopelite) and minor quartzite, calc-silicate granofels and limestone; commonly thin-bedded with abundant poikiloblastic scapolite porphyroblasts, particularly in the north.	Paleoproterozoic

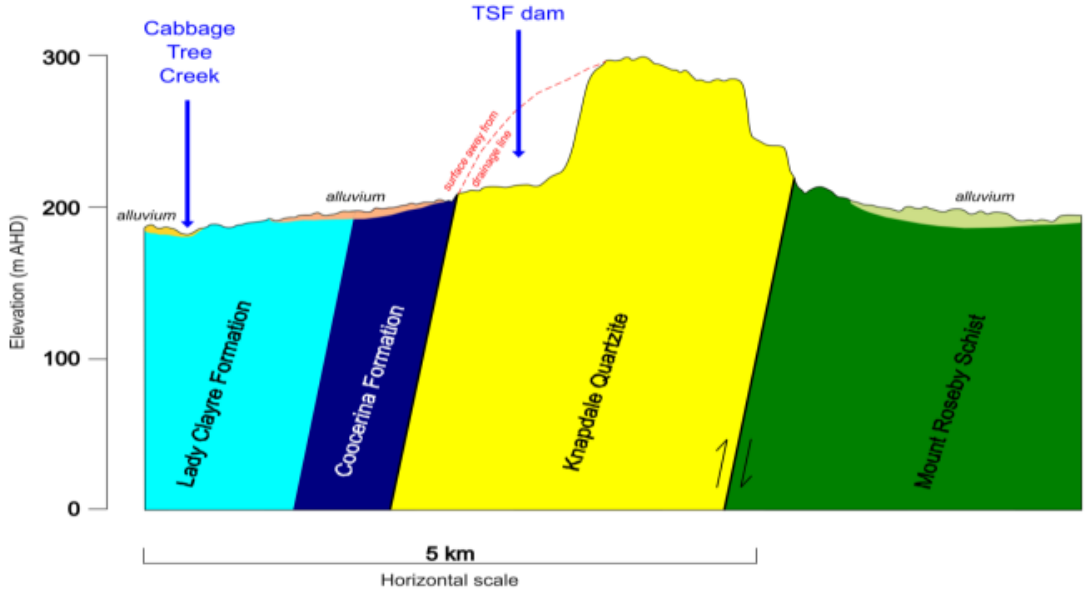

Figure 9. Geology West-East Cross-section (CDM Smith, 2025)

3.1.10.7. Vegetation Communities and Ecological Data

3.1.10.7.1. Matters of National Environmental Significance (MNES)

The Protected Matters Search Tool (PMST), accessed November 2024, was used to conduct a desktop analysis to determine the presence of any Matters of National Environmental Significance (MNES) listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC) (DCCEEW, 2024).

The following MNSES are not present within 50 km of the DRM:

- World Heritage Properties
- National Heritage Planes
- Wetlands of International Importance (Ramsar)
- Great Barrier Reef Marine Park
- Commonwealth Marine Area
- Listed Threatened Ecological Communities

3.1.10.7.1.1. EPBC Listed Threatened Flora Species

One (1) EPBC listed flora species was identified to occur within 50 km of the DRM. The species and likelihood of occurrence is described in Table 22.

Table 22. Listed threatened flora species

Taxa	Common Name (*Scientific name*)	EPBC Status	Likelihood of Occurrence
Flora	Mt Isa Mallee (*Eucalyptus nudicaulis*)	E	**Unlikely -** no records exist within a 50 km buffer of DRM. The 50 km buffer falls outside of the extent of occurrence identified

Taxa	Common Name (*Scientific name*)	EPBC Status	Likelihood of Occurrence
			within the conservation advice for the species.

Key: V = Vulnerable, E = Endangered, CE = Critically Endangered, M = Migratory, Ma = Marine, SL = Special Least Concern, LC = Least Concern, NL = Not Listed

3.1.10.7.1.2. EPBC Listed Threatened Fauna and Migratory Species

Table 23 describes the EPBC listed species identified to potentially occur within 50 km of DRM. Presence was assessed through the PMST mapping and review of survey data within the Project area. The likelihood of occurrence within the Project area was determined by the presence of local records and suitability of habitat.

Table 23. EPBC listed migratory and marine species identified within 50km of DRM

Taxa	Common Name (*Scientific name*)	EPBC Status	Likelihood of Occurrence
Birds ***(n = 24)***	Rainbow Bee-eater *(Merops ornatus)*	Ma	**Known**
	Common greenshank (*Tringa nebularia*)	E, M, Ma	**Possible** - four records exist within 50 km of DRM.
	Curlew sandpiper (*Calidris ferruginea*)	CE, M, Ma	**Possible** - Two records exist within 50 km of DRM.
	Latham's snipe (*Gallinago hardwickii*)	V, M, Ma	**Possible** - Two records are located approximately 40 km southwest of DRM. May fly through the area to access suitable habitat.
	Sharp-tailed sandpiper (*Calidris acuminata*)	V, M, Ma	**Possible –** three records exist within 50 km of DRM
	White-bellied Sea-Eagle (*Haliaeetus leucogaster*)	Ma	**Possible** – multiple records within 50 km of DRM.
	Black-eared Cuckoo (*Chalcites osculans* as *Chrysococcyx osculans*)	Ma	**Possible** – three records exist within 50 km of DRM.
	Cattle Egret *(Bubulcus ibis* as *Ardea ibis)*	Ma	**Possible** – three records exist within 50 km of DRM.
	Australian Painted Snipe (*Rostratula australis* as *Rostratula benghalensis (sensu lato)*	E, Ma	**Possible** - one record approximately 40 km southwest of DRM.
	Carpentarian Grasswren (*Amytornis dorotheae*)	E	**Possible -** one record is located approximately 40 km northwest of DRM.

Taxa	Common Name (*Scientific name*)	EPBC Status	Likelihood of Occurrence
	Grey Falcon (*Falco hypoleucos*)	V	**Possible –** two records exist within 50 km of DRM.
	Painted Honeyeater (*Grantiella picta*)	V	**Possible** – two records exist within 50 km of DRM.
	Glossy ibis (Plegadis falcinellus)	M,Ma	**Possible** - 14 records exist within a 50 km radius of the Project area.
	Common sandpiper (*Actitis hypoleucos*)	M, Ma	**Unlikely** - no records or modelled flight paths exist within 50 km of the Project area.
	Fork-tailed swift (*Apus pacificus*)	M, Ma	**Unlikely -** no records or modelled flight paths exist within 50 km of DRM.
	Grey wagtail (*Motacilla cinerea*)	M, Ma	**Unlikely -** no records exist within 50 km of DRM.
	Barn Swallow (*Hirundo rustica*)	M, Ma	**Unlikely** - no records exist within 50 km of DRM.
	Oriental plover (*Charadrius veredus*)	M, Ma	**Unlikely -** no records exist within 50 km of DRM.
	Oriental pratincole (*Glareola maldivarum*)	M, Ma	**Unlikely -** no records exist within 50 km of DRM.
	Pectoral sandpiper (*Calidris melanotos*)	M, Ma	**Unlikely -** no records exist within 50 km of DRM.
	Yellow wagtail (*Motacilla flava*)	M, Ma	**Unlikely -** no records exist within 50 km of DRM.
	Gouldian Finch (*Chloebia gouldiae* listed as *Erythrura gouldiae*)	E	**Unlikely -** no records exist within 50 km of DRM.
	Red Goshawk (*Erythrotriorchis radiatus*)	E	**Unlikely -** no records exist within 50 km of DRM.
	Night Parrot (*Pezoporus occidentalis)*	E	**Unlikely -** no records exist within 50 km of DRM. The nearest record is over 250 km south.
Mammal (n = 3)	Ghost Bat (*Macroderma gigas*)	V	**Unlikely -** no records exist within 50 km of DRM.
	Greater Bilby (*Macrotis lagotis*)	V	**Unlikely -** no records exist within 50 km of DRM. The nearest record is approximately 250 km southwest of DRM.
	Julia Creek Dunnart (*Sminthopsis douglasi*)	V	**Unlikely -** no records exist within 50 km of DRM.

Taxa	Common Name (*Scientific name*)	EPBC Status	Likelihood of Occurrence
Fish ***(n = 1)***	Freshwater sawfish (*Pristis pristis*)	V, M	**Unlikely -** the nearest record on ALA is located over 250km North of DRM. There is no suitable habitat for this species on-site.
Reptile ***(n = 4)***	Mertens' Water Monitor (*Varanus mertensi*)	E	**Known**
	Freshwater crocodile (*Crocodylus johnstoni*)	Ma	**Possible –** two records exist within 50 km of DRM.
	Plains Death Adder (*Acanthophis hawkei*)	V	**Unlikely -** no records exist within 50 km of DRM.
	Gulf Snapping Turtle (*Elseya lavarackorum*)	E	**Unlikely -** No records exist within 50 km of DRM. The nearest population is over 225 km northwest.

Key: V = Vulnerable, E = Endangered, CE = Critically Endangered, M = Migratory, Ma = Marine, SL = Special Least Concern, LC = Least Concern, NL = Not Listed

3.1.10.7.2. Matters of State Environmental Significance

The following Matters of State Environmental Significance are mapped (Queensland Government, 2022) to occur within the Project area:

- Wildlife habitat (endangered or vulnerable/ special least concern);
- Regulated vegetation (essential habitat); and
- Regulated vegetation (intersecting a watercourse).

Wildlife habitat and essential habitat within the Project area are associated with the presence of the *Petrogale purpureicollis* (purple-necked rock-wallaby) (Figure 10).

3.1.10.7.2.1. Environmentally Sensitive Areas

No Category A Environmentally Sensitive Areas (ESAs) were identified to occur across the Project. The Protected Matters Search Tool (PMST) (DCCEEW, 2024) identified the following Category B Environmentally Sensitive Area within the Project:

- Endangered regional ecosystem 1.3.7 – Red Gum (*Eucalyptus camaldulensis*) woodland on channels and levees.

3.1.10.7.2.2. Regional Ecosystems

The Project area was largely classed as remnant under the *Vegetation Management Act 1999 (*VM Act) with the current footprint now classed as non-remnant. Mapped regional ecosystems (RE) were reviewed using the Queensland Globe interactive mapping tool (QLD, 2022). The Project MLs are

primarily comprised of heterogenous 1.112A/1.7.7A (70/30). Mapped regional ecosystems of the Project area are described in Table 24 and depicted in Figure 11.

An area of the Project is mapped as heterogenous 1.11.2a/1.5.13/1.3.7b (70/25/5). While RE 1.3.7b is considered least concern under the VM Act, it has a biodiversity status of endangered due to its importance as seasonal water bird habitat and a regional corridor for fauna. It is therefore classed as a Category B Environmentally Sensitive Area (ESA) under Schedule 19 of the *Environmental Protection Regulation 2019*.

Table 24. Mapped vegetation communities and their current conservation status (Qld 2021)

Regional Ecosystems	Percentages	Short Description	VM Status*	BD Status#
1.11.2a/1.5.13/1.3.7b	70/25/5	**1.11.2a:** *Eucalyptus leucophloia* low open woodland often with *Corymbia terminalis*, *Corymbia capricornia*, *Terminalia aridicola* and *Eucalyptus leucophylla* with shrub layer of Acacia spp. and ground layer of Triodia spp. Occurs on steep hills and strike ridges. **1.5.13:** *Eucalyptus pruinosa* low open woodland on older alluvial and residual soils. **1.3.7b:** *Eucalyptus camaldulensis* fringing woodland, usually with *Lophostemon grandiflorus* and *Melaleuca bracteata* and/or *M. dissitiflora*. Occurs on recent levees and channel deposits of medium and smaller tributaries which are dry for most of the year; alluvial soils. Riverine.	**1.11.2a**: LC **1.5.13:** LC **1.3.7b:** LC	**1.11.2a:** NC **1.5.13:** NC **1.3.7b:** E
1.11.2a/1.11.3a	90/10	**1.11.2a:** *Eucalyptus leucophloia* low open woodland often with *Corymbia terminalis*, *Corymbia capricornia*, *Terminalia aridicola* and *Eucalyptus leucophylla* with shrub layer of Acacia spp. and ground layer of Triodia spp. Occurs on steep hills and strike ridges. **1.11.3a:** *Eucalyptus leucophylla* low open woodland often with *Corymbia terminalis*, *C. aparrerinja*, *Eucalyptus leucophloia* and *Atalaya hemiglauca* with scattered shrubs of *Acacia chisholmii* and a sparse ground layer of *Triodia pungens* and tussock grasses. Occurs on broad low hills; metamorphosed igneous rocks.	**1.11.2a**: LC **1.11.3a:** LC	**1.11.2a:** NC **1.11.3a:** NC
1.11.2a/1.7.7a	70/30	**1.11.2a:** *Eucalyptus leucophloia* low open woodland often with *Corymbia terminalis*, *Corymbia capricornia*, *Terminalia aridicola* and *Eucalyptus leucophylla* with shrub layer of Acacia spp. and ground layer of Triodia spp. Occurs on steep hills and strike ridges. **1.7.7a:** Low open woodland of Corymbia capricornia, often with *Eucalyptus leucophloia*. Mixed shrub layer usually including *Grevillea wickhamii*. Ground layer of *Triodia pungens* and/or *Triodia bitextura*. Occurs on silcrete	**1.11.2a**: LC **1.7.7a:** LC	**1.11.2a:** NC **1.7.7a:** NC
1.11.3a	100	*Eucalyptus leucophylla* low open woodland often with *Corymbia terminalis*, *C. aparrerinja*, *Eucalyptus leucophloia* and *Atalaya hemiglauca* with scattered shrubs	LC	NC

Regional Ecosystems	Percentages	Short Description	VM Status*	BD Status#
		of *Acacia chisholmii* and a sparse ground layer of *Triodia pungens* and tussock grasses. Occurs on broad low hills; metamorphosed igneous rocks.		
1.11.3a/1.3.13a	90/10	**1.11.3a:** *Eucalyptus leucophylla* low open woodland often with *Corymbia terminalis*, *C. aparrerinja*, *Eucalyptus leucophloia* and *Atalaya hemiglauca* with scattered shrubs of *Acacia chisholmii* and a sparse ground layer of *Triodia pungens* and tussock grasses. Occurs on broad low hills; metamorphosed igneous rocks. **1.3.13a:** Woodland of *Eucalyptus leucophylla*, commonly with *Corymbia terminalis*, *Acacia cambagei*, *Atalaya hemiglauca* and *C. aparrerinja.* Occasional canopy species include *Corymbia confertiflora*, *Lysiphyllum cunninghamii* and *Eucalyptus pruinosa*. The ground layer is a mix of tussock grasses and Triodia spp. Occurs on recent levees of larger watercourses and in-channel deposits of ephemeral streams.	**1.11.3a:** LC **1.3.13a:** LC	**1.11.3a:** NC **1.3.13a:** NC
1.11.7	100	*Acacia cambagei* low woodland. Occurs on metamorphic hills and ranges. Not a Wetland.	OC	OC
1.11.2a	100	*Eucalyptus leucophloia* low open woodland often with *Corymbia terminalis*, *Corymbia capricornia*, *Terminalia aridicola* and *Eucalyptus leucophylla* with shrub layer of Acacia spp. and ground layer of Triodia spp. Occurs on steep hills and strike ridges.	LC	NC
1.11.3a/1.3.13a	90/10	**1.11.3a:** *Eucalyptus leucophylla* low open woodland often with *Corymbia terminalis*, *C. aparrerinja*, *Eucalyptus leucophloia* and *Atalaya hemiglauca* with scattered shrubs of *Acacia chisholmii* and a sparse ground layer of *Triodia pungens* and tussock grasses. Occurs on broad low hills; metamorphosed igneous rocks. **1.3.13a:** Woodland of *Eucalyptus leucophylla*, commonly with *Corymbia terminalis*, *Acacia cambagei*, *Atalaya hemiglauca* and *C. aparrerinja.* Occasional canopy species include *Corymbia confertiflora*, *Lysiphyllum cunninghamii* and *Eucalyptus pruinosa*. The ground layer is a mix of tussock grasses and Triodia spp. Occurs on recent levees of larger watercourses and in-channel deposits of ephemeral streams.	**1.11.3a:** LC **1.3.13a:** LC	**1.11.3a:** NC **1.3.13a:** NC

Regional Ecosystems	Percentages	Short Description	VM Status*	BD Status#
1.5.4a	100	*Corymbia terminalis* low open woodland, scattered shrub layer of *Carissa lanceolata* and tussock grass ground layer. *Eucalyptus pruinosa* is commonly present in the north. Occurs on older alluvial and residual soils with significant clay content.	LC	NC

Key: E = Endangered, OC = Of Concern, LC = Least Concern, NC = No Concern

3.1.10.7.2.3. Regulated Vegetation

Regulated vegetation is vegetation managed through the VM Act. Vegetation classifications described by the VM Act as being Category A, Category B, Category C, Category R or Category X are required to meet certain criteria prior to impact.

The entire DRM ML is mapped as Category B remnant vegetation. Category B vegetation is defined as vegetation, that is either an endangered, of concern or least concern regional ecosystem forming the predominant canopy of the vegetation:

- covering more than 50% of the undisturbed predominant canopy;
- averaging more than 70% of the vegetation's undisturbed height; and
- composed of species characteristics of the vegetation's undisturbed predominant canopy.

3.1.10.7.2.4. EVNT or Special Least Concern Species under the NC Act

Table 25 details EVNT or Special Least Concern Species listed under the NC Act, with potential to occur within 50 km of the Project.

Table 25. EVNT or Special Least Concern Species under the NC Act

Common Name (Scientific Name)	NC Act[1]	Source	Likelihood of Occurrence
Plants			
Ipomoea antonschmidii	NT	WO	**Possible** – There are several records within a 50 km buffer from a central point within the Project area. The initial population is ~40 km to the east of the Project area. A newer population has been found ~100 km northwest of the Project area.
Mt Isa Mallee (Eucalyptus nudicaulis)	E	PMST	**Unlikely** – No records exist within a 50 km buffer from a central point within the Project area. The 50 km buffer falls outside of the extent of occurrence identified within the conservation advice for the species.
Ptilotus maconochiei	NT	WO	**Unlikely** - One record exists approximately 40 km west of the Project area. The majority of records are centred around Mount Isa.
Birds			
Australian Painted Snipe (*Rostratula australis*)	E	PMST, ALA	**Possible** - one record exists approximately 40 km southwest of the Project area.
Carpentarian Grasswren (*Amytornis dorotheae*)	E	PMST, WO, ALA	**Possible -** One record is located approximately 40 km northwest of the Project area.

Common Name (Scientific Name)	NC Act[1]	Source	Likelihood of Occurrence
Purple-crowned Fairy-wren (*Malurus coronatus*)	V	WO	**Possible** - One record exists within a 50 km buffer of a central point within the Project area.
Gouldian Finch (*Erythrura gouldiae*)	E	PMST	**Unlikely** - no records exist within a 50 km buffer of a central point within the Project area.
Grey Falcon (*Falco hypoleucos*)	V	PMST, WO	**Unlikely –** There are two records within 50 km of a central point within the Project area. However, due to the low density of the species, it is considered unlikely to occur in the Project area.
Night Parrot (*Pezoporus occidentalis*)	E	PMST	**Unlikely -** no records exist within a 50 km buffer of a central point within the Project area. The nearest record is over 250 km south of the site.
Painted Honeyeater (*Grantiella picta*)	V	PMST	**Unlikely** – there are two records within a 50 km buffer of a central point within the Project area.
Red Goshawk (*Erythrotriorchis radiatus*)	E	PMST	**Unlikely** - No records exist within a 50 km buffer of a central point within the Project area.
Mammals			
Purple-necked rock-wallaby (*Petrogale purpureicollis*)	V	WO, ALA	**Likely** – 23 records exist within a 50 km buffer of a central point within the Project area.
Short-beaked echidna (*Tachyglossus aculeatus*)	SL	WO, ALA	**Likely** - Four records exist within a 50 km buffer of a central point within the Project area. This species is widely distributed and utilizes a variety of habitats across its range.
Ghost Bat (*Macroderma gigas*)	E	PMST	**Unlikely -** No records exist within a 50 km buffer of a central point within the Project area. The habitat on site may be suitable if roosting structures are available
Greater Bilby (Macrotis lagotis)	E	PMST	**Unlikely** - No records exist within a 50 km buffer of a central point within the Project area. The nearest record in the ALA database is approximately 250 km southwest of the site.
Julia Creek Dunnart (Sminthopsis douglasi)	E	PMST	**Unlikely -** No records exist within a 50 km buffer of a central point within the Project area. Most records for this species are centred around Julia Creek, with occasional outliers.
Reptiles			

Common Name (Scientific Name)	NC Act[1]	Source	Likelihood of Occurrence
Mertens' water monitor (*Varanus mertensi*)	E	WO	**Possible** – Six records exist within 50 km buffer of a central point within the Project area. Several records are located along the Dugald River.
Gulf Snapping Turtle (Elseya lavarackorum)	V	PMST	**Unlikely -** No records exist within a 50 km buffer of a central point within the Project area. The nearest population is over 225 km northwest of the site.
Plains Death Adder (*Acanthophis hawkei*)	V	PMST	**Unlikely** - No records exist within a 50 km buffer of a central point within the Project area. The site is likely unsuitable habitat as this species favours habitat that is flat, while the site is geographically complex.

Key: V = Vulnerable, E = Endangered, SL = Special Least Concern, NT = Near Threatened.

LEGEND

- Mining lease
- MSES - regulated vegetation - intersecting a watercourse
- MSES - wildlife habitat - special least concern animal
- MSES - wildlife habitat - endangered or vulnerable wildlife
- MSES - regulated vegetation - essential habitat

Sources:
QLD Department of Resources
Google

410000E
412000E
414000E
7766000N
7764000N
7762000N
7760000N
7758000N

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MMG DUGALD RIVER MINE

FIGURE 10. MAPPED MATTERS OF STATE ENVIRONMENTAL SIGNIFICANCE

0.8 0 0.8 1.6 km

CRS: GDA2020 / MGA zone 54
Scale: 1:30,000 @A3

Date: 23 April 2025
Author: H. Robb
Version: 0.02

Project Number: 2024.07003
Client: MMG Dugald River Pty Ltd

WULGURU TECHNICAL SERVICES

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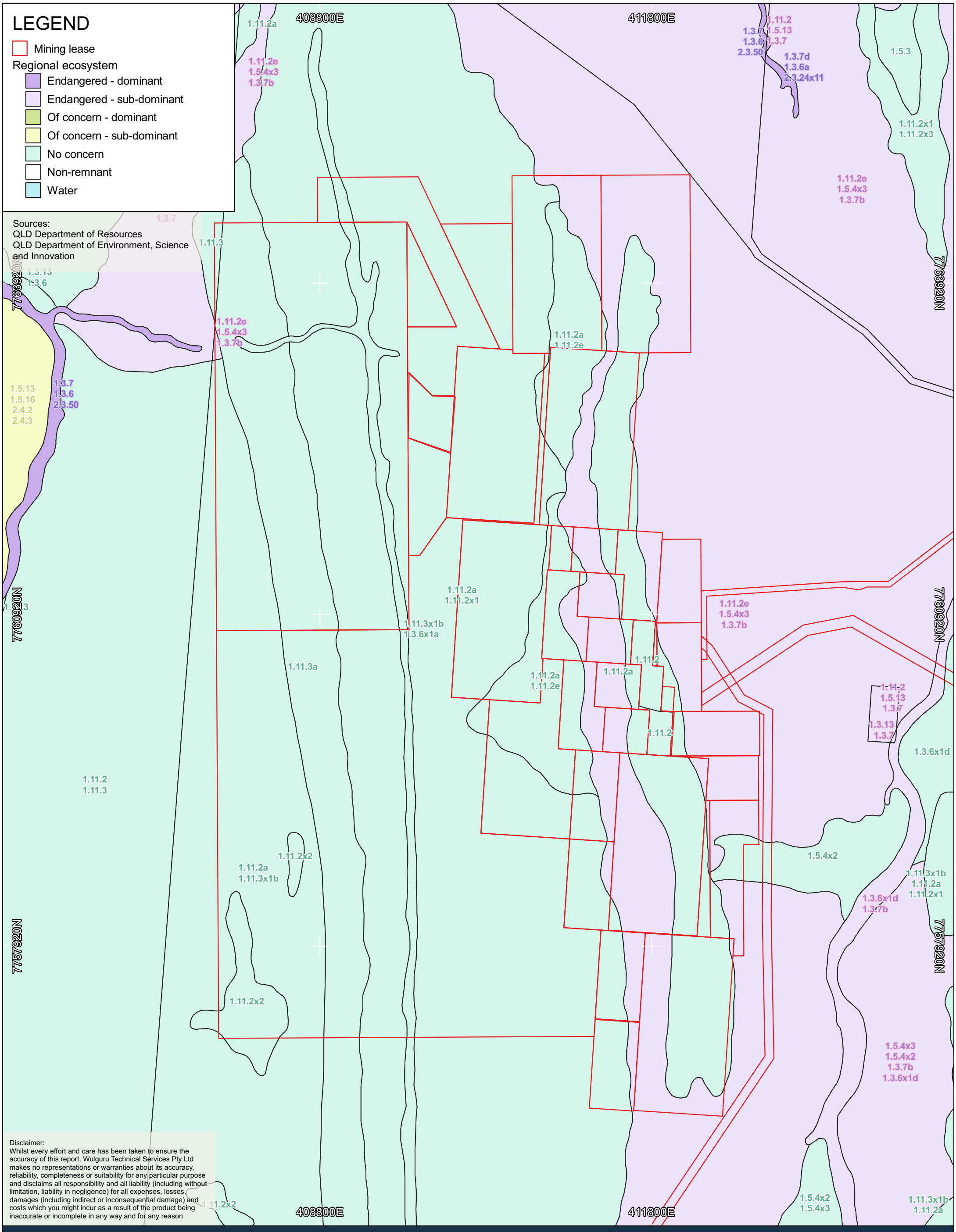

MMG DUGALD RIVER MINE

FIGURE 11. MAPPED REGIONAL ECOSYSTEMS

0.8 0 0.8 1.6 km CRS: GDA2020 / MGA zone 54 Scale: 1:30,000 @A3	Date: 24 April 2025 Author: H. Robb	WULGURU TECHNICAL SERVICES
Project Number: 2024.07003	Client: MMG Dugald River Pty Ltd	Version: 0.02

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3.2. Community

3.2.1. Community Profile

Cloncurry is the closest township to the Project, located approximately 65 km southeast of the Project. The 2021 Census recorded 3,644 people in the population, 56.6% male and 43.4 % female with a median age of 34. The labour force was recorded to be 1,904 people, with 64.9 % working full time. Technicians and Trades Workers was the largest employment industry (19.8%) followed by Machinery Operators and Drivers (17.9%) (ABS, 2021).

The nearest regional centre is Mount Isa, located 80 km southwest of DRM. Mount Isa has a population of over 18,000 and is the administrative, commercial, and industrial centre for north-western Queensland. As of the 2021 Census, the population was 18,727, with a median age of 31 with 51.6% male and 48.4 % female. The labour force was recorded to be 9,790 people, 70.4 % working full time. Technicians and Trades Workers was the largest employment industry at 20.8 % of the working population (ABS, 2021).

The Project employs approximately 700 employees and contractors with a mix of fly-in, fly-out workforce and local Cloncurry residents.

3.2.2. Community Consultation Plan

MMG has a Community and Social Performance Standard (Appendix B), which defines a range of programs that are implemented to meet community expectations. Within this, is a dedicated Community Engagement Plan (CEP) (Appendix C). This CEP documents the iterative consultation process to be followed to enable ongoing engagement with relevant stakeholders.

DRM has a dedicated Community and Stakeholder Advisor, to manage relationships with external stakeholders. In addition to the CEP, a Community Consultative Committee has been established and meets quarterly. The committee acts as a conduit between DRM and its key stakeholders, for sharing information and receiving feedback. The committee currently includes the following members:

- Commerce North West;
- Cloncurry Business Committee Representatives from the local Government;
- Representatives from the Kalkadoon, Mitakoodi and Mayi groups; and
- Pastoralists/landowners.

A community consultation register (Table 26) has been developed and will continue to be updated throughout the life of mine. In 2023, MMG completed targeted consultation with the landholders and Kalkadoon People regarding the PRCP, post mining land uses and the addition of the wind farm. Both parties were supportive of the proposed post mining land uses across the entire Project.

Table 26. Stakeholder consultation register

Activity date	Stakeholder	Communication type	Information provided	Discussion outcomes / issues raised	How issues have been considered	Decisions / outcomes of engagement	Commitment to stakeholder
4 July 2023	Kalkadoon People #4	In person meeting – Coffee Club Mount Isa	Mapping of proposed changes to PMLU	Proposed change to PMLU across the Project	Discussion during meeting.	Mr Kirkhoff, on behalf of the Kalkadoon People, support the change.	Submit application for revised PMLU – completed and approved November 2024.
23 October 2023	Landholder – McMillian family representatives.	In person meeting – Quamby Pub	Mapping of proposed changes to PMLU	Proposed change to PMLU across the Project	Discussion during meeting.	The McMillian family support the change.	Submit application for revised PMLU – completed and approved November 2024.

3.3. Post Mining Land Use

Land must be rehabilitated to a stable condition as defined in section 11A of the EP Act. Land is in a stable condition if:

- the land is safe and structurally stable, and
- there is no environmental harm being caused by anything on or in the land, and
- the land can sustain a Post Mining Land Use (PMLU).

A PMLU is defined under the EP Act as the purpose for which the land will be used after all relevant activities have ceased. The PMLU must be consistent with the outcome of consultation with the community and any strategies for the land of a local government, the State or Commonwealth (Department of Environment and Science, 2021).

3.3.1. Rehabilitation Areas

Project activities are grouped in this PRCP by Rehabilitation Areas (RAs), defined under the Progressive Rehabilitation and Closure Plans guideline as "*an area of land in the PMLU to which a rehabilitation milestone for the post-mining use relates".*

The RAs for the Dugald River Mine are detailed in Table 27 and mapped in Figure 12 and Figure 13.

Table 27. Rehabilitation areas

Rehabilitation Area	Area (ha)
RA1 – Ancillary infrastructure and services	**19.76**
Accommodation village	13.60
Pipeline and accommodation village road	6.00
Pipeline catch dam	0.16
RA2 – Borrow pits and stockpiles	**43.84**
Topsoil Stockpile A	8.23
Borrow Pit A	2.96
Access Road Borrow Pit(s)	4.72
TSF Borrow Pit A, TSF Borrow Pit B, TSF Stockpile	4.10
Topsoil Stockpile B	9.60
TSF Borrow Pit C	9.23
Borrow Pit D	2.06
Borrow Pit E	2.95
RA3 – Dams and diversion structures	**32.28**
Diversion Drains	2.39
Stage 2 PAF PAD Run Off Dam	11.60
Underground Mine Water Collection Dam	0.65
STP Dam Stage 1	0.9
STP Dam Stage 2	4
ROM Area Run Off Dam	3.7
Raw Water Dam	1.8

Rehabilitation Area	Area (ha)
Sediment Dam A	1.1
Process Plant Run Off Dam	1.5
Containment Dam	0.6
Mine Workshop Run Off Dam	0.6
Sediment Dam C	0.30
Sediment Dam D	0.35
Sediment Dam F	1.4
Sediment Dam G	1.4
RA4 - Mineralised waste	**22.56**
NAF WRD	8
PAF WRD	14.56
RA5 – Mining and processing area	**180.78**
ROM pad	3.8
ROM haul road	3.53
Processing plant and conveyor area	13.53
Underground portal and support infrastructure	2.94
Switchyard 1 and 2	2.03
Construction Laydown, Warehouse, Mobile Equipment Laydown and Core Shed	6.8
Office and administration services	2.72
Exploration camp	2.41
Sewage treatment plants	0.16
Workshop and vehicle maintenance	3.80
Raw water pipeline	5.44
Emergency response training	0.5
Explosives magazine	0.6
Communication tower	0.06
Powerlines	65.72
Roads and tracks	47.98
Groundwater infrastructure	0.54
Fuel storage	0.2
West laydown area	10.3
Waste transfer station	0.25
Temporary waste laydown	1
Laydown east	6.47
RA6 - TSF	**109.88**
TSF and seepage collection pond	103.51
TSF pipelines and roads	6.37
RA7 – Renewable Energy Infrastructure	**67.07**
Wind farm pads and ancillary infrastructure	27.86
Roads and tracks (Knapdale Range)	33.08
Laydown west	6.13

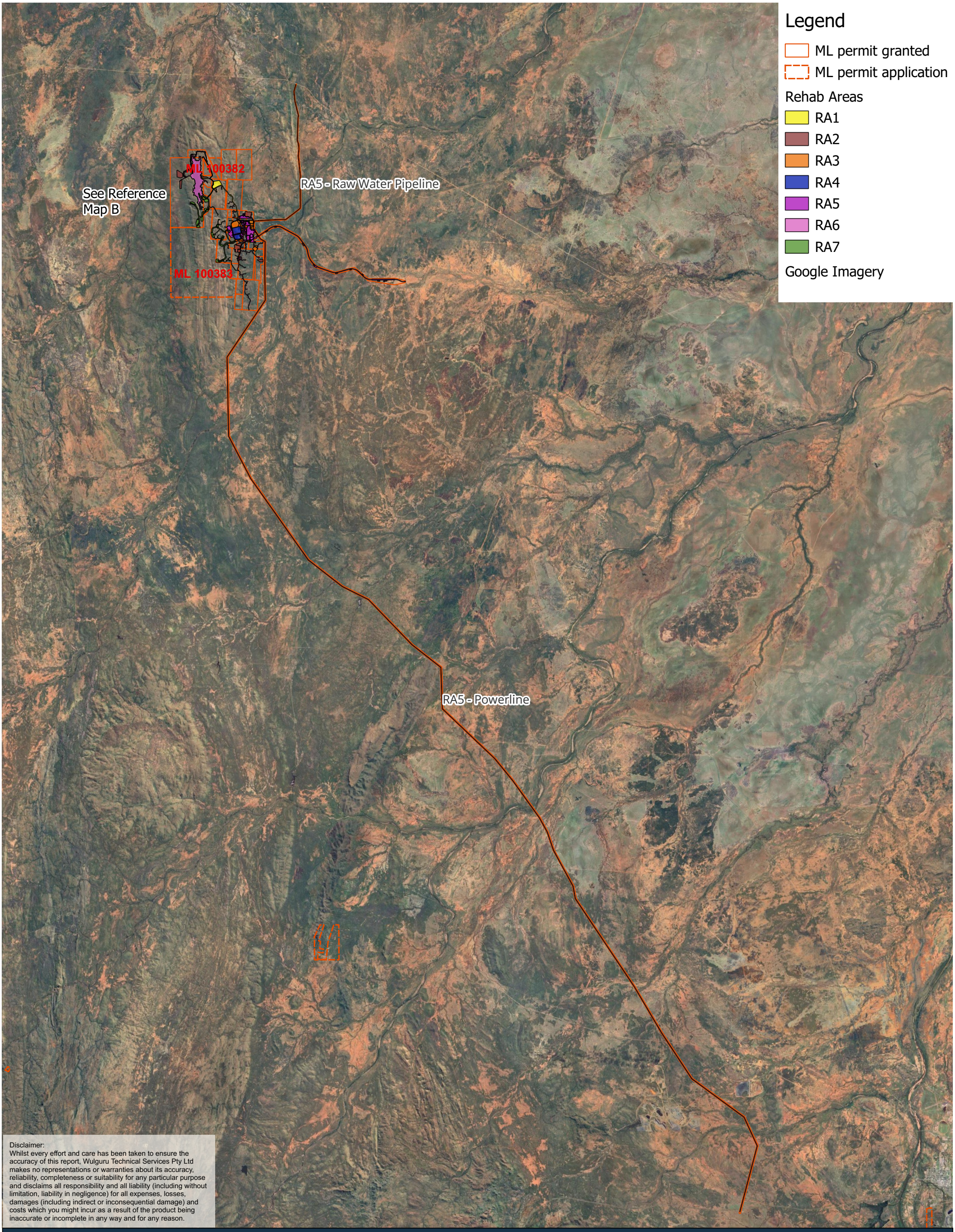

FIGURE 12. REFERENCE MAP A

4.9 0 4.9 9.8 km CRS: GDA94 / MGA zone 54 Scale: 1:175,000 @A3		Date: 4 March 2026 Author: M. Kaminski	WULGURU TECHNICAL SERVICES
Project Number: 2024.07003	Client: MMG	Version: 0.02	

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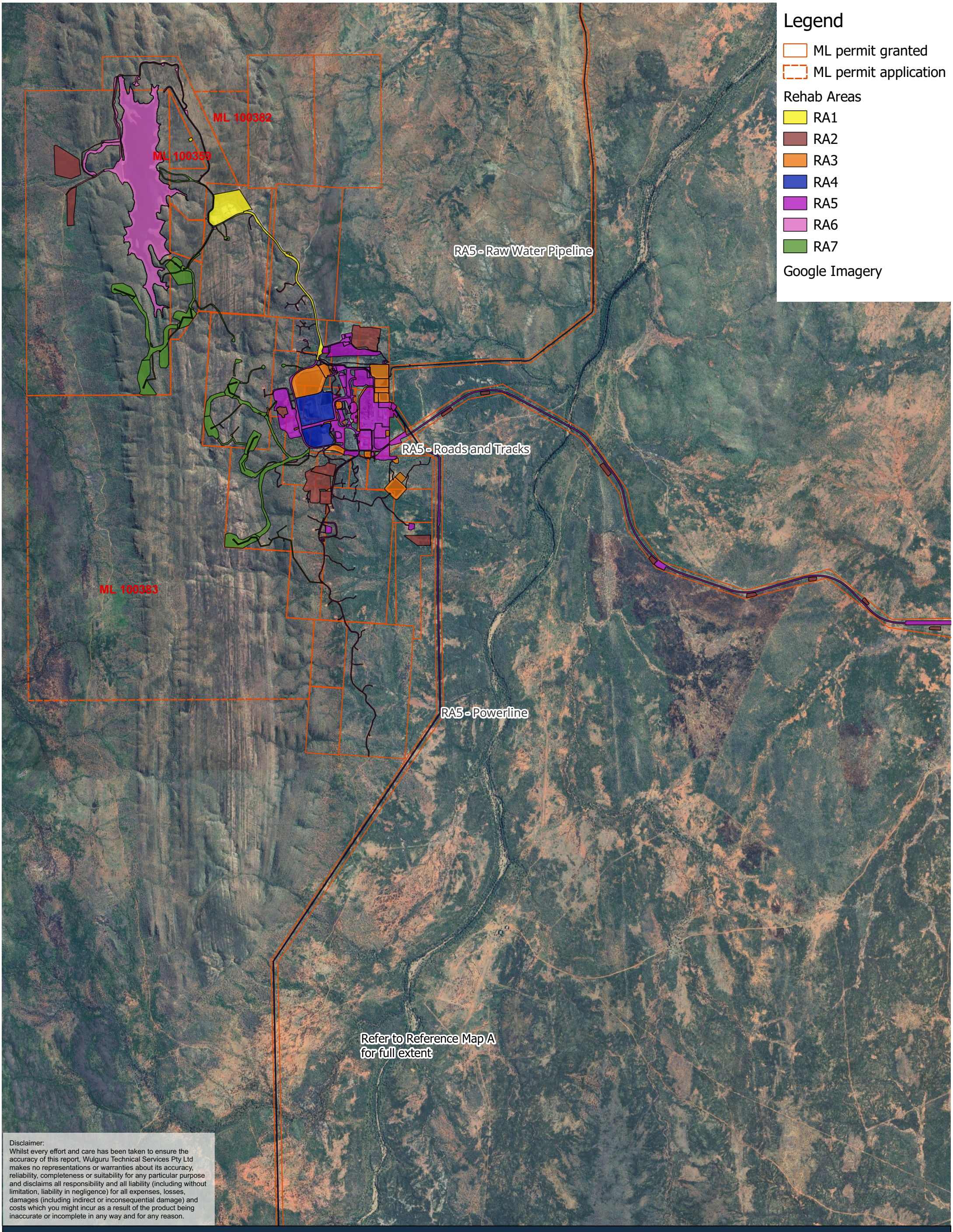

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FIGURE 13. REFERENCE MAP B

CRS: GDA94 / MGA zone 54 Scale: 1:40,000 @A3		Date: 4 March 2026 Author: M. Kaminski	WULGURU TECHNICAL SERVICES
Project Number: 2024.07003	Client: MMG	Version: 0.02	

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3.3.2. Existing Rehabilitation

Exploration disturbance is rehabilitated, within 12 months of disturbance activities. Over the course of operations, the location of exploration disturbance will vary however the rehabilitation strategy will remain the same. All exploration disturbance will be completed in accordance with the EA and the *Code of Environmental Compliance for Exploration and Mineral Development*. Land will be rehabilitated to a stable condition that achieves the relevant post mine land use designated for location of disturbance.

3.3.3. Assessment of PMLU Options

As part of the assessment of PMLUs it is acknowledged that the EP Regulation requires that each PMLU:

a) Is viable having regard to the use of land in the surrounding region, and

b) Satisfies at least one of the following:

   a. the use is consistent with how the land was used before a mining activity was carried out on the land;

   b. the use is consistent with a development approval relating to the land;

   c. the use is consistent with a use of the land, other than a use that is mining, permitted under a State or Commonwealth Act, including, for example, a planning instrument under the Planning Act 2016; and

   d. the use will deliver, or is aimed at delivering, a beneficial environmental outcome.

Low intensity grazing was determined to be the most suitable PMLU for the majority of the Project. This was determined by considering the existing rehabilitation objectives specified in the EA and, community consultation, as well as its environmental, economic, and social benefits. Where the topography inhibits cattle grazing (slopes >10%), native ecosystem was proposed as the most suitable PMLU. Table 28 lists the previously approved PMLU for each mine domain. PMLUs are discussed further in Section 3.3.

This revision of the PRCP does not propose any change to previously accepted PMLUs.

Table 28. Mine domains and agreed PLMU

	Mine Domain	PMLU
RA1	Ancillary infrastructure and services	Native ecosystem
RA2	Borrow pits and stockpiles	Low intensity grazing
RA3	Dams and diversion structures	Low intensity grazing
RA4	Mineralised waste	Low intensity grazing
RA5	Mining and processing area	Low intensity grazing
RA6	TSF	Native ecosystem
RA7	Renewable energy infrastructure	Native ecosystem

Table 29 describes how these PMLU's meet the requirements of the EP Regulation.

Table 29. Requirements of a PMLU

Requirement of a PMLU	Justification
The land is safe and structurally stable, and	All infrastructure will be removed and landforms (e.g. Waste dumps) will be returned to a pre-mining profile. The only feature to remain is the TSF. The final landform of the TSF has been designed by suitably qualified persons. After initial rehabilitation, structures will continue to be monitored by suitably qualified persons to assess stability. Erosion monitoring will be conducted to assess stability. The flat areas (<10% slope) will be made safe to support cattle grazing. The natural steep slopes of the Knapdale range inhibit cattle from accessing RA1, RA6 and RA7. These domains have an assigned PMLU of native ecosystem. During rehabilitation, areas may be fenced to prevent cattle grazing until vegetation has established and the landform is unlikely to cause erosion and sedimentation. There will be no voids or water management structures retained after closure.
There is no environmental harm being caused by anything on or in the land, and	All contaminants will be removed from site. A contaminated land assessment will be conducted following rehabilitation activities to verify the removal of contaminants. All infrastructure and waste will be removed from site during the demolition phase of rehabilitation. All Potentially Acid Forming (PAF) material will be returned to the underground mine void. Water from storage dams will be removed through evaporation and any contaminated sediment will be removed from site. The site will be revegetated to reduce the possibility of erosion. Ongoing surface and groundwater monitoring will be conducted to assess the potential for environmental harm.
The land can sustain a Post Mining Land Use (PMLU).	The proposed PMLU of low intensity cattle grazing is consistent with surrounding land uses. It is also consistent with the Cloncurry Shire Planning Scheme, rural zone. The PMLU of native ecosystem for RA1, RA6 and RA7 is consistent with the pre-mining land use of these areas.

Requirement of a PMLU	Justification
The PMLU is viable having regard to the use of land in the surrounding region, and	The Cloncurry Shire is a significant beef producing region. The proposed PMLU of low intensity cattle grazing is consistent with previous and current land uses in the area. The PMLU of native ecosystem for RA1, RA6 and RA7 is consistent with the pre-mining land use of the area.
The PMLU satisfies at least one of the following: a. the use is consistent with how the land was used before a mining activity was carried out on the land; b. the use is consistent with a development approval relating to the land; c. the use is consistent with a use of the land, other than a use that is mining, permitted under a State or Commonwealth Act, including, for example, a planning instrument under the Planning Act 2016; and d. the use will deliver, or is aimed at delivering, a beneficial environmental outcome.	The proposed PMLUs of low intensity cattle grazing and native ecosystem are consistent with how the land was used before a mining activity was carried out on the land. The PMLUs presented within this PRCP have been previously approved. This revision does not propose any change to any PMLU.

3.3.3.1. Community Consultation

The proposed PMLUs of native ecosystem and grazing are consistent with the community consultation conducted to date, in that they are:

- Consistent with the land use prior to the commencement of mining activities;
- Consistent with the surrounding land use; and
- Compatible with, and beneficial to, the current underlying landholder activities.

In 2023, MMG consulted with the landholders and Kalkadoon People regarding the PRCP, post mining land uses and the addition of the wind farm. Both parties were supportive of the proposed post mining land uses across the entire Project.

There are currently no agreements with landholders for any infrastructure to be retained for future land use.

As this revised PRCP does not propose any change to PMLUs or rehabilitation methods/outcomes, no additional targeted community consultation has been completed for this revision.

3.3.3.2. Regional Planning Integration

3.3.3.2.1. Cloncurry Shire Planning Scheme

Under the Cloncurry Shire Planning Scheme 2016 (the Planning Scheme), the Project is within the Rural zone (Cloncurry Shire Council, 2017). The overall purpose of the Rural zone of the Cloncurry Shire is to:

- Provide for rural uses and activities;
- Provide for other uses and activities that are compatible with –
    - Existing and future rural uses and activities;
    - The character and environmental features of the zone;
- Maintain the capacity of land for rural uses and activities by protecting and managing significant natural resources and processes.

The proposed PMLUs of native ecosystem and grazing are compatible with the planning scheme.

3.3.3.2.2. Regional Strategies

The North West Regional Plan (DIP, 2010) identifies both mining and beef production as significant primary industries with long histories in the region. The plan identifies the need to manage the cyclical nature of mining by ensuring that its development complements other industries. The plan also places importance on cultivating a natural environment that is resilient to the impacts of climate change and one that is well managed to maintain biodiversity, ecological processes, water resources and scenic amenity.

The proposed PMLUs of grazing and native ecosystem are compatible with the North West Regional Plan in that they provide an alternative land use (grazing), that is complementary to the mining industry and provides positive environmental outcomes.

Similar to the North West Regional Plan, the Cloncurry Shire Council Economic Development Strategy identifies mining and agriculture as key contributors to the regional economy, as the two highest employment industries. The strategy highlights future development of the beef industry with the potential for expanded saleyards, and beef processing and feed lotting facilities being investigated.

The proposed PMLU of grazing is consistent with the Cloncurry Shire Council Economic Development Strategy.

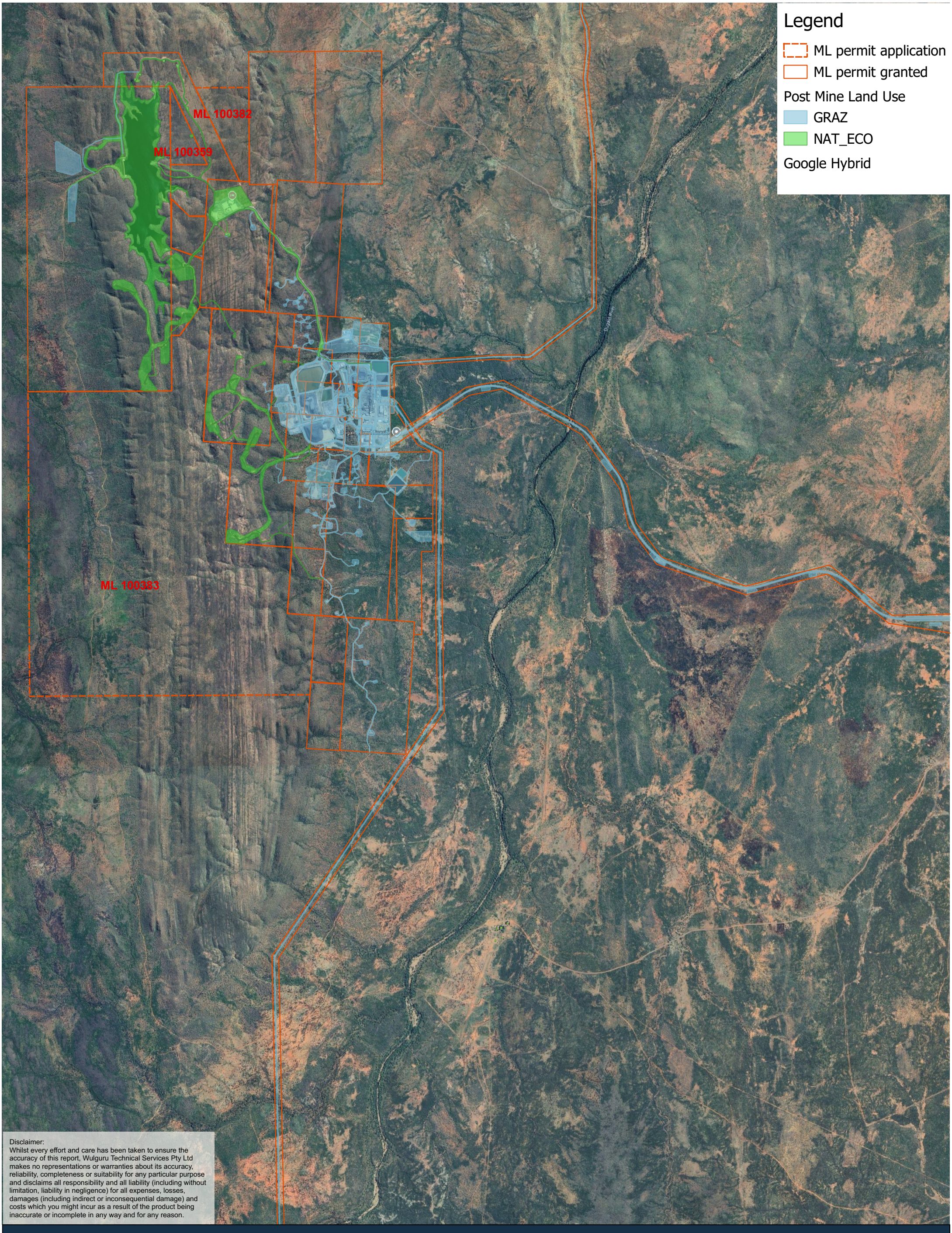

FIGURE 14. PROPOSED POST MINE LAND USE

1 0 1 2 km	CRS: GDA94 / MGA zone 54 Scale: 1:40,000 @A3	Date: 4 March 2026 Author: M. Kaminski	WULGURU TECHNICAL SERVICES
Project Number: 2024.07003	Client: MMG	Version: 0.03	

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3.3.4. Proposed PMLU

3.3.4.1. RA1 – Ancillary Infrastructure and Services

3.3.4.1.1. Overview

This RA includes the accommodation village, pipeline, catch dam and associated roads on the northern section of the ML. The RA is situated on the crest of the Knapdale Range. The area will be ripped however will not be topsoiled, consistent with the natural profile of the Knapdale Range. Revegetation will target species of regional ecosystem 1.11.2a/1.7.7a, consistent with the pre-clearance environment. Target species include *Eucalyptus leucophloia*, *Corymbia terminalis* and *Corymbia capricornia* with a groundcover of *Aristida latifolia*, *Eriachne obtusa*,*Sporobolus australasicus*,*Themeda triandra* and *Triodia pungens*. The target regional ecosystems will support native fauna populations, in keeping with the surrounding habitats. Features such as large woody debris or boulders will be selectively placed to provide suitable refuge for the purple neck rock wallaby.

3.3.4.1.2. Outcome

The PMLU for Ancillary Infrastructure and Services is native ecosystem.

3.3.4.1.3. Environmental Benefit

Revegetation will target species of regional ecosystem 1.11.2a/1.7.7a, consistent with the pre-clearance environment. This will establish connectivity with the surrounding environment. The revegetated area will provide additional habitat and foraging for the purple neck rock wallaby, which is known to inhabit the surrounding area.

3.3.4.1.4. Economic Benefit

The PMLU of native ecosystem does not have a direct economic benefit.

3.3.4.1.5. Social Benefit

The social benefit of re-establishing native ecosystem is the aesthetic appearance and cohesion with the surrounding environment.

3.3.4.2. RA2 – Borrow Pits and Stockpiles

3.3.4.2.1. Overview

RA2 of the Project includes borrow pits and topsoil stockpiles. Once borrow pits have been exhausted, the area will be reshaped, where required, to prevent water ponding and erosion. Topsoil stockpiles will be utilised in rehabilitation activities. The underlying footprint will be ripped and seeded.

3.3.4.2.2. Outcome

The proposed PMLU for the RA2 is low intensity grazing.

3.3.4.2.3. Environmental Benefit

The establishment of low intensity grazing will provide a coverage of vegetation, which will minimise the chance of erosion as a result of runoff. The establishment of pasture on the domains will also limit the amount of fuel load, reducing the impact of potential bushfires.

The pasture covered PMLU may provide a food source for native fauna. The pasture cover will produce seed and flowers throughout the seasons, which may be utilised by native fauna, therefore helping support local ecosystems.

Additionally, other than occasional watering during closure, no further activities would be required to form a stable landform consistent with grazing.

3.3.4.2.4. Economic Benefit

Establishing grazing pastures will result in a lower cost of direct seeding and a quicker establishment of adequate vegetation cover, potentially leading to an earlier relinquishment of the ML.

Additionally, the future landowners of the Project area will likely be pastoralists as per the surrounding land uses. Rehabilitating RA2 to low-intensity grazing will create additional grazing areas, leading to a direct increase in the economic benefit to the future landholder.

3.3.4.2.5. Social Benefit

Future landholders will likely be pastoral holdings. Returning the land to grazing pastures will result in a PMLU that is consistent with surrounding land uses.

3.3.4.3. RA3 – Dams and Diversion Structures

RA3 of the Project include diversion drains, sediment dams, PAF runoff dam, infrastructure runoff dams, STP dams, and raw water dams. At this stage there are no formal landholder agreements to retain any dams onsite. As such, water and sediment will be removed from dams and the dams will be filled with NAF or other suitable material. The landform will be shaped to be gently sloping, characteristic of the natural landform with drainage reinstated. The footprint will be ripped and seeded.

3.3.4.3.1. Outcome

The proposed PMLU for the RA3 is low intensity grazing.

3.3.4.3.2. Environmental Benefit

The establishment of low intensity grazing will provide a coverage of vegetation, which will minimise the chance of erosion as a result of runoff. The establishment of pasture on the domains will also limit the amount of fuel load, reducing the impact of potential bushfires.

The pasture covered PMLU may provide a food source for native fauna. The pasture cover will produce seed and flowers throughout the seasons, which may be utilised by native fauna, therefore helping support local ecosystems.

Additionally, other than occasional watering during closure, no further activities would be required to form a stable landform consistent with grazing.

3.3.4.3.3. Economic Benefit

Establishing grazing pastures will result in a lower cost of direct seeding and a quicker establishment of adequate vegetation cover, potentially leading to an earlier relinquishment of Mine Leases.

Future landowners of the Project area will likely be pastoralists as per the surrounding land uses. Rehabilitating to low-intensity grazing will provide an additional grazing area, leading to a direct increase in the economic benefit to the future landholder.

Additionally, other than occasional watering during closure, no further activities would be required to form a stable landform consistent with grazing.

3.3.4.3.4. Social Benefit

Future landholders will likely be pastoral holdings. Returning the land to grazing pastures will result in a PMLU that is consistent with surrounding land uses.

3.3.4.4. RA4 – Mineralised Waste Dumps

RA4 of the Project includes the PAF waste rock dump, NAF waste rock dump and the temporary ore stockpile. At the end of mine life, material from the PAF waste rock dump will be returned underground as part of the stope filling. Approximately 0.5 m of material will be excavated from the footprint of the PAF waste rock dump and disposed of in the TSF.

NAF waste rock will be removed and used as cover material for the TSF. NAF material may also be used to rehabilitate other areas onsite (eg. infill dams). A materials balance is provided in Table 32.

Once the material has been removed, the footprint of each of the WRDs will be graded to conform to the surrounding landscape. Topsoil will be applied at 0.1 - 0.2 m depth and the areas will be ripped and seeded with pasture species.

3.3.4.4.1. Outcome

The proposed PMLU for the RA4 is low intensity grazing.

3.3.4.4.2. Environmental Benefit

The establishment of low intensity grazing will provide a coverage of vegetation, which will minimise the chance of erosion as a result of runoff. The establishment of pasture on the domains will also limit the amount of fuel load, reducing the impact of potential bushfires.

The pasture covered PMLU may also provide a food source for native fauna. The pasture cover will produce seed and flowers throughout the seasons, which may be utilised by native fauna, therefore helping support local ecosystems.

Additionally, other than occasional watering during closure, no further activities would be required to form a stable landform consistent with grazing.

3.3.4.4.3. Economic Benefit

Establishing grazing pastures will result in a lower cost of direct seeding and a quicker establishment of adequate vegetation cover, potentially leading to an earlier relinquishment of Mine Leases.

Future landowners of the Project area will likely be pastoralists as per the surrounding land uses. Rehabilitating to low-intensity grazing will provide an additional grazing area, leading to a direct increase in the economic benefit to the future landholder.

Additionally, other than occasional watering during closure, no further activities would be required to form a stable landform consistent with grazing.

3.3.4.4.4. Social Benefit

Future landholders will likely be pastoral holdings. Returning the land to grazing pastures will result in a PMLU that is consistent with surrounding land uses.

3.3.4.5. RA5 – Mining and Processing Areas

RA5 of the Project includes ROM haul roads, processing plant, sewage treatment plant, battery farm, vehicle maintenance area and laydown yards. To achieve the nominated PMLU, domain infrastructure such as concrete hardstands, buildings, telecommunications, electrical supply etc., will be decommissioned and removed. With infrastructure removed, the landform will be shaped to be a stable, free draining landform. Topsoil will be applied at 0.1 - 0.2 m depth and the areas will be ripped and seeded with pasture species.

3.3.4.5.1. Outcome

The proposed PMLU for the RA5 is low intensity grazing.

3.3.4.5.2. Environmental Benefit

The establishment of low intensity grazing will provide a coverage of vegetation, which will minimise the chance of erosion as a result of runoff. The establishment of pasture on the domains will also limit the amount of fuel load, reducing the impact of potential bushfires.

The pasture covered PMLU may provide a food source for native fauna. The pasture cover will produce seed and flowers throughout the seasons, which may be utilised by native fauna, therefore helping support local ecosystems.

Additionally, other than occasional watering during closure, no further activities would be required to form a stable landform consistent with grazing.

3.3.4.5.3. Economic Benefit

Establishing grazing pastures will result in a lower cost of direct seeding and a quicker establishment of adequate vegetation cover, potentially leading to an earlier relinquishment of MLs.

Future landowners of the Project area will likely be pastoralists as per the surrounding land uses. Rehabilitating to low-intensity grazing will provide an additional grazing area, leading to a direct increase in the economic benefit to the future landholder.

Additionally, other than occasional watering during closure, no further activities would be required to form a stable landform consistent with grazing.

3.3.4.5.4. Social Benefit

Future landholders will likely be pastoral holdings. Returning the land to grazing pastures will result in a PMLU that is consistent with surrounding land uses.

3.3.4.6. RA6 – TSF

RA6 of the Project includes the Tailings Storage Facility and associated pipelines and seepage collection system.

3.3.4.6.1. Outcome

The proposed PMLU for RA6 is native ecosystem.

The TSF will be capped and revegetated with a mix of shallow rooting native species so as not to compromise the integrity of the sealing layer. The vegetation will act in removing moisture from the infiltration layer and prevent surface ponding and infiltration to subsequent layers of the TSF. Target species include *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus,Themeda triandra* and *Triodia pungens.* The downstream embankment will be reshaped to create a safe, stable and non-polluting landform. Once monitoring indicates the absence of seepage, the seepage collection system will be rehabilitated, by removing contaminated sediment with the footprint graded, ripped and seeded.

3.3.4.6.2. Design

All infrastructure such as pumps and pipelines will be flushed and removed from site to be disposed of in a licenced waste facility. The final surface of the TSF will be shaped to be self-shedding. The tailings surface will be capped with a cover system that:

- Minimises infiltration to the maximum extent, such that seepage from the TSF is minimised.
- Minimises capillary rise from the tailings into the cover system, thereby contaminating the cover soils.
- Is physically stable
- Is chemically stable
- Is able to sustain a PMLU of native ecosystem.

The downstream embankment will be reshaped for stability. The spillway will be reinstated at RL 242.1 m acting as an outlet for the final TSF landform. Full details on the design of the TSF is provided in Appendix D.

3.3.4.6.3. Environmental Benefits

Revegetating with a mix of shallow rooting species will maintain the integrity of the capping layer and prevent potential contamination from tailings. Surface drainage will be directed over the cover system to the spillway outlets to allow continuous flow across the catchment.

3.3.4.6.4. Economic Benefit

The PMLU of native ecosystem does not have a direct economic benefit.

3.3.4.6.5. Social Benefit

The social benefit of re-establishing native ecosystem is the aesthetic appearance and cohesion with the surrounding environment.

3.3.4.7. RA7 – Renewable Energy Infrastructure

RA7 incorporates eight wind turbines, ancillary infrastructure such as cabling and meteorological masts, two laydowns and access roads.

3.3.4.7.1. Outcome

The proposed PMLU for RA7 is native ecosystem.

All infrastructure, including turbine components, hardstands, and underground and aboveground cabling, will be decommissioned and removed. All infrastructure will be decommissioned and disposed of in accordance with manufacturer's specifications and waste disposal regulations. No infrastructure will remain within the footprint of the wind farm.

During construction of the turbines, pads are required to be levelled for stability. Hardstands will be constructed for the assembly, construction and erection of the turbines. These hardstands will be retained throughout the life of operations for maintenance and decommissioning purposes. On closure, the hard stands will be removed. Each pad will be recontoured slightly to prevent water ponding. This will prevent water flows from accumulating and concentrating energy to create gullies. No other landform design or earthworks is required.

Revegetation will target species of regional ecosystem 1.11.2a/1.7.7a and RE1.11.3a/1.3.13a consistent with the pre-clearance environment. Target species include *Eucalyptus leucophloia*, *Corymbia terminalis* and *Corymbia capricornia* with a groundcover of *Aristida latifolia*, *Eriachne obtusa*,*Sporobolus australasicus*, *Themeda triandra* and *Triodia pungens*. The target regional ecosystems will support native fauna populations, in keeping with the surrounding habitats. Features such as large woody debris or boulders will be selectively placed to provide suitable refuge for the purple neck rock wallaby.

After infrastructure is removed, the natural landform will remain. Disturbances on the Knapdale Range will not be topsoiled, consistent with the natural profile of the range. The areas will be ripped and seeded with pasture species.

Access roads will be ripped and seeded as above.

3.3.4.7.2. Economic Benefit

The PMLU of native ecosystem does not have a direct economic benefit.

3.3.4.7.3. Social Benefit

The social benefit of re-establishing native ecosystem is the aesthetic appearance and cohesion with the surrounding environment.

3.4. Non-use management areas

There are no non-use management areas proposed for the Project.

3.5. Rehabilitation and Management Methodologies

The rehabilitation and management methodologies for each RA are described in Table 30. General rehabilitation principles are described further, throughout Section 3.5.

Table 30. Key rehabilitation activities

Rehabilitation Area	Relevant Activities	Rehabilitation Activities	Rehabilitation Timing	Rehabilitation Milestones
RA1 – Ancillary infrastructure and services	Accommodation village Remaining Ancillary Infrastructure and Services (e.g. warehousing, powerline, raw water pipeline etc)	• Decommission and remove infrastructure. • Remove all surfaces (concrete footings, culverts, road base etc.). • Conduct a contaminated land assessment. • Remove any contaminated material and dispose of at a licenced facility. • Complete validation sampling to determine success of contamination removal. • Shape landform to be free draining and of similar shape to the surrounding topography. • Rip landform parallel to landform contours. • Apply ~ 0.2m growth media. • Monitor to assess natural revegetation establishment. • Apply selected native vegetation seed mix • Monitor to assess rehabilitation success and whether the PMLU has been achieved.	• The accommodation village will become available for rehabilitation once mining activities have ceased and the mining and closure workforce is no longer required. • Available 2044	RM1 RM2 RM3 RM9 RM10 RM12 RM14
RA2 – Borrow pits and stockpiles	Borrow Pit Topsoil Stockpiles	• Borrow pits have previously been shaped to be stable and free draining post construction. Further shaping may be required if borrow pits are to be recommissioned or additional pits are utilised. • Remove topsoil and utilise in rehabilitation activities. • Rip landform parallel to landform contours. • Apply ~0.2m growth media. • Monitor to assess natural revegetation establishment. • Apply selected pasture seed mix. • Monitor to assess rehabilitation success and whether the PMLU has been achieved.	• Area will be available for rehabilitation once borrow pit and topsoil stockpiles have been exhausted. • Available 2050, after the TSF cover system has been applied.	RM4 RM9 RM11 RM13 RM15

Rehabilitation Area	Relevant Activities	Rehabilitation Activities	Rehabilitation Timing	Rehabilitation Milestones
RA3 – Dams and diversion structures	Dams and diversion structures	• Pump residual water to the TSF for evaporation. • Decommission any water management infrastructure (pumps, electricity supply etc.) and remove/dispose of. • Undertake assessment for contaminated sediment • Desilt dams and dispose of sediment to the TSF. • Remove liners if present. • Infill dams with inert material and shape landform to be free draining of similar shape to the surrounding topography. • Restore natural watercourses. • Rip landform parallel to landform contours. • Apply ~0.2m growth media. • Monitor to assess natural revegetation establishment • Apply selected pasture seed mix if natural revegetation has not been successful (<30% coverage of analogue site) • Monitor to assess rehabilitation success and whether the PMLU has been achieved.	• The runoff dam will be rehabilitated after associated areas (WRDs) have been revegetated. • Available 2051, after all mineral waste has been removed. • Sediment dams will be retained onsite until upstream landforms have been revegetated.	RM1 RM2 RM5 RM9 RM11 RM13 RM15
RA4 – Mineralised waste	Mineralised waste dumps	**Potentially Acid Forming Material** • Dispose of any PAF to underground • Excavate approximately 0.5m of material from underneath the PAF waste rock dumps and dispose within the TSF. • Undertake assessment for contaminated sediment. • Rip landform parallel to landform contours. • Apply ~0.2m growth media. • Monitor to assess natural revegetation establishment • Apply selected pasture seed mix.	• Any PAF remaining on the surface after closure will be returned underground before the portal is sealed. • The NAF waste rock dump will be rehabilitated concurrently with the TSF. • Available 2048 after the TSF has completed drying and is trafficable for placement.	RM2 RM6 RM9 RM11 RM13 RM15

Rehabilitation Area	Relevant Activities	Rehabilitation Activities	Rehabilitation Timing	Rehabilitation Milestones
		• Monitor to assess rehabilitation success and whether the PMLU has been achieved **Non-Acid Forming Material** • Remove NAF from dumps for use in rehabilitation of the TSF. • Undertake assessment for contaminated sediment. • Rip landform parallel to landform contours. • Apply ~0.2m growth media. • Monitor to assess natural revegetation establishment. • Apply selected pasture seed mix. • Monitor to assess rehabilitation success and whether the PMLU has been achieved		
RA5 – Mining and processing area	Mining and processing areas	• Remove surface infrastructure. • Undertake assessment for contaminated land and remediate if required. • Remove contaminated material and dispose in the TSF (if required). • Seal the portals and declines with a 5m long bulkhead. • Backfill the box cut void and portal with NAF waste rock. • Excavate approximately 0.5m of material from underneath the processing areas, and dispose of in the TSF • Rip landform parallel to landform contours. • Apply ~0.2m growth media. • Monitor to assess natural revegetation establishment.	• Ore may be processed after the cessation of mining activities. Processing areas will become available after all ore has been processed. • Available 2044 • The ROM, ROM haul roads, processing plant and conveyor area and powerlines will be retained until 2045 to allow processing of any residual ROM ore after closure.	RM1 RM2 RM6 RM9 RM11 RM13 RM15

Rehabilitation Area	Relevant Activities	Rehabilitation Activities	Rehabilitation Timing	Rehabilitation Milestones
		• Apply selected pasture seed mix. • Monitor to assess rehabilitation success and whether the PMLU has been achieved		
RA6 - TSF	Tailings Storage Facility and Seepage Detection System	**Seepage Detection System** • Water in seepage collection system is pumped back to the TSF (If any). • Complete ongoing monitoring of seepage rates and quality until seepage has ceased. • Decommission and remove infrastructure. • Undertake assessment for contaminated land and remediate if required. • Remove contaminated material and dispose in the TSF (if required). • Undertake assessment to determine if contaminated land had been successfully removed • Backfill the seepage detection pond, drain and sump with NAF waste rock. • Rip landform parallel to landform contours. • Apply ~0.2m growth media. • Monitor to assess natural revegetation establishment • Apply selected seed mix to support PMLU. • Monitor to assess rehabilitation success and whether the PMLU has been achieved **Tailings Storage Facility** • The tailings pipeline will be flushed, decommissioned and disposed of in a licenced facility.	• The TSF may remain active post mining cessation as processing of mined ore may continue until ore is depleted. TSF will be available for rehabilitation at the completion of processing. • Available 2044. Drying of tailings has been modelled to require four years.	RM1 RM7 RM9 RM10 RM12 RM14

Rehabilitation Area	Relevant Activities	Rehabilitation Activities	Rehabilitation Timing	Rehabilitation Milestones

		• Other TSF infrastructure (electrical equipment, water pump back pipelines etc.) to be decommissioned and removed.
		• Reshape TSF surface to achieve a grade of <1.5%.
		• Complete construction of cover system and spillway/erosion control features.
		• Reinstate spillway at RL 242.1m.
		• Conduct QA/QC testing at a rate of 1 sample per hectare to confirm depth of layers and permeability is as specified in the designs and no PAF material is present within the cover system.
		• Monitor to assess natural revegetation establishment
		• Apply selected native seed mix.
		• Install monitoring locations determined from rehabilitation trials, including:
		  • Meteorological station
		  • Piezometers within the tailings and capillary break layer
		  • Automated in situ water content and suction sensors in each layer of the cover system
		  • Temperature sensors
		  • A lysimeter.
		• Monitor to assess rehabilitation success and whether the PMLU has been achieved		

RA7 – Renewable energy infrastructure	Renewable Energy Infrastructure	• Decommission and remove infrastructure. • Remove all surfaces (concrete footings, culverts road base etc.). • Minor rounded at pad crests, where required.	• The renewable energy infrastructure will continue to be utilised to power the operation until all other infrastructure has been removed. • Available 2044	RM1 RM2 RM6 RM8 RM9

Rehabilitation Area	Relevant Activities	Rehabilitation Activities	Rehabilitation Timing	Rehabilitation Milestones
		• Locally stockpiled material from road and drainage development is replaced. • Monitor to assess natural revegetation establishment. • Apply selected native vegetation seed mix if natural revegetation has not been successful (<30% coverage of analogue site). • Monitor to assess rehabilitation success and whether the PMLU has been achieved.		RM10 RM12 RM14

3.5.1. Voids in Floodplains

There are no proposed voids associated with the Project.

3.5.2. Site Services

To ensure site safety, all services will be terminated, disconnected and isolated. Generators will be decommissioned and removed from site. Power substations will be removed, or sold or used as part of another project, and the switch room will be disconnected. Licenced contractors will remove sewerage to a licensed offsite facility. Telecommunication services will be disconnected and removed.

The infrastructure at the Project site will be decommissioned, removed, dismantled, or salvaged.

3.5.3. Built Infrastructure

After all services have been disconnected, built infrastructure will be demolished by a suitably qualified person and will be removed from site. All infrastructure will be transported and disposed to a facility authorised to receive the waste type. The infrastructure to be removed from site is detailed in Table 31.

Table 31. Built infrastructure

Rehabilitation/Improvement Area	Built Infrastructure	Decommissioning methodology
RA1 – Ancillary infrastructure and services	• Accommodation village and associated facilities • Pipeline and accommodation village road	• Electrical and mechanical disconnection from all building facilities. • Empty building contents, remove steel roofs, wall cladding, fencing and concrete slabs. • Dispose of building waste to offsite disposal facility authorised to receive waste. • Disposal of fuels and regulated waste to an offsite disposal facility authorised to receive waste. • Remaining infrastructure decommissioned, cut and removed from site to authorised disposal facility offsite. • Pipes flushed, cut, capped, and removed. • Road base removed.
RA2 – Borrow pits and stockpiles	• No built infrastructure present during LOM.	• Not applicable.

Rehabilitation/Improvement Area	Built Infrastructure	Decommissioning methodology
RA3 – Dams and diversion structures	• Pumps and pipelines • Liners	• Water removed from structures. • Pumps disconnected and removed from site. • Removal and disposal of synthetic liners to the TSF. • Pipes flushed, cut, capped, and removed.
RA4 – Mineralised waste	• No built infrastructure present during LOM.	• Not applicable.
RA5 – Mining and processing area	• ROM haul road • Processing plant and conveyor • Switchyards • Warehouse and core shed • Office and administration services • Exploration camp • Sewage treatment plants • Workshop and vehicle maintenance • Raw water pipeline • Explosives magazine • Communication tower • Powerlines • Fuel storage • Waste transfer station	• Disconnection and termination of all services at building boundaries e.g. Gas, electricity, and water. • Empty building contents, remove steel roofs, wall cladding, fencing and concrete slabs. • Dispose of building waste to offsite disposal facility authorised to receive waste. • Disposal of fuels and regulated waste to an offsite disposal facility authorised to receive waste. • Remaining infrastructure decommissioned, cut and removed from site to authorised disposal facility offsite. • Removal of any liquids and chemicals prior to demolition. • Decommission of the Processing Plant and related infrastructure (e.g. conveyor) • Pipes flushed, cut, capped, and removed. • Road base removed. • Demolition and removal of powerlines to Chumvale Power Station.
RA6 – TSF	• Pipelines • Pumps • Liners	• Pipes flushed, cut, capped, and removed. • Pumps disconnected and removed from site.

Rehabilitation/Improvement Area	Built Infrastructure	Decommissioning methodology
		• Removal and disposal of seepage detection pond liner to the TSF.
RA7 – Renewable Energy Infrastructure	• Wind turbine pads and ancillary infrastructure	• All infrastructure, including turbine components, hardstands, underground and aboveground cabling will be decommissioned and removed from site.

3.5.4. Contaminated Land Assessment

A contaminated land assessment is to be completed by a suitably qualified person, at all rehabilitation areas. Any contaminated material will be removed and disposed of at a licenced facility authorised to accept such waste, where required. Validation sampling will be completed to determine if the contaminant removal has been completed appropriately.

3.5.5. Site Preparation

Water storages and the TSF will be dewatered through enhanced evaporation.

Once all infrastructure and any contaminated material has been removed, the surface will be prepared to promote establishment of vegetation. Compacted surfaces will be deeply ripped to at least 300 mm into the soil profile. The application and incorporation of ameliorants such as gypsum, lime and other organic materials will be assessed based on the outcome of soil sampling at the time of use.

3.5.6. Material Assessment

3.5.6.1. Material Quantity and Quality

The materials required to successfully rehabilitate certain mine domains include topsoil and inert material (such as NAF waste rock). These materials shall provide armour between potential contaminants and supplement the growth of vegetation, reducing erosion and helping to sustain the PMLU. Material for rehabilitation will be sourced from site at locations shown in Figure 15.

A materials balance has been created, assuming that 0.1 to 0.2 m of topsoil will be required across all RAs. The materials balance and topsoil application rates will continue to be investigated over the LOM, utilising results from ongoing rehabilitation trials and monitoring. Further investigation will occur to determine alternative growth media options.

During operations, waste rock will continue to be managed in accordance with the *DRM Management of Mineral Waste Procedure*. Mineral waste generated from the mining operations is classified as either NAF or PAF and temporarily stored within designated WRDs. The NAF waste pad can accommodate 1,550,000 m^3 of material. There is sufficient NAF to be utilised in the closure of the TSF.

A preliminary materials balance is provided in Table 32. These volumes will continue to be finalised as the mine plan is updated and rehabilitation commences. Two cover systems are currently being considered for the TSF. The material balance below considers the largest material requirement; this demand will reduce if a geosynthetic clay liner (GCL) is utilised. If required, this will be sourced by a commercial provider.

Table 32 Preliminary materials balance

RA	Area (ha)	Topsoil application depth (m)	Volume of topsoil required (m^3) (assumed 50% coverage)	Volume of topsoil required (m^3) (assumed 100% coverage)	Volume of NAF required (m^3)
RA1	19.76	0	0	0	0
RA2	43.84	0	0	0	0
RA3	32.28	0.1	16,140	32,280	0
RA4	22.56	0.1	11,280	22,560	0
RA5	180.78	0.1	90,390	180,780	0
RA6	109.88	0.2	109,880	219,760	970,470
RA7	67.07	0	0	0	0
Total			**227,690**	**455,380**	**970,470**
Available			**144,002**	**144,002**	**1,550,000**

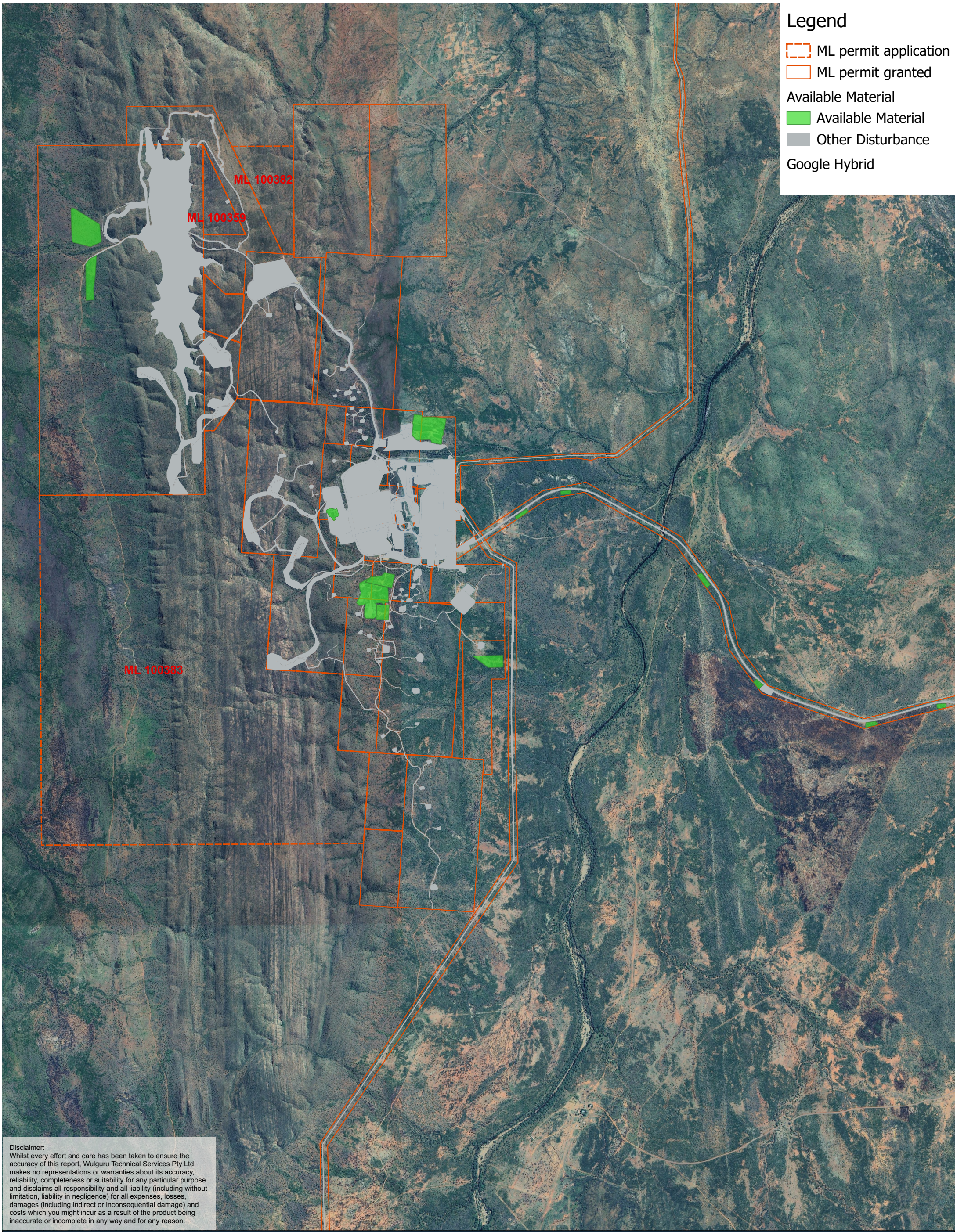


FIGURE 15. AVAILABLE MATERIALS

0.9 0 0.9 1.8 km

CRS: GDA94 / MGA zone 54
Scale: 1:35,000 @A3

Date: 4 March 2026
Author: M. Kaminski
Version: 0.05

WULGURU TECHNICAL SERVICES

Project Number: 2024.07003

Client: MMG

C:\Users\MichaelKaminski\OneDrive - Wulguru Tech Services\DugaldRiver\Dugald_Process.qgz

3.5.6.2. Topsoil Striping

Where available, topsoil was stripped during the construction phase of the project. Topsoil is currently stockpiled at locations shown on Figure 15. Approximately 17,160 m^3 of topsoil is expected to be generated from the additional features proposed within the EA amendment application subject of this PRCP amendment. Prior to new ground disturbance, topsoil will stripped and added to one of the existing stockpiles. Stockpiles are surveyed annually, and the total volume is recorded in the Topsoil Stockpile Register.

Table 33. Stockpiles topsoil volumes

Stockpile category	Description	Volume (m^3)
TsH	High quality soil, almost entirely covered by regrowth, with high species diversity.	0
TsM	Medium quality soil with moderate regrowth visible and some species diversity.	5,003
TsL	Low quality soil, combined with subsoil, with some regrowth visible.	80,858
SkS	Skeletal soil (abundant rocks) with little to no regrowth.	35,329
Vg	Predominately vegetation stockpiles	5,652
Total stockpiled		**126,842**
Additional to be accessed during proposed construction of the TSF lift and PAF expansion borrow pit		17,160
Total		**144,002**

3.5.6.3. Topsoil Stockpiling

Once stripped, topsoil is stored at a maximum height of 2 m, and only in locations that have been previously designated by site plans. A register of topsoil stockpiles is kept and maintained on-site, recording stockpile number, placement date, source location, soil type, and any relevant comments. Stockpiles are designed and located to minimise topsoil loss through runoff and erosion and are marked and identifiable with signage. Active stockpiles are inspected as part of ongoing environmental inspections.

3.5.6.4. Soil Monitoring Program

Due to the long life of the operation, the condition of the topsoil is better assessed closer to its application. An assessment will be conducted to identify the need for any soil amelioration such as fertilizer, gypsum and/or organic matter. The results of the analysis will determine if any ameliorants are required and the application rate.

A soil monitoring program will be developed for the topsoil stockpiles, prior to use, and will aim to:

- Optimise rehabilitation processes;
- Accurately measure utilisation of stockpile storage and soil reuse; and

- Identify the need and rate of soil amelioration.

Samples will be acquired and analysed at an accredited laboratory. The analytes proposed to be tested are detailed in Table 34. This analysis program may be amended, as additional information is made available from the rehabilitation trials and ongoing monitoring.

Table 34. Analysis parameters for the soil monitoring program

Parameter	Purpose	Target values	Treatment
pH	Identify variations that may inhibit plant growth and sustainability.	5.5 – 8.0	Higher alkaline and acidic soils may have low nutrient levels. Lime or dolomite can be applied to treat the soil.
EC and Chloride	Identify areas that may inhibit germination and establishment.	<1 mS/cm	Plant adaptive species which can withstand conditions.
Exchangeable Sodium percentage (ESP)	The percentage of exchangeable cation capacity of the soil occupied by sodium	Loams <6% Clays <15%	ESP can be reduced by use of Gypsum.
Exchangeable cations	Links to soil stability, fertility, nutrient availability, and structure.	N/A	N/A
Organic carbon	Indicates soil nutrient stores and soil structure. Variations can indicate successfulness.	N/A	N/A
Major elements including N, P, K, S, Ca, and Mg.	Indicator of nutrients and potential for runoff or acid Metalliferous drainage.	N/A	N/A
Trace elements including Mn, Fe, Zn, and Cu	All are important to the vegetation success.	N/A	N/A
Metals	Metals that have been identified as occurring at elevated levels during material characterisation should be tested for during monitoring.	N/A	N/A
Physical parameters	Soil texture and other characteristics will affect water entry and storage as well as impact on erosion, dispersion, and success.	N/A	N/A

Parameter	Purpose	Target values	Treatment
Field analysis	Gain an understanding of soil profile characteristics for interpretation purposes.	N/A	N/A

3.5.6.5. Topsoil Application

The Project is partially located on the rocky scarps of the Knapdale Range. The Knapdale soil management unit and Miners soil management unit is described as being shallow rocky soils. Similarly, the Red Plains, Prospectors and Pocket soil management units are described as being shallow soils.

Disturbances located on the Knapdale Range will be ripped and seeded with no topsoil application. Where required, topsoil will be applied at high risk areas such as the TSF and processing areas. Topsoil will be placed in strips approximately 5 m in width, 0.1 – 0.2 m deep to maximise application.

If required, additional topsoil will be sourced from a commercial supplier.

3.5.6.6. Soil Loss

A tolerable soil loss rate is an acceptable soil loss that does not impede on long term soil productivity. Currently there are no acceptable erosion rates defined for rehabilitated lands. An erosion target of a mean average annual erosion rate of 5 t/ha/year and a mean maximum annual rate at any one point of 10 t/ha/year is commonly referred to as an acceptable rate to prevent rilling. It is noted that these rates are based on studies completed in the Pilbara, Western Australia (Loch, 2019) and may not be relevant to North Western Queensland.

Continent scale study results indicate that the current annual average erosion rates in the vicinity of the Project are greater than 10 t/ha/year and potentially in the range of 20 – 50 t/ha/year. This high erosion rate is due to the intense rainfall and semi-arid climate and soils of Northern Queensland.

Erosion modelling has been completed on the TSF, being the only mine structure to be retained. The modelling indicates that the TSF can achieve an erosion rate of between 1 t/ha/year and 13 t/ha/year, depending on the percentage of vegetation cover. A tolerable soil target for the Project has been defined as a mean average annual erosion rate of 5 t/ha/year and a maximum annual rate at any one point of 10 t/ha/year. This is suitable, given the following factors:

- Continental scale mapping for the region;
- Proposed PMLU of native vegetation and habitat on the TSF; and
- Removal and disposal of residual contaminants from other RAs.

Additionally, the risk of erosion will be minimised with a secondary rehabilitation milestone of “absence of erosion rills >30 cm”.

3.5.6.7. Erosion and Sediment Control

Erosion and sediment control measures will be implemented in accordance with the Best Practice Erosion and Sediment Control, published by the Australasian International Erosion Control Association (IECA). Revegetation will minimise erosion and act as a sediment control, and ensure landforms are both geochemically and physically stable.

Effective erosion and sediment control structures were installed during the operational phase of the project. An allowance has been made to retain four additional sediment controls post mine closure, with some minor earthworks required to ensure these controls are safe and effective. The site runoff dam is the primary sediment control on the Project. Site affected water will continue to be directed to this structure whilst closure activities are in progress. Once upstream features have successfully revegetated, the runoff dam will be rehabilitated.

Erosion and sediment control plans will be considered when conducting rehabilitation activities, and should include the following:

- Contours and drainage lines;
- Disturbance limits;
- Earthwork extents;
- Control measure locations;
- Order of work schedule;
- Construction details and notes; and
- Specific operating procedures.

3.5.7. Revegetation Plan

3.5.7.1. Low Intensity Grazing

The revegetation objectives for the following RAs are to achieve a PMLU of low intensity grazing that is safe, stable non-polluting and self sustaining:

- RA2 Borrow pits and stockpiles
- RA3 Dams and diversion structures
- RA4 Mineralised waste
- RA5 Mining and processing area

Once revegetation has occurred, rehabilitation areas will be secured to prevent cattle access whilst vegetation establishes. Cattle will only be permitted to graze once the achievement of surface requirements (RM13) have been achieved. Fire breaks will be maintained and weed management controls will be implemented as required, to ensure success of revegetation.

3.5.7.1.1. Seed Mix

The Project is located within the Southern Gulf Land Management Region, with the infrastructure areas within pastureland C2 land class. This class is defined as suitable for grazing native pastures, with or without the introduction of pasture species and within low fertility soils.

All soil units have very low plant-available water, erosion potential and limited nutrient availability. Grazing on unimproved pastures requires the establishment of an ecosystem to support sustainable productivity. Vegetation surveys confirm that disturbance areas are predominantly located within RE 1.11.3a and 1.11.2a. The native shrub and tree species have been selected from these REs to provide necessary stability during drought and fix nitrogen to allow productive pasture without external inputs such as fertiliser.

A species mix for revegetation (Table 35) has been developed based on these REs to maximise the success of the PMLU of grazing. Locally sourced seeds will be prioritized to optimise success. When possible, areas will be seeded directly with selected species. Where direct seeding is not possible, seeds will be manually broadcast.

Rehabilitation areas will be fenced to prevent access to cattle whilst vegetation establishes. Cattle will only be permitted to graze once the achievement of surface requirements (RM13) has been achieved. Fire breaks will be maintained and weed management controls will be implemented as required, to ensure success of revegetation.

Table 35. Grazing seed mix

Rehabilitation Area	Ground cover	Shrubs	Trees
RA2, RA3, RA4, RA5	*Triodia pungens* Appropriate 3P grass species to support the PMLU	*Acacia chisholmii* *Carissa lanceolata*	*Eucalyptus leucophloia* *Corymbia Capricornia* *Corymbia terminalis* *Eucalyptus pruinose* *Eremophila longifolia* *Atalaya hemiglauca* *Terminalia aridicola*

3.5.7.2. Native Ecosystem

Native ecosystem is the target PMLU for the following RAs:

- RA1 Ancillary infrastructure and services
- RA6 TSF
- RA7 Renewable energy infrastructure

Native ecosystem has been proposed for these RAs due to the steep terrain of the Knapdale Range. Revegetation will target the historic ecosystem, being REs 1.11.2 and 1.11.3.

3.5.7.2.1. Seed Mix

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. Native flora consistent with the descriptions for REs 1.11.2 and 1.11.3 is proposed for the vegetation of the TSF. Treeless areas of both 1.11.2 and 1.11.3 are common throughout the REs' ranges, and across the proposed TSF area. In addition to the species identified in Table 36, sterile cover crops may be utilised to provide rapid soil stabilisation and improve soil health.

Table 36. Native ecosystem seed mix

Rehabilitation Area	Ground cover	Shrubs	Trees
RA1	*Aristida latifolia* *Eriachne obtusa,* *Sporobolus australasicus,* *Themeda triandra* *Triodia pungens*	*Acacia chisholmii,* *Senna notabilis,* *A. chippendalei,* *A. holosericea,* *Gossypium australe*	*Eucalyptus leucophloia* *Corymbia terminalis* *Corymbia capricornia*
RA6	*Aristida latifolia* *Eriachne obtusa* *Sporobolus australasicus* *Themeda triandra* *Triodia pungens*	Nil	Nil
RA7	*Aristida latifolia* *Eriachne obtusa,* *Sporobolus australasicus,* *Themeda triandra* *Triodia pungens* Plus other suitable wetland groundcover species in riparian vegetation zones.	*Acacia chisholmii,* *Senna notabilis,* *A. chippendalei,* *A. holosericea,* *Gossypium australe*	*Eucalyptus leucophloia* *Corymbia terminalis* *Corymbia Capricornia* *Eucalyptus camaldulensis* *Melaleuca species* *Lophostemon species*

3.5.7.3. Revegetation Method

Surfaces will be prepared for vegetation, by ripping compacted surfaces and applying topsoil, where relevant. Ameliorants will be applied if determined to be required by the soil monitoring program (Section 3.5.6.4).

Revegetation methods used will be based on the RA position in the landscape and may include one or more of the following methods:

- Return from topsoil;
- Hand or broadcast seeding;
- Mechanical seeding;
- Drone or other aerial seeding techniques; or
- Manual tube stock planting.

A single application of fertiliser will be applied during seed application. Where possible, vegetation works will be completed prior to the onset of the wet season. The proposed seed mix has been selected as suitable for the regional climate. Permanent irrigation infrastructure is not proposed to be constructed. However, rainfall in revegetated areas will be monitored closely in the six to 12 months post seeding to determine if supplementary watering is required.

Other management actions to be considered based on the response of RA to the seeding activities include:

- The exclusion of cattle and other herbivores, via temporary measures;
- Pest and weed management; and
- Supplementary seeding and/ or fertilisation.

Supplementary planting will be conducted if monitoring indicates a risk of relevant rehabilitation milestones not being achieved.

3.5.7.4. Application Rate

Application/planting rates are generally based on a number of factors including:

- Structure of the target vegetation community, i.e. the presence of tree and shrub layers;
- Density of the target vegetation community, i.e. the typical basal area of the climax community - woodland or forest;
- Seed size; and
- Surface requirements, i.e. erosion control for sloped surfaces.

A seeding rate of 4 -10 kg/ha is provided as a guide; rates will be considered in conjunction with supplier recommendations at the time of rehabilitation and informed by ongoing monitoring during the LoM.

3.5.7.5. Weed Management

A desktop review of local biosecurity plans, and spatial analysis identified weed and pest species with the potential to occur within the Project area (Table 37).

Weed hygiene practices will continue to be implemented at all stages of operation and closure. All mobile plant, machinery, heavy vehicles and earthmoving equipment will be inspected upon entry to site. If weeds or seeds are identified, vehicles and equipment will be cleaned in the site washbay.

Weed density will be monitored as part of rehabilitation monitoring, and appropriate treatment controls will be implemented as required. Weed treatment will integrate manual, mechanical, fire, grazing, and herbicide control measures and will be conducted in accordance with the *Accepted Development Vegetation Clearing Code: Managing Weeds* (2023), developed by the Department of Resources. Control methods described in Table 37 may be applied individually or in combination, at the discretion of a suitable qualified person. It is anticipated that the focus of the weed control program would be the management of Cabbage Tree (*Calotropis procera*) due to its potential toxic effect on grazing cattle.

Table 37. Weed and pest species

Species	Legislative Status	Priority
Weeds		
Athel Pine (*Tamarix aphylla*)	WONS; Cat 3; Class 3: Locally Declared	1
Bellyache bush (*Jatropha gossypilifolia*)	WONS; Cat 3; Class 2	1
Hymenachne (*Hymenachne amplexicaulis* & hybrids)	WONS; Cat 3; Class 2: Locally Declared	1
Lantana (*Lantana camara*)	WONS; Cat 3; Class 2: Locally Declared	1
Mesquite (Prosopis sp)	WONS; Cat 3; Class 2: Locally Declared	1
Mother of Millions (*Bryophyllum delogoense*)	WONS; Cat 3; Class 2: Locally Declared	1
Parkinsonia (*Parkinsonia aculeata*)	WONS; Cat 3; Class 2: Locally Declared	1
Parthenium (*Parthenium hysterophorus*)	WONS; Cat 3; Class 2: Locally Declared	1
Prickly Acacia (*Acacia nilotica*)	WONS; Cat 3; Class 2: Locally Declared	1
Rubbervine (*Cryptostegia grandiflora*)	WONS; Cat 3; Class 2: Locally Declared	1
Salvinia (*Salvinia molesta*)	WONS; Cat 3; Class 1&2; Locally Declared	1
Siam Weed (*Chromolaena odorata*)	Cat 3; Class 1; Locally Declared	1
Agave (Agave spp)	Locally Declared; Unregulated	2
Awnless barnyard grass (*Echinochloa colona*)	Locally Declared; Unregulated	2
Bathurst Burr (*Xanthium spinosum*)	Locally Declared; Unregulated	2
Calotrope (*Calotrpis procera*)	Locally Declared; Unregulated	2
Castor Oil Plant (*Ricinus communis*)	Locally Declared; Unregulated	2
Chinee Apple (*Zizphus mauritiana*)	Cat 3; Class 2; Locally Declared	2
Colocynth (*Citrullus colocynthis*)	Locally Declared; Unregulated	2
Coral Cactus (*Culindropuntia fulfida* var. mamillata)	Cat 3; Class 2; Locally Declared	2
Gamba Grass (*Andropogon gayanus*)	Cat 5; Class 2; Locally Declared	

Species	Legislative Status	Priority
Giant Rat's Tail Grass (*Sporobolus pyramidalis*, S. natalensis)	Cat 3; Class 2; Locally Declared	2
Grader Grass (Themeda spp.)	Locally Declared; Unregulated	2
Harrisia Cactus (*Harrisia's martini, tortuosa* & *pomanensis*)	Cat 3; Class 1&2; Locally Declared	2
Leucaena (*Leucaena leucocephala*)	Locally Declared; Unregulated	2
Milk Weed (*Euphorbia heterophylla*)	Locally Declared; Unregulated	2
Mimosa Bush (*Vachellia farnesiana*)	Locally Declared; Unregulated	2
Neem Tree (*Azadirachta indica*)	Locally Declared; Unregulated	2
Noogoora burr (*Xanthium occidentale*)	Locally Declared; Unregulated	2
Porcipine Flower/ Barleria (*Barleria prionitis*)	Locally Declared; Unregulated	2
Sicklepods (Sicklepod *Senna obtusifolia*, foetid senna, *Senna tora* and hairy senna, *Senna hirsuta*)	Cat 3; Class 2; Locally Declared	2
Water Hyacinth (*Eichhornia crassipes*)	Cat 3; Class 2; Locally Declared	2
Yellow Oleander (*Cascabela thevetia*)	Cat 3; Class 3; Locally Declared	3
Pests	**Legislative Status**	**Priority**
Cane Toad (*Bufo marinus*)* *	Class 1; Locally Declared	1
Chital Deer (*Axis axis*)	Cat 3,4&6; Class 1&2; Locally Declared	1
Feral Cat (*Felis catus* & *Prionailurus bengalensis* x *Felis catus*)	Cat 3, 4 &6; Class 1&2; Locally Declared	1
Feral Goats (*Capra hircus*)	Cat 3, 4 &5; Class 1&2; Locally Declared	1
Feral Pig (*Sus scrofa*)	Cat 3,4 &6; Class 1&2; Locally Declared	1
Feral Rusa Deer (*Cervus timorensis*)	Cat 3,4&6; Class 1&2; Locally Declared	1
Wild dog (*Canis familiaris* & C. *familiaris dingo*)	Cat 3,4, 5*&6 ; Class 1&2 ; Locally Declared	1
Foxes (*Vulpes vulpes*)	Cat 3,4,5 & 6; Class 2; Locally Declared	2

Table 38. Weed control techniques

Management Technique	Description and Applicability
Mechanical control	Mechanical control involves the use of powered tools and machinery to manage weeds. Mechanical control can include slashing with tractors or mowers, felling, pulling, or dragging with bulldozers, or grading the top layer of soil. Mechanical control is ideal for larger infestations as it reduces manual effort.
Manual removal	Manual removal of weeds using handheld tools such as a mattock or hoe. Manual removal may also include pulling weeds by hand and is therefore more suitable for smaller areas. This method is best applied to areas where the species have only recently started to occur or at the end of an intensive treatment regime where there are only isolated plants occurring.

Management Technique	Description and Applicability
Foliar spraying	Foliar spraying is where a herbicide is diluted with water or diesel at a specific rate and sprayed over the foliage until every leaf is wetted, but not dripping. Suitable for shrubs, grasses and dense vines less than 6 m tall so that complete coverage is achieved. Advantages include speed of application and economy. Disadvantages include the potential for spray drift and off-target damage. Methods include blanket spraying using a boom spray mounted on a vehicle or spraying with a handgun connected by a hose to a herbicide tank and pump, carried by a tractor or vehicle. Smaller infestations can be sprayed using a backpack/knapsack spray unit. Foliar spraying should not be used during rainfall, or when rainfall is forecast in the proceeding 6 hours, to prevent run-off.
Cut stump	The cut stump method is where the plant is cut off completely at its base (typically no higher than 15 cm from the ground) using a chainsaw, axe, brush cutter or machete (depending on the thickness of the stem/trunk). Herbicide is then sprayed, squirted or painted on to the exposed surface of the cut stump emerging from the ground, killing the stump and the root system.
Basal bark spray	Basal bark spraying is where an oil-soluble herbicide is mixed with diesel and sprayed around the full circumference of the trunk or stem of the plant. This is suitable for plants with basal diameters up to 10 cm and heights of 30 to 100 cm with thin-barked woody weeds and undesirable trees. This is also effective to treat saplings, regrowth and multi-stemmed shrubs and weeds in inaccessible areas such as steep banks.
Fire control	Some weeds are fire-sensitive (fire will either destroy or suppress them). However, the susceptibility of plants to fire varies greatly. In some cases, fire is used to destroy the weed, in other cases it is used to get access to the weed. If required, controlled burns would be undertaken in accordance with the fire regimes specified for each respective regional ecosystem within the Queensland Herbarium Regional Ecosystem Fire Guidelines (2024).

3.5.8. Water Management

3.5.8.1. Stormwater Management

The operational water management strategy for the Project aims to separate clean stormwater from potentially affected site water. The water management objectives for closure are:

- Remove all unnecessary infrastructure and hard stand areas at closure. This will reduce overall runoff and peak flows, reducing downstream flood risk, as well as limiting erosion risk.
- Infill and regrade dams such that they do not hold water post closure.
- Remediate ground areas to naturalise flows and install flow reduction measures (such as swales) where required. Any installed infrastructure should be as simple as possible, requiring minimal ongoing monitoring and maintenance.
- Revegetate cleared or disturbed areas. This will help to slow runoff, promote infiltration, and reduce sediment runoff and erosion risk.

- Naturalise drainage channels and connect site drainage to downstream watercourses (ATC Williams, 2025).

The following closure strategy will be implemented:

- Infrastructure and hardstand areas will be removed.
- Any contaminated soil will be removed and placed within the TSF.
- Surfaces will be trimmed and graded.
- Surfaces will be revegetated.
- Site drainage will be reconnected to natural upstream and downstream watercourses.

A site wide final landform with surface water flows is provided in Figure 16 to Figure 21. Further detail is provided in Appendix K. Ongoing monitoring of TSF seepage rates and quality, along with regular surface and groundwater monitoring will guide further works, if required. Contaminated land validation sampling will verify that contaminated material has been removed or if additional work is required to prevent the release of contaminants to waters.

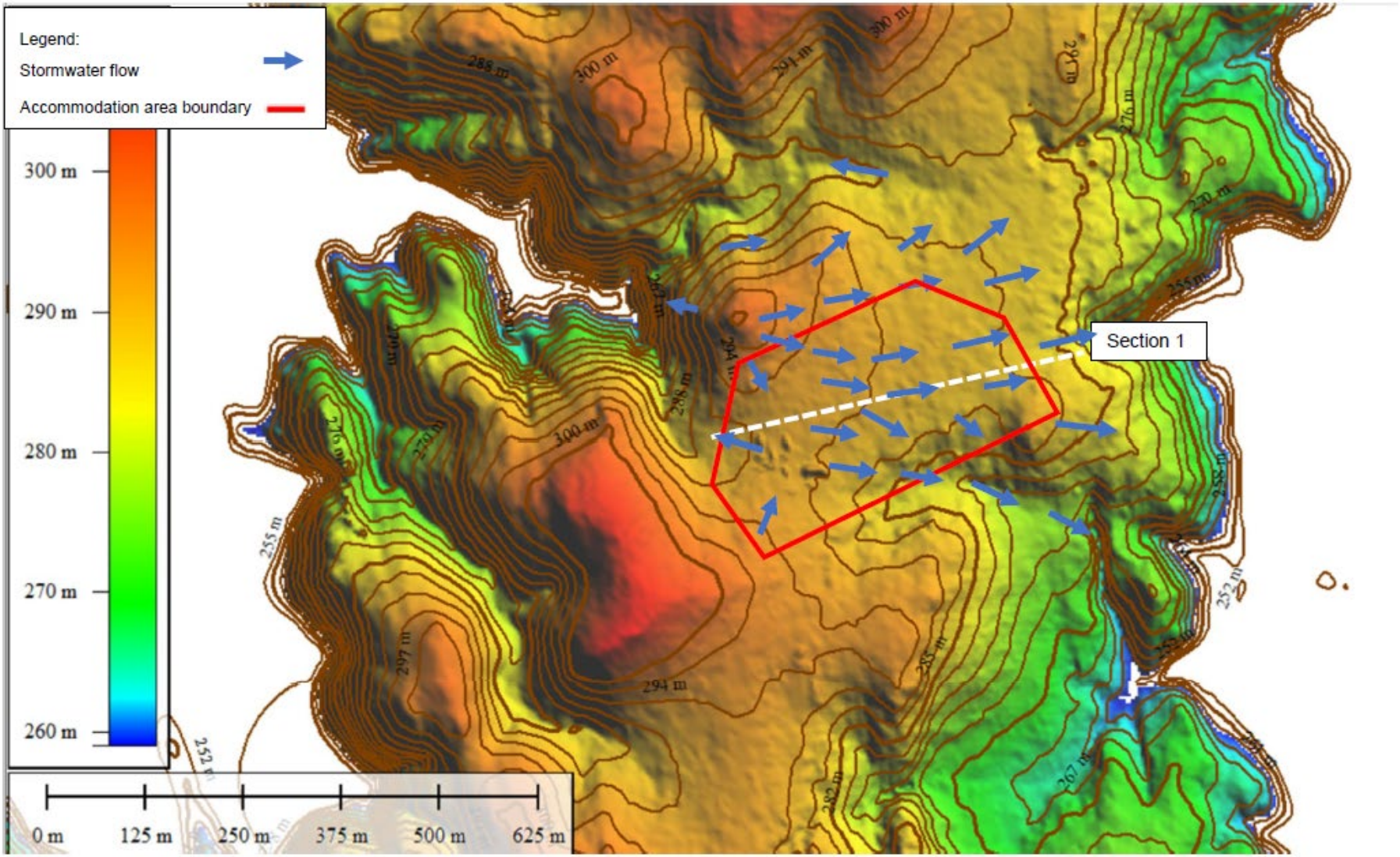


Figure 16. Closure landform surface and stormwater accommodation area (ATCW, 2025c)

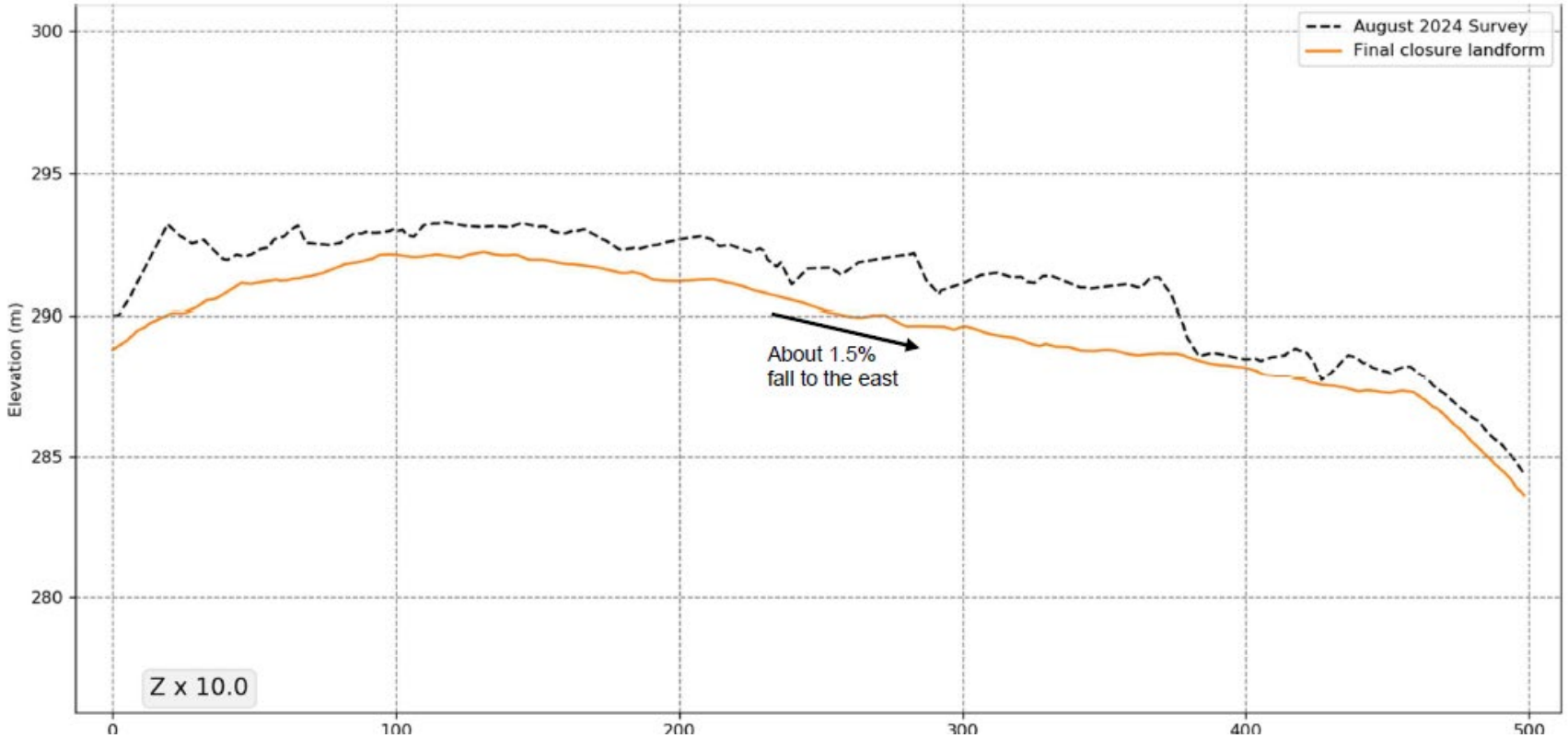


Figure 17. Closure landform surface and stormwater accommodation area cross section (ATCW, 2025c)

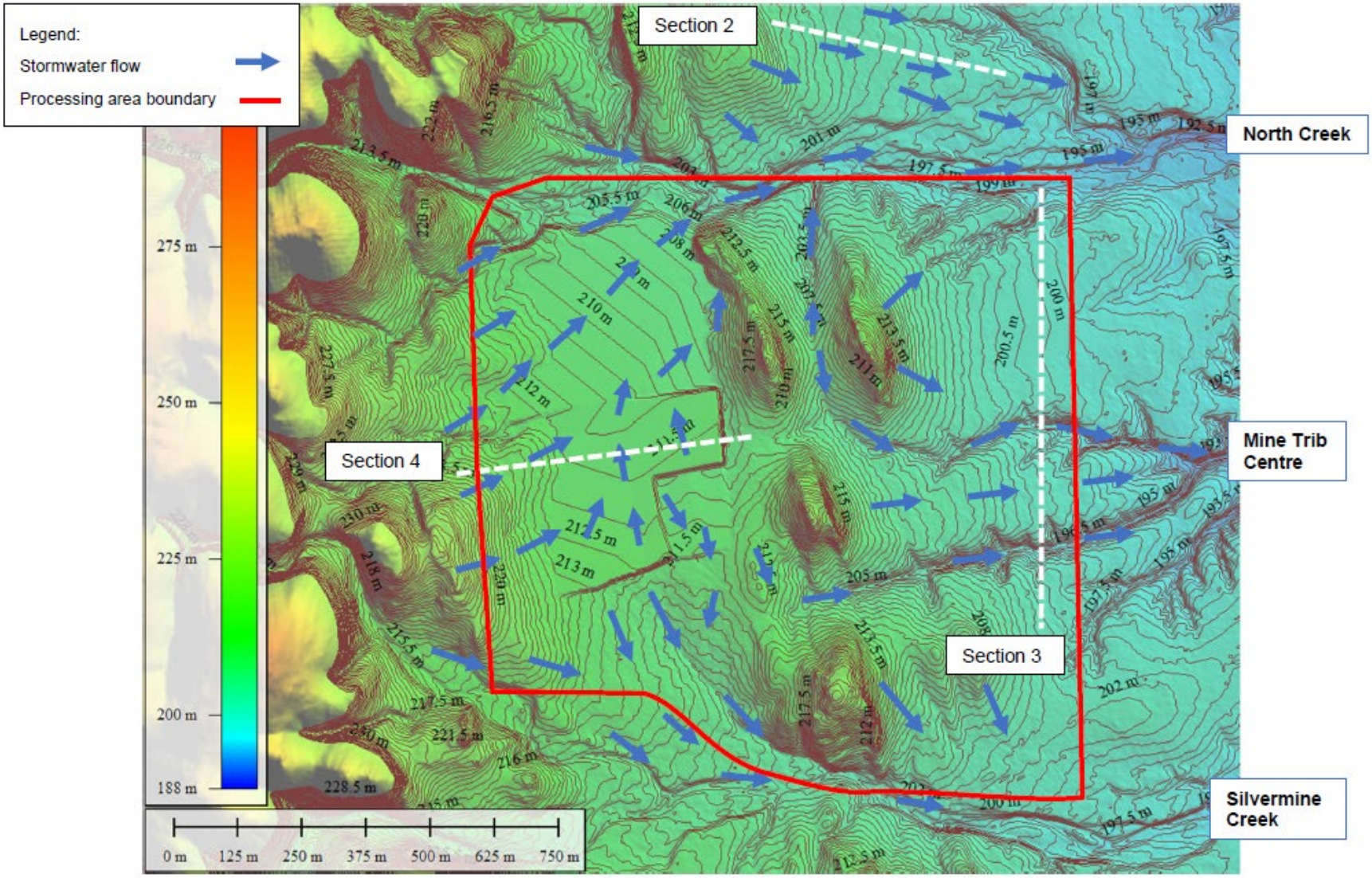


Figure 18. Closure landform surface and stormwater accommodation area (ATCW, 2025c)

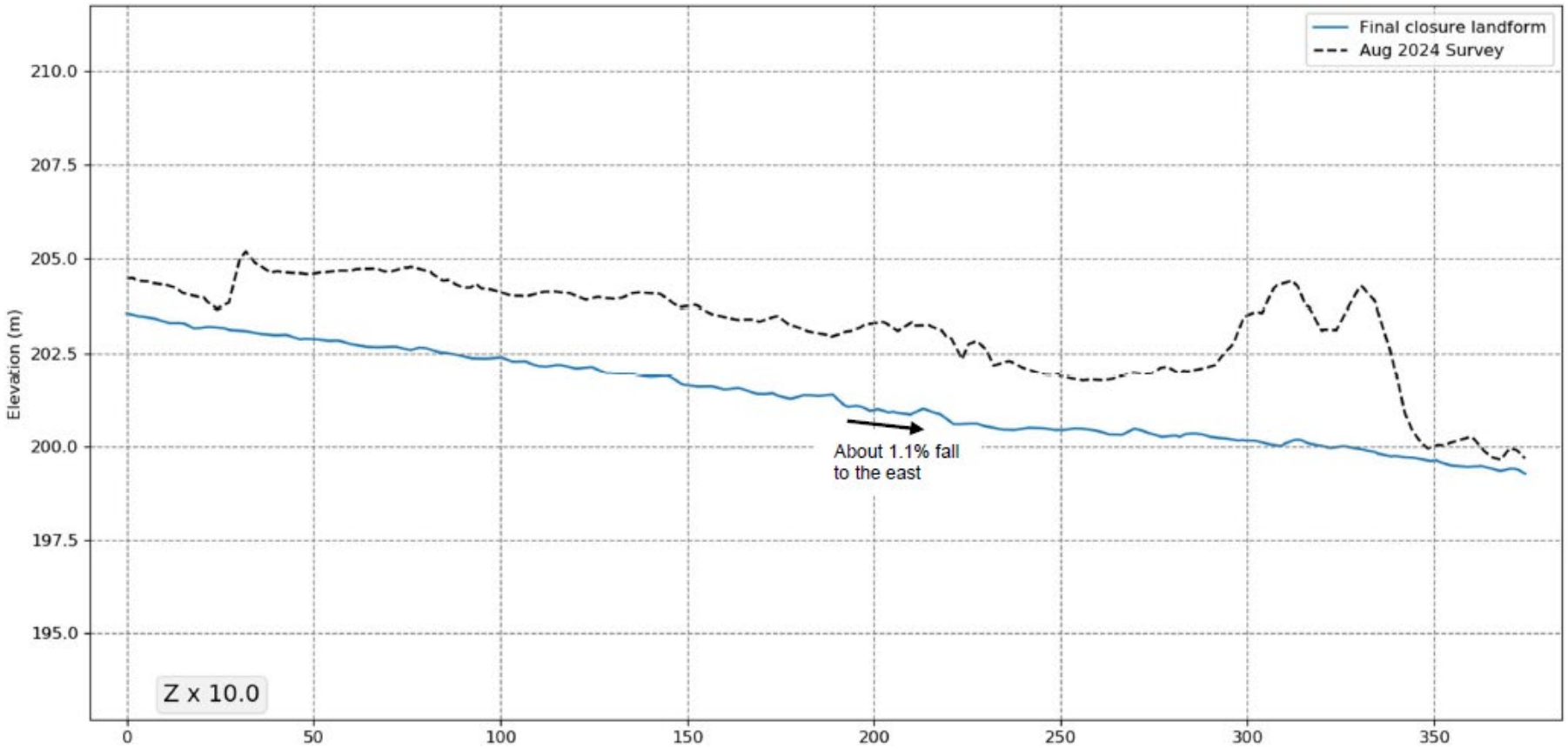


Figure 19. Closure landform surface and stormwater accommodation area cross section (ATCW, 2025c)

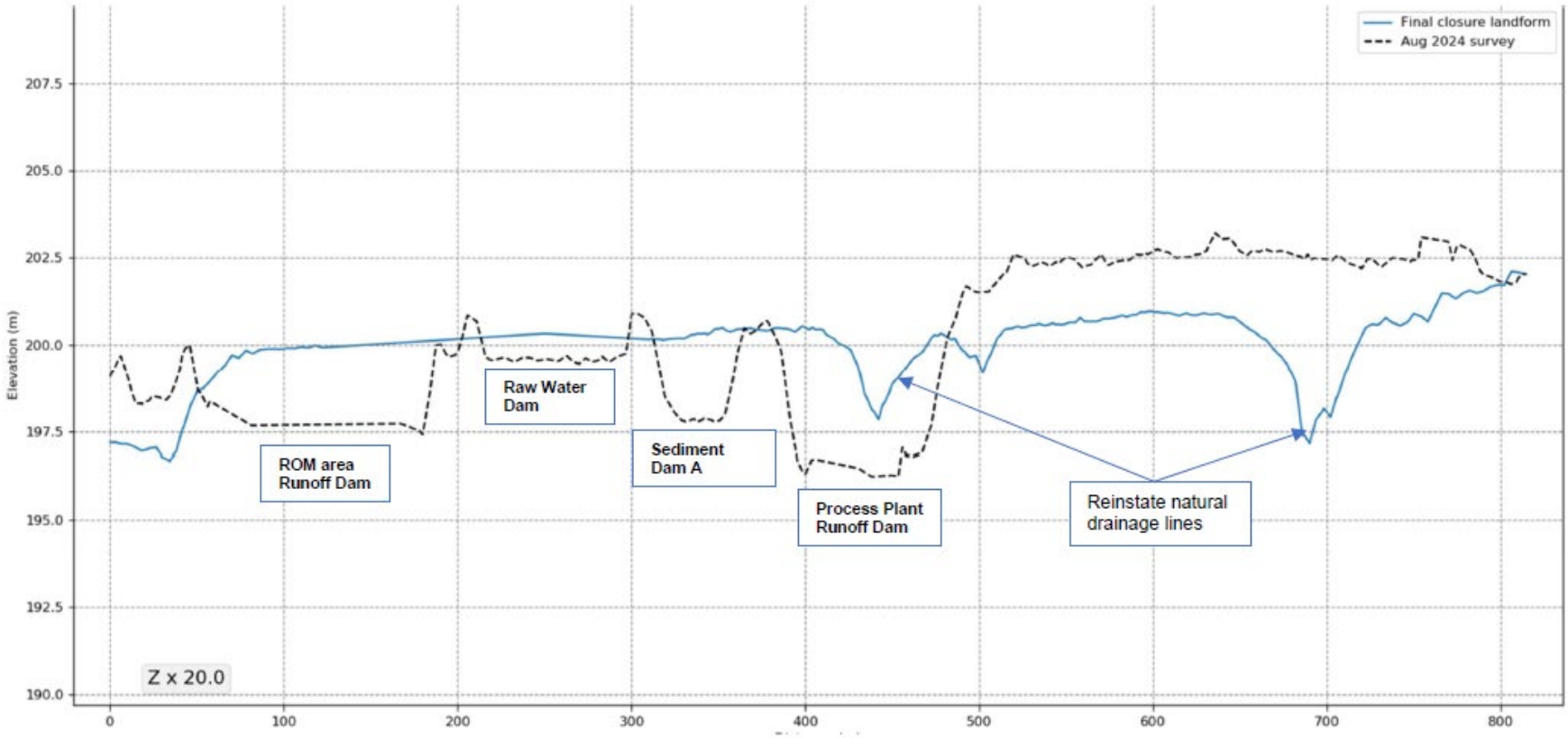


Figure 20. Closure landform surface and stormwater processing area cross section (ATCW, 2025c)

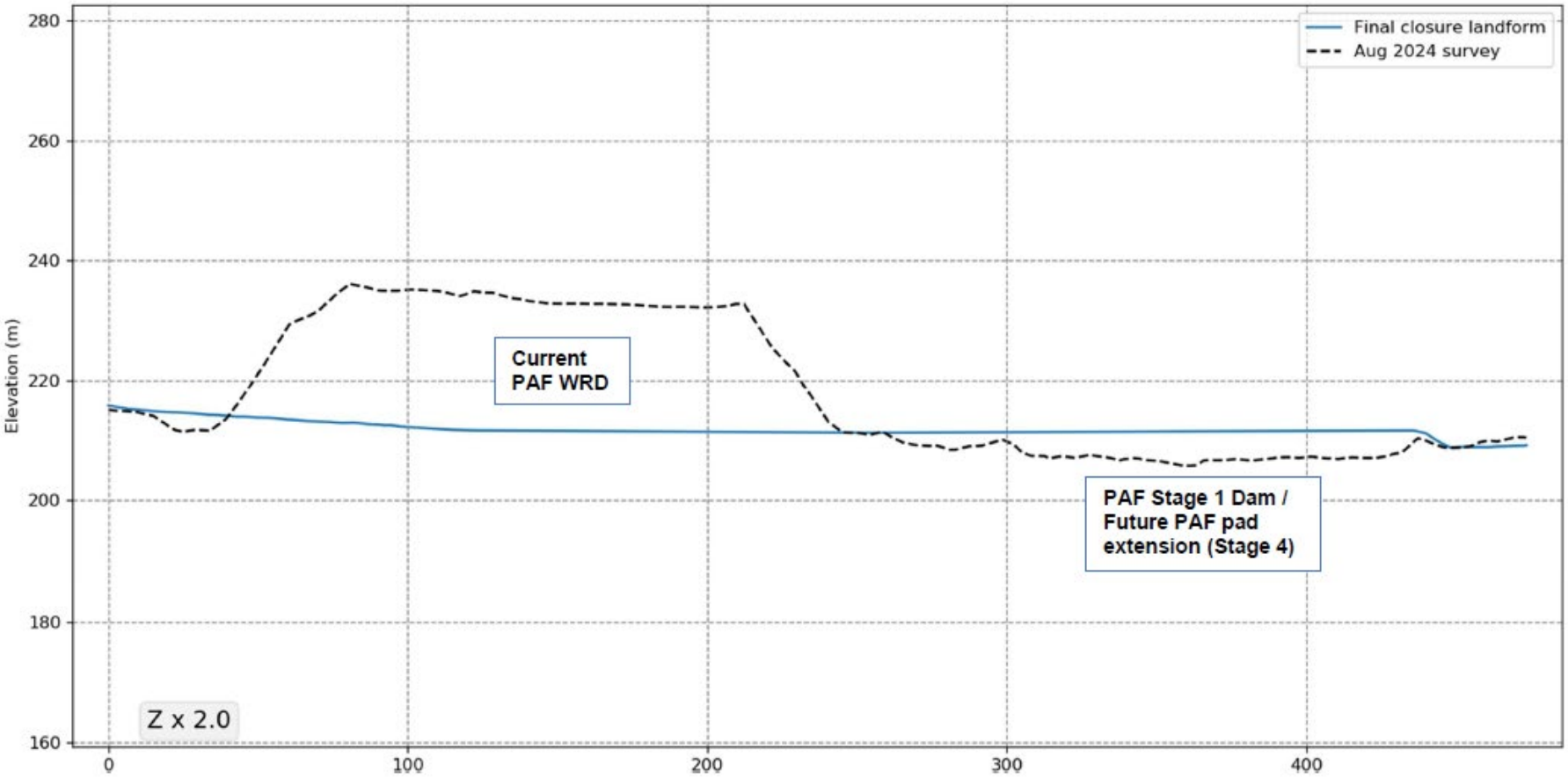


Figure 21. Closure landform surface and stormwater waste storage area cross section (ATCW, 2025c)

3.5.8.2. Closure Water Balance

Water balance modelling was conducted to determine the volume of water requiring management at closure. The model assumed that all water requiring containment would be pumped to the TSF for evaporation.

The results of the modelling are shown in Table 39. Due to the large volumes of water expected to require management on closure, intervention is likely (i.e. enhanced evaporation). Modelling identified that the use of mechanical evaporation would empty the TSF and contributing water storages 2.5 years after closure (2046). This dewatering timeline has been incorporated into the PRC schedule.

Table 39. Water management volumes

Purpose	Storage	Management Strategy	Volume at Closure (ML)	
			Median	10^{th} – 90^{th} percentile
Clean water dams	Raw water dam	Release	28.3	28.3 – 28.3
Sediment dams	Mine Workshop Runoff Dam	Release	0.0	0.0 – 1.4
	Sediment dam A		0.5	0.1 – 2.7
	Sediment dam C		0.0	0.0 – 1.0
	Sediment dam D		0.0	0.0 – 1.2
	Sediment dam F		0.1	0.0 – 3.0
	Sediment dam G		0.0	0.0 – 0.7
Total volume available to release			29	27 – 38
Mine water management	Process Plan Containment Dam	Contain/treat	0.2	0.0 – 1.4
	Process Plant Runoff Dam		0.7	0.1 – 6.2
	ROM Area Runoff Dam		3.2	1.9 – 9.3
	Underground Mine Water Containment Dam		3.3	3.2 – 3.3
Stockpile runoff	PAF pond stage 2	Contain/treat	54.9	39.8 – 74.6
STP containment	STP Dam 1	Contain/treat	0.3	0.1 – 1.0
	STP Dam 2		14.5	2.5 – 27.5
Tailings management	TSF Decant Pond	Contain/treat	2.751	1,829 – 3,882
	Seepage Collection Pond		0.2	0.1 – 0.2
Total volume required to contain or treat prior to release (ML)			2,828	1,877 – 4,006
Total combined volume (ML)			2,857	1,905 – 4,044

3.5.8.3. Flooding

Flood modelling completed for the project indicates that the mining operations and infrastructure are located above the Dugald River and Silver Creek 100-year ARI flood levels (WRM, 2010). Whilst the operations would not be impacted by flooding, the main access road from the Burke Developmental Road is susceptible to flooding at four locations. Due to the design of the crossings, the road would be overtopped whenever a significant runoff event occurs. The risk of flooding is not expected to impact upon the success of rehabilitation activities.

Flood mapping (ATC Williams, 2021) shows that the mine portals are not located below the 0.1% AEP flood level and are therefore not located within the floodplain. Further, both portals are at very low risk from flooding. The North Portal and the South Portal are not subject to inundation in any events up to and including the probable maximum flood (PMF). Additionally, the mine portals will be capped at closure, to prevent water entering the mine workings.

Post closure, the TSF will be the only remaining built landform, although this will be capped with surface drainage directed towards the spillway. The preliminary design has adopted a self-shedding cover system, with the main embankment flattened to a nominal 1V:6.5H to stabilise the embankment long-term and eliminate water ponding within the TSF. The Stage 2 spillway will be reinstated as the surface water outlet at closure. A spillway channel will be added, to achieve the following:

- Prevent water from ponding against the upstream face of the embankment;
- Prevent flow over the top of the embankment;
- Divert flows away from the toe of the embankment; and
- Reconnect catchment flows with the downstream watercourse.

The flood modelling demonstrates that the proposed spillway design is suitable to safely convey events up to and including the PMF. Additional engineering design activities will be undertaken to ensure the spillway channel accommodates the peak flood flow velocity (predicted to be 6.2 m/s) so as to achieve a stable spillway condition.

There are no voids or water containment structures proposed to be retained on closure, therefore there is no risk of flooding of such structures.

The flood modelling is presented in Appendix F.

3.5.9. Subsidence Management

The Project employs a sub level open stope mining method with both cemented and rock backfill. This method increases the long-term stability of the mine and ensures consolidation of voids.

DRM completed a geotechnical study (Appendix G) on surface subsidence risk and the implications for closure. The study found that the risk of surface subsidence is low. The Project has a shallow weathering profile and shallow ground water, therefore there is minimal influence of groundwater on the underground stability and crown pillar stability (MMG, 2020). All stopes extracted underground have limited stope strikes and are cable bolted to increase the short-term stability and are all backfilled with either waste rock or cemented backfill to ensure long term stability and confinement of voids to prevent long term subsidence (MMG, 2020). Surface subsidence will continue to be monitored throughout the life of the operations.

3.5.10. Waste Structures

3.5.10.1. Waste Rock Dumps

3.5.10.1.1. Waste Rock Characterisation

Geochemical characterisation has been undertaken on DRM waste rock and to determine the potential for generation of sulphate-rich neutral mine drainage. Studies were conducted on drill core samples by Minenco Pty Ltd in 1991, AARC in 2008, and EGi in 2010, with a cumulative 211 samples across the seven lithologies (Table 40).

3.5.10.1.1.1. Methodology

The initial study (Minenco, 1991) involved the assessment of the acid forming potential of 18 drill core samples and five samples within the Zn/Pb lode. A second investigation (AARC, 2008) included geochemical analysis of 121 drill core samples and the establishment of a series of kinetic leach column tests. The testing programs for both studies included measurements of:

- Existing pH and conductivity;
- Total sulphur content;
- Acid neutralising capacity (ANC); and
- Net acid producing potential (NAPP).

Multi element assays were also carried out on all samples in the 1991 study and half the samples in the 2008 study.

In the most recent geochemical study, 72 drill cores were sampled. Samples underwent static geochemical testing to evaluate the risk associated with the potential oxidation of sulphides, acid generation, and the presence of metals/metalloids and salts. Static analysis included the following analytes:

- Existing pH and conductivity;
- Total sulphur content;
- Maximum potential acidity (MPA);
- Acid neutralising capacity (ANC);
- Net acid producing potential (NAPP); and
- Net acid generation (NAG) capacity.

More detailed analyses were completed on selected samples to clarify acid rock drainage (ARD) classifications, assess sulphide or carbonate reactivity, and identify elemental enrichments and their potential leachability. A full description of the sampling methodology is presented in Appendix H.

3.5.10.1.1.2. ARD Classification

The ARD classifications of the 18 waste rock samples from the 1991 study were based solely on NAPP values. For all other samples, the ARD classifications were assigned on both NAPP values and net acid generation (NAG) capacity. ARD classifications are defined in Table 40. In summary, PAF waste rock from within the lode will have a high to very high capacity for acid generation. NAF waste rock is expected to be neutral to moderately alkaline.

Table 40. ARD classification of DRM waste rock (EGi, 2010)

Lithology	Number of samples	PAF	NAF
Calc-silicate	31	0 (0%)	31 (100%)
Mafic feldspar porphyry	7	0 (0%)	7 (100%)
White mica schist	17	2 (12%)	14 (88%)
Hanging wall slate	52	28 (54%)	24 (46%)
Lode waste	18	13 (72%)	5 (28%)
Footwall slate	44	9 (20%)	35 (80%)
Footwall limestone	42	1 (2%)	41 (98%)

3.5.10.1.1.3. Elemental Analysis

Elemental analyses of selected samples were carried out to identify any enrichments that might impact the quality of mine water and waste dump seepage. No significant metal or metalloid enrichments were identified in the calc-silicate, mafic feldspar porphyry and white mica schist but many of the hanging wall slate, footwall slate and lode waste samples were highly enriched with one or more of a range of environmentally important elements on comparison to concentrations typically occurring in background soils (EGi, 2010). The most prevalent enrichments were arsenic, cadmium and zinc. There was also less frequent enrichment with copper, lead, mercury, and selenium (EGi, 2010). Leach tests identified that releases of these elements were confined to PAF waste rock. NAF waste rock is not expected to release metals.

3.5.10.1.2. Identification of Waste Rock

Waste rock material is initially classified by the MMG Geologist using both the geological model and the limestone wireframe. Following firing and stockpiling of waste, the MMG Geologist inspects the material and confirms the initial classification as either NAF or PAF. Classified waste rock not required for use as backfill underground is transported to the surface for placement in the appropriate WRD. Once in the dump, the waste rock is again sampled to verify the classification. This ensures that the material has been placed in the correct location.

3.5.10.1.3. Waste Rock Dump Design

The PAF waste rock dump areas are used for the temporary storage of PAF and high sulphur NAF, until the material can be returned underground for stope fill. The PAF waste rock dumps were constructed with a 1 m layer of compacted low sulphur NAF waste rock at the base of the dump, to

prevent infiltration of contaminants to groundwater. The Stage 4 extension to the PAF Pad, which decommissioned PAF Dam 1, will be constructed with a 1.5 m thick layer of compacted NAF rockfill overlain by 0.5 m thick low permeability earthfill (ATCW, 2025c).

The waste rock dumps were designed with appropriate surface water drainage controls to ensure that leachate is minimised, and no discharges occur to surface or groundwater resources. Runoff from the PAF waste rock dump is directed to and collected in the Stage 2 PAF Pad Run Off Dam. Dams are regularly inspected, and water levels and quality are monitored as part of DRMs Water Management Strategy. Water captured in the runoff dams is either evaporated or sent to the TSF through the process plant water system. Any water retained within the runoff dam on closure will be pumped to the TSF for management.

3.5.10.1.4. Implications for Closure

EGi (2010) noted that it was essential that PAF waste rock was not unduly exposed to atmospheric conditions. The PAF waste rock is progressively returned to the underground for use as stope fill. NAF material is suitable to remain on the surface and will be used as a revegetation layer for other domains.

3.5.10.2. Tailings Storage Facility

3.5.10.2.1. Tailings Characterisation

Geochemical characterisation of Project tailings was undertaken by EGi and summarised by AARC for the DRM Environmental Impact Statement (EIS) (AARC, 2010), as detailed here-in.

Tailings liquor is classified as circum-neutral (pH 7.3) and moderately alkaline (53 mg CaCO3/L). The major ion chemistry is dominated by sulphate (1,310 mg/L), chloride (714 mg/L) and sodium (175 mg/L). There are also high concentrations of calcium, magnesium and potassium. Amongst the trace elements there were some soluble manganese, lead and zinc, but the concentrations of other environmentally important elements were relatively low. The low concentrations of dissolved metals are consistent with solubility constraints commonly observed under pH neutral conditions.

Assay results of tailings solids confirm the presence of high concentrations of sulphur (7.9%), lead (0.99%) and zinc (2.6%). In addition to the resource metals, the tailings were also enriched with non-resource elements including antimony, arsenic, bismuth, cadmium, mercury and molybdenum. All of these elements are part of the general elemental association reported for hydrothermal sulphide ores, and therefore it is expected that they are to occur in the tailings. The results demonstrate minor enrichment relative to background soil of chromium, copper, nickel, selenium and uranium.

Tailings solids have high pyritic-S content and a correspondingly high capacity for acid generation. Based on the net acid producing potential (NAPP) and net acid generation (NAG) testing, the Project tailings were classified as potentially acid forming (PAF). The results indicate that the acid neutralising capacity (ANC) of the DRM tailings is considered within the low to moderate range for process tailings. The tailings had a strongly positive NAPP result, indicating PAF material.

Column leach testing was undertaken over a 52-week period, which identified the main environmentally important metals that were released during testing were zinc, manganese, lead and cadmium. The concentrations of these metals were typically one or two orders of magnitude higher than the corresponding metal concentrations in tailings liquor, indicating mobilisation. These metals are captured in both the surface water and groundwater monitoring programs as potential contaminants of concern.

MMG implements a program of progressive tailings characterisation, including monthly analysis. A review of data collected from 2018 to 2020 was undertaken to confirm pre-development predictions. The review determined that the geochemical character of the as-deposited tailings has remained consistent throughout the operation to date and is broadly consistent with pre-development predictions.

3.5.10.2.2. Tailings Physical Properties

Tailings samples were prepared and shipped (Amdel Mineral Laboratories, 2008) to the National Association of Testing Authorities (NATA) accredited ATC laboratory for characterisation of their physical properties.

These samples were analysed by AARC for the EIS (2010), with the physical properties of the tailings summarised as follows:

- Specific Gravity (SG) – 2.96;
- Particle Size Distribution – P80 approximately 50 µm;
- Atterberg Limits:
    - Liquid Limit = 21; and
    - Plasticity Index = 6.
    - Unified Soil Classification – Low plasticity Silt; and
    - Segregation Threshold – 46% solids.

The tailings design density parameters that were adopted are presented in Table 41.

Table 41. Tailings design density parameters

Discharge Solids Content (%)	Sedimented Density		Shrinkage Limit Density (t/m^3)
	Solids Content (%)	Density (t/m^3)	
50	66	1.18	1.63

A stability assessment was conducted for the TSF Stage 3 embankment lift (ATCW, 2025f). The scenario and criteria modelled for the stability assessment are presented in Table 42, and the material properties are presented in Table 43.

Table 42. Stability assessment criteria

Scenario	Shear Strength Model	Minimum Factor of Safety (FoS)
Long-Term	Effective Strength	1.5
Dam Crest Flood	Effective Strength	1.3
End of Construction	Effective Strength	1.3

Table 43. Material properties

Material	Strength Envelope	Unit Weight (kN/m3)
Zone 2B	c' = 0 kPa, f' = 35°	20
Zone 2C	Leps' Lower-Average (Capped at 40°)	22.5
Zone 3A	Leps' Average (Capped at 40°)	22.5
Zone 3B		
Foundation – Quartzite Rock	Bedrock (Impenetrable)	22.5
Tailings	No strength	20

The results of the stability assessment are provided in Table 44. All analysed cases exceed the required FoS.

Table 44. Stability Assessment

Scenario	Description	Failure Direction	FoS Required	FoS Modelled
Long-Term	Tailings at RL 240 m Pond at RL 248 m	Downstream	1.5	1.66
		Upstream		2.34
Liner Leak	Tailings at RL 240 m Pond at RL 248 m	Downstream	1.5	1.66
Dam Crest Flood	Tailings at RL 240 m Pond at RL 253.5	Downstream	1.3	1.66
End of Construction	Tailings at RL 222 m Pond at RL 236 m	Upstream	1.3	1.62

3.5.10.2.3. TSF Construction

Civil construction of the existing TSF occurred from June 2016 to June 2018, with only non-civil works completed thereafter. The TSF was originally designed to be constructed in two stages, to facilitate disposal for the LoM. In August 2016, MMG decided to combine the Stage 1 and Stage 2 Works and construct the TSF embankment to its Stage 2 height.

Containment of the tailings is provided almost entirely by the natural topography of the valley, with the main built feature being the downstream embankment. The existing TSF consists of the following built infrastructure (ATCW, 2025f):

- The 37 m high TSF embankment, which is a water-retaining structure comprising of zoned rockfill and granular material with an impermeable bituminous geomembrane (BGM) liner;
- An emergency spillway excavated into the rock on the northern abutment of the TSF embankment, with a base width of 10 m;

- A seepage collection pond constructed downstream of the TSF embankment, to monitor and collect foundation seepage before it discharges off-site;
- The tailings delivery system, comprising the pumping station, steel pipelines, high-density polyethylene (HDPE) pipelines, spill containment ponds and end-point discharges; and
- Return water system, comprising a skid-mounted pump, floating offtake, and a discharge pipeline to pump water from the TSF decant water pond, which forms over the deposited tailings centrally within the TSF. The skid-mounted decant pump transfers water to a booster pump station on the east side of the TSF, from where it is pumped back to the Process Plant.

The Stage 3 TSF raise, submitted for assessment in April 2025 proposes the following works:

- Downstream raising of the existing TSF embankment by 9.25 m to a crest level of RL 253.5 m;
- Excavation of a new spillway approximately 250 m north of the TSF embankment;
- Construction of a new seepage collection system downstream of the TSF embankment;
- Construction of a discharge bund on the northern side of the impoundment (~9.5 m high);
- Construction of a haul road to the west of the TSF;
- Construction of access roads to the discharge points; and
- Relocation of the Return Water System and construction of a new access platform.

A general layout of the design is provided in Figure 22 (ATCW, 2025d).

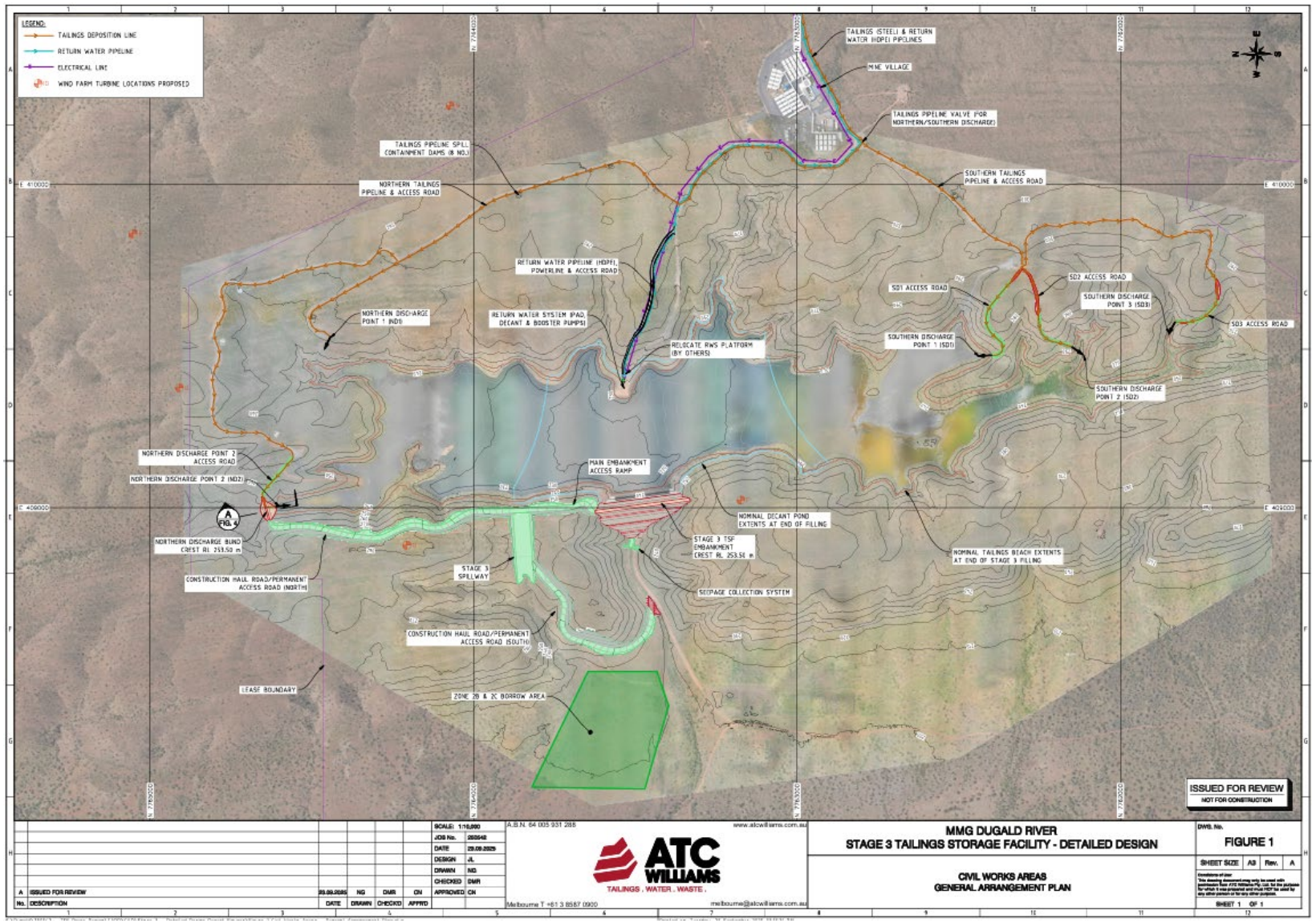


Figure 22. TSF raise design

3.5.10.2.4. TSF Closure Objectives

The PMLU for the TSF is native ecosystem. The closure landform has been developed to achieve a structure that is safe, stable and non-polluting through (ATCW, 2025b):

- Erosional stability;
- Geotechnical stability;
- Supporting and integrating the design cover system to promote geochemical stability;
- Supporting the PMLU of native ecosystem; and
- Forming a free-flowing landform that conveys surface waters from the upstream catchment through an outlet structure with no storage within the former TSF.

A detailed TSF Closure Plan is provided in Appendix E.

3.5.10.2.5. Tailings Deposition Strategy and Landform Surface

Tailings are deposited via sub-aerial deposition (i.e. on a drying beach). A bathymetric survey of the TSF was undertaken in January 2025, which showed sub-aerial (above water level) beach slopes ranging from 0.1 to 0.5%. Sub-aqueous (below water level) beach slopes ranged from 1.0 to 5.5%. On closure, the final surface will be modified to create a self-shedding and stable final landform.

The target beach slopes for the final TSF are <1.5%. Approximately 1.7 Mm^3 of cut and 1.9 Mm^3 of fill will be utilised to reshape the tailings surface. The additional material will be either won from the cut embankment or NAF waste rock (ATC Williams, 2025).

After final deposition, in 2043, a decant pond volume of 4,070 ML will progressively be removed through either natural or enhanced evaporation. Dewatering is expected to be achieved within 3 – 4 years.

Following surface reshaping, the spillway will be reinstated at RL 242.1 m acting as an outlet for the final TSF landform. Surface waters from upstream catchments will be conveyed through a series of surface channels to the outlet structures, located on either side of the embankment. Outlets have been sized to pass the peak flood resulting from the PMP.

A conceptual final tailings surface is provided in Figure 23 to Figure 25. Further detail is provided in Appendix L.

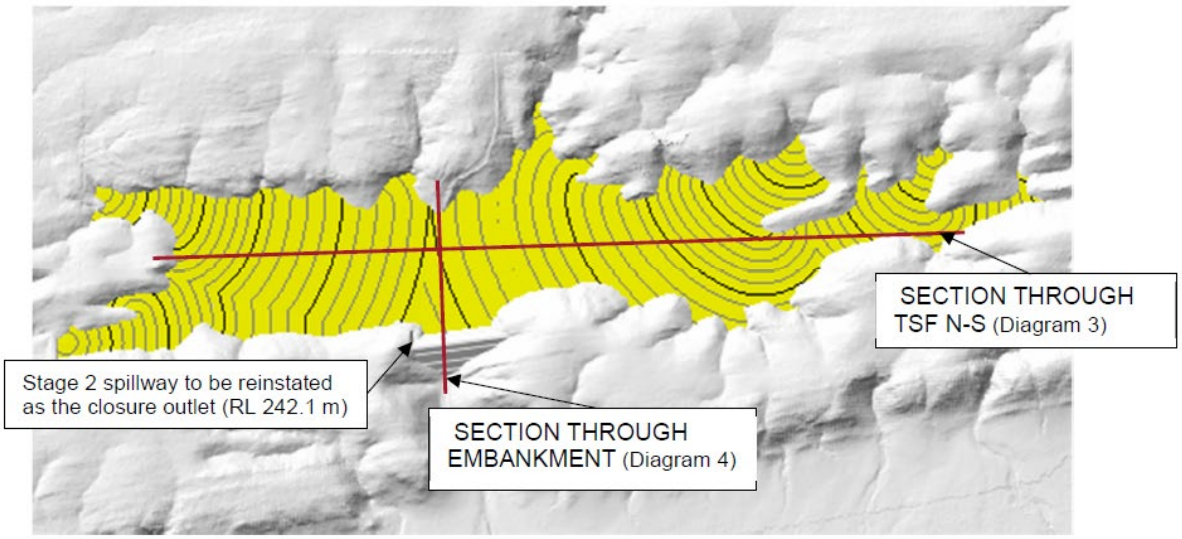


Figure 23. Conceptual closure final tailings surface (ATCW, 2025b)

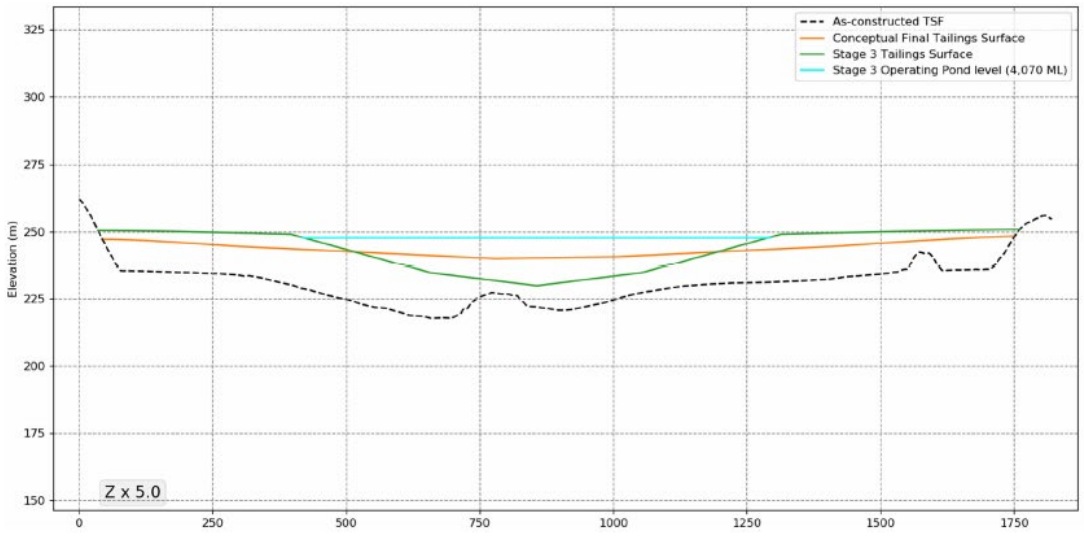


Figure 24. Conceptual closure final tailings surface – Section N-S (ATCW, 2025b)

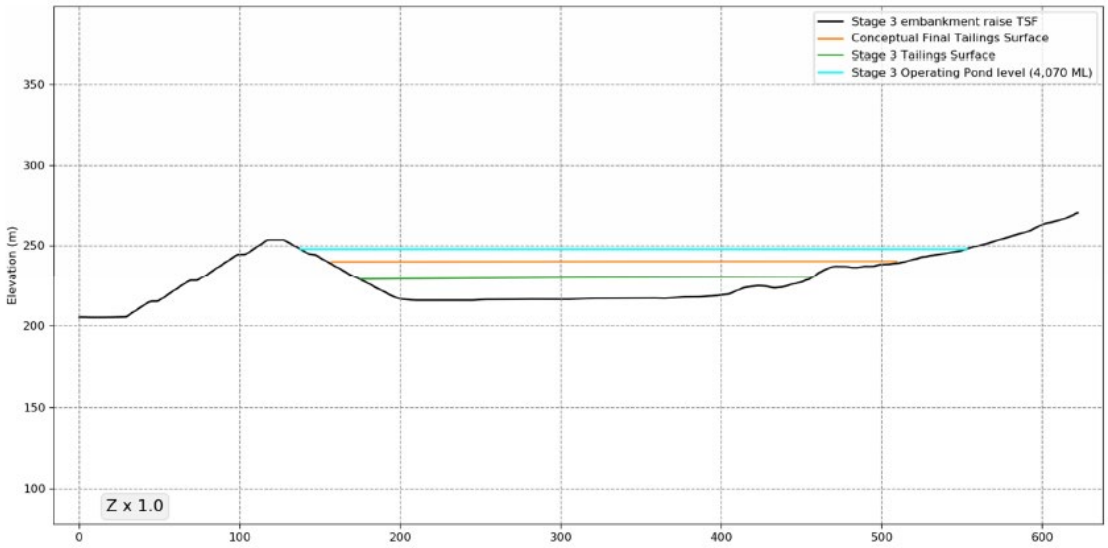


Figure 25. Conceptual closure final tailings surface – embankment (ATCW, 2025b)

3.5.10.2.6. Final Landform Design

As described above, the final tailings surface will be dewatered and reshaped to achieve a self-shedding landform.

The downstream face of the TSF main embankment will be flattened to a nominal 1V:6.5H to stabilise the embankment in the long term and eliminate water ponding and storage within the TSF. Reshaping will require approximately 170,000 m^3 of cut and 110,000 m^3 fill. The excess cut will be utilised for reshaping the tailings surface.

The Stage 3 embankment shell will be constructed from coarse rockfill and would therefore be resistant to erosion. The landform surface is designed to allow for stormwater to flow in a controlled manner towards the outlet structures and therefore, the TSF final landform will not hold water. The Stage 2 spillway at elevation of RL 242.1 m (covered by Stage 3 embankment raise) will be reinstated for closure following reshaping of the embankment, acting as an outlet for the final TSF landform (ATCW, 2054b). This outlet is sized to pass the peak flood resulting from the Probable Maximum Precipitation (PMP). To reduce the risk of erosion, a network of surface channels is proposed to convey flows from the upstream catchments to the discharge outlet structure (ATCW, 2025a). Erosion controls, such as erosional velocity dampeners will be designed by a suitably qualified person to ensure long term stability of the embankment and spillway.

To ensure long term stability of the TSF embankment, the crest will be cut down to the final tailings level and the downstream face will be flattened to direct storm water flows off the rehabilitated TSF embankment and out of the Knapdale Valley in a controlled manner. The embankment will be raised, and new spillway channels will be excavated at the northern and southern abutments to allow attenuation and controlled discharge. Additional engineering design activities will be undertaken to ensure the spillway channel accommodates the peak flood flow velocity (predicted to be 6.2 m/s) to achieve a stable spillway condition. Erosion controls, such as erosional velocity dampeners will be designed by a suitably qualified person to ensue long term stability of the embankment and spillway.

The concept plan of the flattened embankment is provided in Figure 26 to Figure 27.

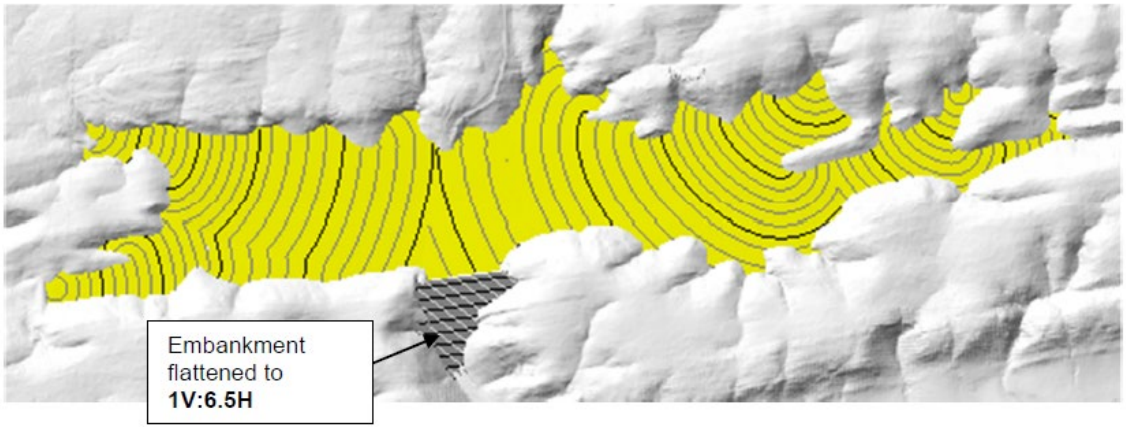


Figure 26. Embankment at closure (ATCW, 2025b)

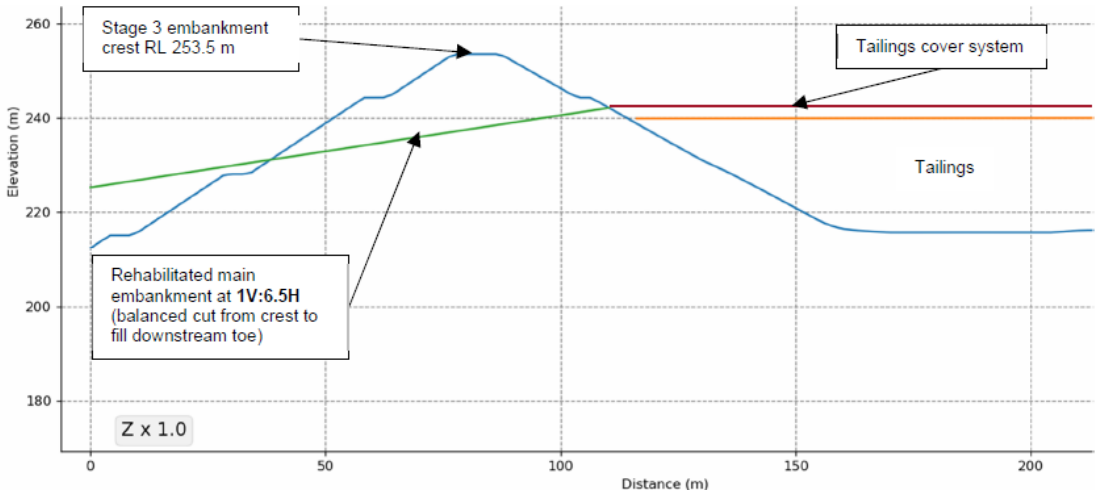


Figure 27. Embankment at closure – section (ATC Williams, 2025b)

3.5.10.2.7. TSF Cover System

A cover system will be constructed on the TSF surface to minimise infiltration and therefore seepage. Several potential cover systems were investigated before determining the most suitable outcome for the TSF. Additional details on the cover system options analysis is provided in Appendix J.

The selected cover system for the TSF final landform (Option 1 Store and Release) is described in Table 45 and Figure 28.

Table 45. TSF cover system

Layer	Depth (m)	Purpose	Source and description
Topsoil	0.2	Support vegetation	Site stockpiles or commercial provider.
Infiltration Storage Layer	1	Store moisture to support vegetation growth and limit downward flux into the tailings.	This material would be sourced from a borrow located near the TSF, and comprise the subsoil, being the material immediately beneath the topsoil and above the weathered rock.
Reduced permeability layer (RPL)	0.5	Limit flux through the cover system into the tailings.	A suitable source has not been identified on site. This would be sourced from a commercial provider.
Capillary Break Layer	0.3	Disrupt the upward and downward movement of water (and hence salt) through capillary action by providing a change in pore size distribution.	To comprise a clean gravel product. A manufactured material, sourced from a licenced quarry or crushed and screened NAF waste rock.
Geomembrane (GCL/HDPE)	N/A	Low permeability barrier, to be used in the absence of an RPL, if required. Geosynthetic clay liner (GCL) is a sodium-bentonite clay	To be purchased from specialised supply companies and installed by qualified installers.

Layer	Depth (m)	Purpose	Source and description
		sandwiched between non-woven geotextile and forms a very low permeability barrier to water but is susceptible to structural changes from high calcium content. High density polyethylene (HDPE) or Linear Low Density Polyethylene (LLDPE) are thermoplastic polymer sheets that form an impermeable barrier to water and many contaminants.	

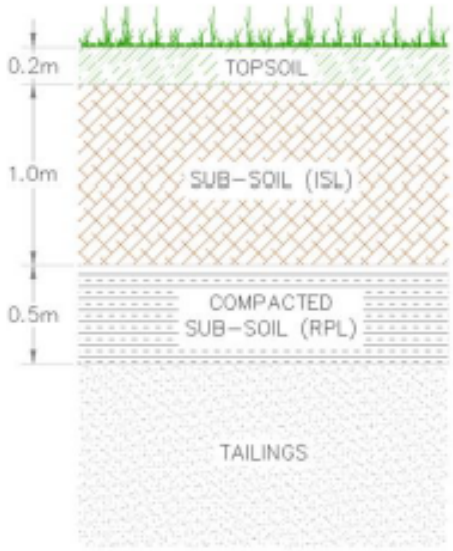
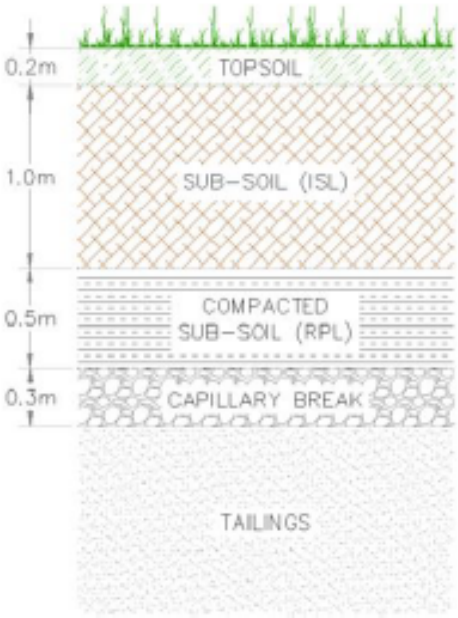
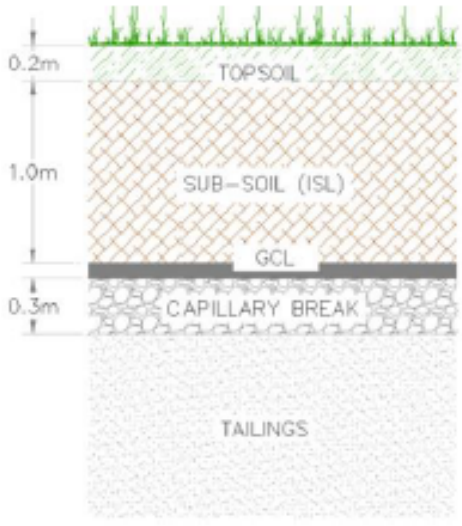
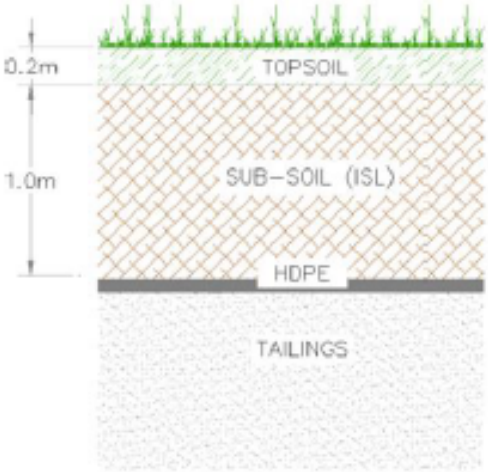
COVER 1: STORE AND RELEASE	COVER 2: CAPILLARY BREAK (PRCP)
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL)	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL) • 0.3 m Capillary Break
	
COVER 3: GCL	**COVER 4: HDPE**
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • GCL • 0.3 m Capillary Break	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • HDPE
	

Figure 28. TSF cover system configuration (ATCW, 2025d)

3.5.10.2.8. Seepage Management

During operations, TSF seepage will be managed through a seepage collection system, comprised of a rockfill seepage collection drain reporting to either a seepage monitoring sump or pond.

Numerical groundwater modelling from the Stage 2 TSF and the proposed Stage 3 TSF indicated that the raise will not result in increased groundwater levels, suggesting no significant impact on regional groundwater conditions (CDM Smith, 2025). Groundwater flux is the rate of groundwater movement through an aquifer and represents the rate of seepage predicted to occur from the TSF. The numerical model for the Stage 2 TSF returned a groundwater flux of 5.5 x 10-8 m3/sec/m2, compared to 6.2 x 10-8 m3/sec/m2 for the Stage 3 TSF. This is within the margin of error, and indicates that there will be no increase in seepage from the TSF as a result of the proposed Stage 3 raise.

No seepage is expected to occur from the TSF post-closure due to the reduction in rainfall infiltration as a result of capping the TSF (CDM Smith, 2025). It is expected that seepage collection and management would be required until the cover system has been applied across the entire TSF surface. During the rehabilitation period, seepage will continue to be contained and pumped to the TSF, if available, or removed from site as a regulated waste. Seepage rates will continue to be monitored until continuous recording demonstrates seepage volume is decreasing.

Following this, infrastructure and any potentially contaminated material will be removed. The drain, sump and/or pond will be backfilled with NAF material and revegetated.

3.5.10.2.9. Revegetation Strategy

Water balance modelling of the proposed cover system was completed to identify water availability to support vegetation (Table 46) (ATC Williams, 2025). The results indicate that with both proposed cover system options, there is a net deficit of rainfall that will require drought tolerant species to be utilised. Endemic native species have been utilised in the revegetation plan to increase the potential for survival and establishment. Refer to Appendix M for further detail.

The revegetation strategy is defined in Section 3.5.7.

Table 46. Annual cover water balance (ATC Williams, 2025)

Cover	Mean Annual Water Balance				
	Rainfall (mm/year)	Runoff (mm/year and % of rainfall)	Evaporation (mm/year and % of rainfall)	Transpiration (mm/year and % of rainfall)	Net Percolation (mm/year and % of rainfall)
Store and release cover	472.7	2.6 (0.5 %)	83.8 (17.7 %)	386.6 (81.7 %)	0.7 (0.2 %)
HDPE lined cover	472.7	3.5 (0.7 %)	85.9 (18.2 %)	382.4 (80.9 %)	0.0 (0.0 %)

3.5.10.2.10. Long Term Stability

The primary objectives for the closure landform with response to erosion are to:

- Avoid erosion which would impact the performance of the cover system;
- Prevent exposure of the underlying tailings; and

- Ensure long term stability of the landform. (ATC Williams, 2025)

Water Erosion Prediction Project (WEPP) modelling was undertaken on the TSF surface to predict long term erosion. Results of the modelling indicate that the TSF would achieve between 1.11/ha/year and 12.7 t/ha/year of soil loss, depending on the vegetation cover (Table 47).

A mean average annual erosion rate of 5 t/ha/y and a mean maximum annual rate at any one point of 10 t/ha/y is commonly referred to as acceptable rates to prevent rilling. This milestone has been applied to the Project.

Table 47. WEPP model results - TSF surface

70 % Vegetation Cover	30 % Vegetation Cover	0 % Vegetation Cover
1.11 t/ha/year	3.89 t/ha/year	12.70 t/ha/year

A hydraulic assessment indicates that flow velocity on the embankment would range from 1.5 m/s at the crest to 2.1 m/s and the toe of the embankment. Recommended D50 rock sizing for this range of flow velocities range from 150 mm to 300 mm (ATCW, 2025a). This material is available from the proposed borrow pit. Refer to Appendix N for further detail.

3.5.10.2.11. Limitations and Assumptions

The final closure landform is dependent on the mining schedule, which can change due to increased geological knowledge as mining progresses, exploration drilling, market factors and technology. This may result in a change to the predicted tailings volume within the TSF at the end of the LoM.

The assumption is that material properties will remain consistent with observed properties. Stability targets will be maintained in the final closure landform design.

The following timeline is assumed based on implementing enhanced evaporation at the TSF at closure:

- Years 1-4, Dewatering and consolidation of the tailings (4 years)
- Years 5-7, Placement of cover layers (3 years, dry season only)

Factors such as workforce availability and extreme weather may affect the assumed timeline.

3.5.10.2.12. QAQC

Construction of the landform will be deemed consistent with design by a suitably qualified professional (QA/QC), verified by a QA/QC document, confirming that the landform is stable and meets design specifications. This includes, but is not limited to, materials, workmanship, and components of the work. Control points are established in constructing the work and instrumentation shall be appropriately calibrated. Controls will be issued indicating procedures where corrections are necessary. Testing will be completed post-construction and QA/QC methodologies will be followed. This data will be aligned with the TSF OMS and used to inform TSF closure design inputs and rehabilitation.

3.5.10.2.13. Rehabilitation Trials

This PRCP application proposes to amend Condition PRCP5 to allow field trials to commence within 12 months of completion of the stage 3 TSF embankment raise to investigate the performance of the

cover system for the TSF. A suitable trial location has been identified in the north east corner of the TSF. Although this area is currently inaccessible, works can be undertaken during the proposed raise to establish a trial area. This will enable rehabilitation trials to be conducted directly on the TSF surface, rather than relying on laboratory or off-site manufactured trials. Establishing the trial in situ will provide site-specific data and ultimately produce more meaningful and representative results.

The field trials will be established and maintained for a minimum of five consecutive years. The trials will be carried out in accordance with the following requirements, prescribed in condition PRCP5 of the approved PRCP schedule:

a) The field trials may be located on another area of the tenure if the mine waste structures have not yet been constructed. The field trials must include multiple alternate cover systems, including the default high risk cover system specified in item #9.01 in Table of Values in the administering authority's ERC Calculator (ESR/2015/1824 Version 5) and the cover system proposed in the Rehabilitation Planning Part.
b) The following information must be documented prior to commencement of any trials:
    I. chemical and physical properties of material contained in the landform demonstrating it is representative of the mine waste.
    II. chemical and physical properties of all cover materials.
    III. surface and sub-surface preparation requirements including the base/lining layer under the landform (for example, ripping, compacting, establishing bunds).
    IV. amelioration requirements (for example, gypsum/lime etc, rate, spreading/layer application)
    V. details of installation methodology.
    VI. monitoring equipment installation.
    VII. QA and QC tests and processes implemented for the construction of each layer of the alternate cover system.
c) Prior to commencement of the trials, a planning report must be submitted to the administering authority that provides details as relevant for the matters above and also provides the following:
    I. specific objectives of the proposed design cover (i.e. reduction in surface water infiltration to a specified rate, prevention of salt rise that would impact on the establishment of vegetation).
    II. detailed design.
    III. justification for the quality control and assurance processes that will be implemented for the construction of each layer of the alternate cover system.
    IV. lab-based material characterisation results.
d) At a minimum, the following information must be collected during the course of the trial:
    I. Monitoring as per Section 8, INAP Global Cover System guideline (INAP 2017).
    II. Site specific climate data collected for the duration of the trial.
    III. Data relating to surface conditions (biological and erosion monitoring.
    IV. Data from in situ monitoring for:
        1) contaminant transport.
        2) drainage performance.

3) evapotranspiration.
4) soil performance
5) stability and biological factors..

e) Following completion of the trial a completion report incorporating supporting data must be provided demonstrating the performance of all trialled cover systems. This report must provide details of the matters described above, in addition to the following:
   I. Demonstration that the proposed cover system will achieve a stable condition (pursuant to section 111A of the EP Act) and comply with criteria specified in this PRCP schedule.
   II. Updated Landform Evolution Modelling and infiltration modelling based on the results of the trial.
   III. Calibration processes for all instrumentation.
   IV. SILO data for the duration of the trial period.
   V. As constructed plans and report by an appropriately qualified person certifying that each cover system was constructed according to the design in the trial planning report.
   VI. Destructive/non-destructive testing of each capping layer in the trial plot.
   VII. In situ QA and QC test report for each capping layer.
   VIII. QA and QC information for the overall landform construction.
   IX. Independent* certification from an appropriately qualified third party specifying the cover system for full scale application, based on the findings from the trial and including any necessary changes.
   X. Recommendations from an appropriately qualified person regarding the location of primary and secondary monitoring sites and the location of additional lysimeters referred to in RM7.

3.5.11. Voids

There are no proposed voids associated with the Project.

3.5.12. Summary of Key Rehabilitation Milestones

Table 48 summarises the Project rehabilitation milestones. The rehabilitation activities drive achievement of the Project rehabilitation milestones and inform the associated PRCP schedule. Where a milestone criterion requires any of the following, MMG will maintain appropriate records and will provide to DETSI on request:

- Certifications or assessments to be undertaken;
- Monitoring or maintenance to be carried out;
- Final design plans and/or specifications to be developed; and
- Reports, such as contaminated land investigations, rehabilitation reports (including monitoring records), validation reports and quality assurance/quality control reports.

Table 48 Key rehabilitation and management practices

Rehabilitation Milestone	
RM1	Infrastructure decommissioning and removal

Rehabilitation Milestone	
RM2	Remediation of contaminated land
RM3	Landform development and reshaping (RA1)
RM4	Landform development and reshaping (RA2)
RM5	Landform development and reshaping (RA3)
RM6	Landform development and reshaping (RA4/RA5)
RM7	Landform development and reshaping (RA6)
RM8	Landform development and reshaping (RA7)
RM9	Surface preparation
RM10	Revegetation (native ecosystem)
RM11	Revegetation (grazing)
RM12	Achievement of surface requirements (native ecosystem)
RM13	Achievement of surface requirements (grazing)
RM14	Achievement of post mining land use to a stable condition (native ecosystem)
RM15	Achievement of post mining land use to a stable condition (grazing)

3.5.13. Rehabilitation Milestones

A Rehabilitation Milestone (RM) is defined as *each significant event or step necessary to rehabilitate the land to a stable condition* (Department of Environment and Science, 2021). Rehabilitation milestones are used to determine if the rehabilitation area has been rehabilitated to a point that the PMLU has been achieved.

The rehabilitation milestones for each rehabilitation area are outlined below (Table 49). Where a milestone criteria requires any of the following, MMG will maintain appropriate records and will provide to DETSI on request:

- Certifications or assessments to be undertaken;
- Monitoring or maintenance to be carried out;
- Final design plans and/or specifications to be developed; and
- Reports, such as contaminated land investigations, rehabilitation reports (including monitoring records), validation reports and quality assurance/quality control reports.

In addition to the site wide rehabilitation milestones, the following reporting conditions are applied to the Renewable Energy Project:

- **PRCP6** Prior to the commissioning of the Renewable Energy Project* and within two (2) years of the PRCP effective date, the PRCP holder must develop an End of Operation Decommissioning Management Plan (EODMP). The EODMP must:

- Be prepared by a Registered Professional Engineer of Queensland who is experienced in the relevant decommissioning type; and
- Provide for the complete removal of all wind turbine infrastructure and ancillary infrastructure* from site; and
- Include a conceptual timeline for the decommissioning of wind turbine infrastructure and ancillary infrastructure in accordance with the associated milestone and criteria in this schedule; and
- Include a checklist of actions required to be completed for achievement of each applicable rehabilitation milestone and criteria; and
- Include an assessment of relevant rehabilitation intersects during decommissioning. This includes but is not limited to:
  - material balance and suitability assessments and management; and
  - flooding modelling assessments and management: and
  - water management; and
  - revegetation assessments and managements; and
- Include the plan required by condition **PRCP7;** and
- Be endorsed by an independent and suitably qualified and experienced third party; and
- Be submitted to the administering authority within 5 business days of request.

- **PRCP7** The EODMP required by condition **PRCP6** must include:
  - a Final Landform Design Plan which must:
    - Be prepared by a Registered Professional Engineer of Queensland with experience in the relevant decommissioning type; and
    - Be endorsed by an independent third party who is a suitably qualified and experienced person; and
    - Provide for reinstatement of all areas associated with the Renewable Energy Project including wind turbine infrastructure and ancillary infrastructure to approximate original contours; and
    - Demonstrate that all reinstated areas are geotechnically and erosionally stable and will achieve a stable condition (pursuant to section 111A of the EP Act); and
    - Demonstrate that all rehabilitated watercourse crossing designs have considered fluvial geomorphology, with certification by a suitably qualified and experienced person that the design achieves a safe, stable and non polluting outcome for rehabilitated watercourses.
- **PRCP8** The PRCP holder must revise the EODMP required by condition **PRCP6** within six months of becoming aware of a proposed change and/or update to the construction, operational and/or decommissioning phase of the Renewable Energy Project.

- **PRCP9** The PRCP holder must decommission the Renewable Energy Project in accordance with the EODMP under the supervision of an appropriately qualified person.

Table 49. Rehabilitation milestones

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
RM1	Infrastructure decommissioning and removal	For all areas: a) All buildings and associated infrastructure dismantled and removed offsite. b) All hardstand and concrete areas decommissioned removed. c) Fences are removed. d) All pipelines are removed. e) Powerlines and supporting electrical infrastructure (above and below ground) are removed. f) Roads removed (with the exception of those being retained for future site access). g) Waste is removed. h) Drillholes, sediment ponds and sumps decommissioned. i) Machinery/ equipment not required for rehabilitation removed from site. For RA7: j) All infrastructure is decommissioned and removed from site in accordance with EODMP under the supervision of an AQP	Infrastructure is required to be removed from site to enable surface treatment of areas	• Documented Inspections
RM2	Removal of contaminated land	a) Contaminated land assessment is completed by a suitably qualified person.	• Contaminated material is required to be removed to	• Preliminary Site Investigation Report • Detailed Site Investigation Report

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		b) Any identified contaminated material is removed from the mine domain and disposed of at a licenced facility. c) Validation sampling determines that contaminant removal has been successful. d) The validation sampling report is accepted by a suitably qualified Contaminated Land Auditor stating that contamination removal has been successful.	minimise potential for environmental harm • A validation report will provide verification that contaminants have been removed and landform shaping can commence	• Validation Investigation Report
RM3	Landform development and reshaping (RA1)	a) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. b) Landform is ripped parallel to contour. c) Features such as large woody debris or boulders are situated to provide suitable habitat for the Purple Neck Rock Wallaby. d) RA1 is determined to be geotechnically stable by a suitably qualified geotechnical engineer.	• The final landform must be consistent with the surrounding land and profiled to limit erosion • RA1 has been designated as a native ecosystem and therefore needs to support fauna populations	• Survey • Certification reporting from a suitably qualified person
RM4	Landform development and reshaping (RA2)	a) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. b) Landform is ripped parallel to contour.	The final landform must be consistent with the surrounding	• Survey • Certification reporting from a suitably qualified person

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		c) RA2 determined to be geotechnically stable by a suitably qualified geotechnical engineer.	land and profiled to limit erosion	
RM5	Landform development and reshaping (RA3)	a) General earthworks completed. b) HDPE Liner removed. c) Dams filled with NAF or other suitable material. Material placed in 500mm lifts, watered and compacted. d) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. e) RA3 determined to be geotechnically stable by a suitably qualified geotechnical engineer.	The final landform must be consistent with the surrounding land and profiled to limit erosion	• Survey • Certification reporting from a suitably qualified person
RM6	Landform development and reshaping / re-profiling (RA4 / RA5)	a) Removal of waste rock. PAF material is disposed of underground. NAF material is utilised in rehabilitation. b) Major earthworks are completed. c) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. d) Land reshaped to final landform design with suitable material as assessed by AQP and as per EODMP, where required. e) RA4/RA5 is determined to be geotechnically stable by a suitably qualified geotechnical engineer.	The final landform must be consistent with the surrounding land and profiled to limit erosion	• Survey • Certification reporting from a suitably qualified person

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
RM7	Landform development and reshaping (RA6)	a) The construction of the cover system has been certified by an appropriately qualified person as being consistent with the cover design. b) QAQC testing is completed post construction at a rate of at least 1 sample per ha and confirms depth of layers and permeability is to specified designs and no PAF material is present within the cover system. c) Primary monitoring locations have been established in representative locations recommended as an outcome of the trial mentioned in Condition PRCP5(e) and include: I. An automated meteorological station that records the following: rainfall (tipping bucket), i. evaporation, ii. relative humidity, iii. wind strength, iv. wind direction, and v. air temperature. II. piezometers within the tailings and capillary break layer, III. automated in situ water content and suction sensors in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals (except in the capillary break),	• The final landform has been designed to shed water and provide stable slopes • RA6 has been designated as a native ecosystem and therefore needs to support fauna populations • Excessive rilling is unlikely to occur at erosion rates of <5t/ha/y • Erosion rilling <0.2m will prevent exposure of tailings	• Construction and maintenance design • Survey • Certification reporting from a suitably qualified person

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		IV. temperature sensor in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals, V. a lysimeter. d) Secondary monitoring locations have been established in representative locations recommended as an outcome of the trial mentioned in Condition PRCP5(e) and include in each layer of the cover system and in the tailings below the cover system: I. piezometers within the tailings and capillary break layer, II. automated in situ water content sensors in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals (except in the capillary break). e) Temperature sensor in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals. All sensors are calibrated to each material type using the manufacturers specifications. f) Lysimeters and associated drainage collection and monitoring system are installed in at least 3 locations that are recommended as an outcome of the trial mentioned in Condition PRCP5(e).		

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		g) Sediment capture flumes have been installed and calibrated at the base of the TSF embankment. h) All monitoring equipment has been installed and calibrated by an appropriately qualified person. i) Slopes of TSF surface have a grade of <1.5% j) Certification by an AQP that landform has been constructed according to the design and has achieved an acceptable factor of safety. k) Spillway is reinstated at RL 242.1 m. Spillway has an approximate length of 330m and a longtitudinal grade of 2.0%. l) TSF is assessed as geotechnically stable by a suitably qualified geotechnical engineer. m) Features such as large woody debris or boulders are present to provide suitable habitat for the Purple Neck Rock Wallaby. n) TSF surface has been shaped to prevent ponding and concentration of surface water flow. o) Spillway is designed and constructed to support peak flood flow velocity. p) Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y. q) Erosion rilling is <0.3m. r) No surface ponding.		

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		s) Installation of erosion and sediment control structures that comply with International Erosion Control Association (IECA).		
RM8	Landform development and reshaping (RA7)	a) Land reshaped to final landform design with suitable material as assessed by AQP and as per EODMP. b) Features such as large woody debris or boulders are situated to provide suitable habitat for the Purple Neck Rock Wallaby. c) RA7 is determined to be geotechnically stable by a suitably qualified geotechnical engineer.	• Minimise surface flows and gully erosion	• Documented Inspections • Survey
RM9	Surface preparation	a) Deep ripping of compacted surfaces, at least 300mm into soil profile, where required and avoiding habitat features associated with RM3 and RM8. b) An assessment of the need for soil amelioration undertaken and soil ameliorants such as fertiliser, gypsum and/or organic matter have been applied at rates determined by an appropriately qualified person. c) Topsoil placement of a minimum 0.1 - 0.2 m	• Ripping and application of growth media will encourage establishment of vegetation	• Survey • Certification reporting from a suitably qualified person
RM10	Revegetation (native ecosystem)	a) Seeding rate of 4 – 10 kg/ha is applied. b) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2 and 1.7.7 on RA1 including *Eucalyptus leucophloia, Corymbia terminalis, Corymbia capricornia* with a groundcover of *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus,Themeda triandra, Triodia pungens.*	• Monitoring will assess success of natural revegetation and determine if intervention measures are required eg.	• BioCondition Assessment Report • Annual REMP report • Laboratory Certificates of Analysis (COAs) • Annual Rehabilitation Monitoring Report

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		c) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2 and 1.7.7 on RA6 including *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus,Themeda triandra, Triodia pungens.* d) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2a/1.7.7a and RE1.11.3a/1.3.13a on RA7, including the terrestrial species of *Eucalyptus leucophloia, Corymbia terminalis* and *Corymbia capricornia* with a groundcover of *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus, Themeda triandra* and *Triodia pungens.* e) Direct seeding species mix on RA7 including riparian species of *Eucalyptus camaldulensis, Corymbia capricornia, Sporobolus australasicus*, Melaleuca species, Lophostemon species and other suitable wetland groundcover species in riparian vegetation zones. f) Deep rooting vegetation such as Eucalyptus Spp not present on RA6. g) Groundcover >50%.	further application of seed is required • Vegetation species have been selected based on pre mine Regional Ecosystems • Deep rooting species present a risk of exposing capped tailings on RA6	

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
RM11	Revegetation (grazing)	a) Direct seeding is applied at a rate of 4 – 10 kg/ha. b) Direct seeding of native species including *Eucalyptus leucophloia, Corymbia capricornia, Terminalia aridicola, Corymbia terminalis, Triodia pungens, Eucalyptus pruinose, Eremophila longifolia, Atalaya hemiglauca, Acacia chisholmi,i Atalaya hemiglauca, Carissa lanceolata* as well as appropriate 3P grass species to support the PMLU. c) Pasture vegetation seeding creates cover >30%.	• Monitoring will assess success of natural revegetation and determine if intervention measures are required eg. further application of seed is required • Vegetation species have been selected based on PMLU of grazing	• BioCondition Assessment Report • Annual REMP report • Laboratory Certificates of Analysis (COAs) • Annual Rehabilitation Monitoring Report
RM12	Achievement of surface requirements (native ecosystem)	For all areas: a) Weed species in densities less than 10% total coverage. b) Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y. c) Vegetation cover 70%. d) Species used in revegetation in RM10 remain present and showing evidence of natural recruitment. e) Surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8	• Excessive rilling is unlikely to occur at erosion rates of <5t/ha/y • Surface water values have been selected based on the Projects classification as slightly to	• BioCondition Assessment Report • Annual REMP report • Laboratory Certificates of Analysis (COAs) • Annual Rehabilitation Monitoring Report

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		(SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly to moderately disturbed). f) Stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low. g) Quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA. h) Soil testing indicates the following parameters are met: I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth). For RA6:	moderately disturbed • Livestock drinking water values have been selected based on surrounding land use of grazing • Monitoring sites have been selected to capture all areas of disturbance, including downstream of the TSF • Soil parameters are consistent with pre-mine condition • TSF seepage is expected to decrease after rehabilitation	

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		i) There is no evidence of water ponding on the surface of the TSF. j) Continuous recording demonstrates seepage volume is decreasing. k) In-situ permeability and surface infiltration are not significantly decreasing compared with initial rates based on statistical analysis. l) In-situ permeability and surface infiltration are not significantly decreasing compared with initial rates based on statistical analysis. For RA7: m) Certification from AQP that all actions required in EODMP to achieve surface requirements have been completed. n) All temporary erosion and sediment control and stormwater management structures have been removed. o) No erosion classified as “moderate” or “severe”[3]. p) Riparian monitoring is undertaken every year[5], which shows a progressive improvement in the following attributes; tree species richness, bank stability, recruitment and projected foliage cover, or is similar to, representative reference ephemeral waterways in the region	• RA will be compared to reference sites to account for seasonal fluctuations	

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		q) Rehabilitated watercourses are stable and do not create any upstream or downstream impacts, as certified by an AQP.		
RM13	Achievement of surface requirements (grazing)	a) Weed species in densities less than 10% total coverage. b) Pasture covers has reached 70% of surface area. c) Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y. d) Surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly disturbed). e) Stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low. f) Quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA.	• Site specific vegetation completion criteria will be determined based on reference site monitoring • Excessive rilling is unlikely to occur at erosion rates of <5t/ha/y • Surface water values have been selected based on the Projects classification as slightly to moderately disturbed • Livestock drinking water values have been	• BioCondition Assessment Report • Annual REMP report • Laboratory Certificates of Analysis (COAs) • Annual Rehabilitation Monitoring Report

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		g) Soil testing indicates the following parameters are met: I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth). For RA5: h) Certification from AQP that all actions required in EODMP to achieve surface requirements have been completed.	selected based on surrounding land use of grazing • Monitoring sites have been selected to captured all areas of disturbance, including downstream of the TSF • Soil parameters are consistent with pre-mine condition • TSF seepage is expected to decrease after rehabilitation • RA will be compared to reference sites to account for	

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
			seasonal fluctuations	
RM14	Achievement of post-mining land use to a stable condition (native ecosystem)	For all areas: a) Vegetation cover exceeds 70% of the surface area. b) All species used in RM10 show natural recruitment. c) Weed species in densities less than 10% total coverage. d) Native fauna observed or indicators of these species have been recorded. e) There is no evidence of seepage occurring within the mining tenure. f) Certification from an REPQ that the domain has achieved stable condition.4 g) Certification from an AQP that the landform achieved a factor of safety 1.5. h) All results from surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly disturbed) for a minimum of 5 consecutive years.1 i) All results from stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8	• Site specific vegetation completion criteria will be determined based on reference site monitoring • Excessive rilling is unlikely to occur at erosion rates of <5t/ha/y • Surface water values have been selected based on the Projects classification as slightly to moderately disturbed • Livestock drinking water values have been selected based	• BioCondition Assessment Report • Annual REMP report • Laboratory Certificates of Analysis (COAs) • Annual Rehabilitation Monitoring Report

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low for a minimum of 5 consecutive years. j) All results from quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA for a minimum of 5 consecutive years. k) Soil testing undertaken at yearly intervals indicates the following parameters are met: I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth). For RA1: l) No evidence of erosion classified as 'Severe'[3]. m) No active erosion present as demonstrated by no increase in erosion ratings[3] over time. For RA6: n) There is no evidence of water ponding on the surface of the TSF.	on surrounding land use of grazing • Monitoring sites have been selected to captured all areas of disturbance, including downstream of the TSF • Soil parameters are consistent with pre-mine condition • TSF seepage is expected to decrease after rehabilitation • RA will be compared to reference sites to account for seasonal fluctuations	

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		o) Average erosion rate of <5 t/ha/y. p) No evidence of erosion classified as ‘moderate’ or 'severe'. q) No evidence of salt rise through the cover system of the TSF. r) In-situ permeability and surface infiltration are not significantly decreasing compared with initial rates based on statistical analysis. s) Results of monitoring gathered from primary and secondary monitoring stations established in RM7 demonstrate the following has been maintained for a minimum of 10 years: I. Hydraulic conductivity of the cover system is less than 1 x 10-8 m/s for at least 10 years, II. Net percolation through the cover into the tailings has been reduced to <5% of rainfall for at least 10 years as measured by primary and secondary monitoring locations and lysimeters, III. Water content of the reduced permeability layer is maintained above 85% over a 10 year period, IV. Temperature within the tailings has not increased over a 10 year period, V. Volumetric water content of tailings does not respond to rainfall events.		

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		For RA7: t) Certification by AQP that all actions as required in the EODMP to achieve a stable condition have been completed. u) No evidence of erosion classified as “moderate” or “severe”[3]. Riparian monitoring undertaken every year5 shows an achievement in the following attributes; tree species richness, bank stability, recruitment and projected foliage cover, which is similar to, representative reference ephemeral waterways in the region.		
RM15	Achievement of PMLU to a stable condition (grazing)	a) Weed species in densities less than 10% total coverage. b) Vegetation cover has reached 70%. c) All established species show natural recruitment. d) Land suitability assessment by an appropriately qualified person certifies land has achieved a post-mine land suitability[2] of 4[2] or better. e) Minimum of 4 palatable perennial pasture species and 2 shade tree species established. f) No evidence of erosion classified as ‘Severe’[3]. g) No active erosion present as demonstrated by no increase in erosion ratings[3] over time. h) There is no evidence of seepage occurring within the mining tenure.	• Site specific vegetation completion criteria will be determined based on reference site monitoring • Excessive rilling is unlikely to occur at erosion rates of <5t/ha/y. • Certification from a AQP is	• BioCondition Assessment Report • Annual REMP report • Laboratory Certificates of Analysis (COAs) • Annual Rehabilitation Monitoring Report

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		i) Certification from an REPQ that the domain has achieved stable condition. j) Certification from an AQP that the landform achieved a factor of safety 1.5. k) All results from surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly to moderately disturbed) for a minimum of 5 consecutive years.1 l) All results from stream sediment at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with limits set for low risk and no adverse effects in ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low for a minimum of 5 consecutive years. m) All results from quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA for a minimum of 5 consecutive years.	required for relinquishment • Surface water values have been selected based on the Projects classification as slightly to moderately disturbed • Livestock drinking water values have been selected based on surrounding land use of grazing • Monitoring sites have been selected to captured all areas of disturbance, including downstream of the TSF	

Rehabilitation milestone		Milestone criteria	Justification of completion criteria	Verification
		n) Soil testing undertaken at yearly intervals indicates the following parameters are met: PAWC >50 at Red Plain and Pocket soil types, I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth), IV. Carrying capacity is suitable to support a sustainable level of grazing. For RA5: o) Certification by AQP that all actions as required in the EODMP to achieve a stable condition have been completed.	• Soil parameters are consistent with pre-mine condition • TSF seepage is expected to decrease after rehabilitation • RA will be compared to reference sites to account for seasonal fluctuations	

[1] Sites on tributaries of Dugald River sample daily for the first two days when stream flows commence. If flows persist, sample weekly until flow ceases.

Dugald River Sites sample Dugald River sites daily while flows are present downstream of the mine and daily for one week after cessation of flows in the tributaries downstream of the mine. Sample monthly if flows are present in Dugald River during the wet season.

Cabbage Tree Creek sites Sample CT3 08, CC 05 and CC 06 daily when flows are present at CT3 08 and sample CC 05 and CC 06 daily for two days after flows at CT3 08 cease. Sample CC-05 and CC-06 weekly if flows are present.

[2] Department of Science, Information Technology and Innovation and Department of Natural Resources and Mines (2015) Guidelines for Agricultural Land Evaluation in Queensland (Second Edition), State of Queensland or later version. (https://www.publications.qld.gov.au/dataset/qld-agricultural_land-evaluation-guidelines/resource/d6591386-08e2-453f-a6fa-dff2a756215f)

[3]Erosion classification framework

Erosion classification	Minor	Moderate	Severe
Sheet erosion	Shallow soil deposits downslope	Partial exposure of roots; moderate soil deposits downslope, etc.	Loss of surface horizon; root exposure, etc
Rill/gully erosion	<15 rills and <0.3m deep	15-30 rills and <0.3m deep	>30 rills and/or any >0.3m deep.
Tunnel erosion	-	-	Present
Mass movement	-	-	Present

3.6. Risk Assessment

A closure and rehabilitation risk assessment has been prepared in accordance with Section 126C(1)(f) of the EP Act. The risk methodology utilised has been developed based on the *Australia and New Zealand Standard AS/NZS for Risk Management – Principles and Guidelines* (ISO 31000:2018).

The risk management process involves the systematic application of policies, procedures, and practices to the activities of communicating and consulting, establishing the context and assessing, treating, monitoring, reviewing, recording, and reporting risk (Figure 29).

Closure and rehabilitation risk assessments have the objective to identify and define specific risks from closure and rehabilitation and associated activities toward environmental, economic, and social values.

Figure 29. ISO 31000: 2018 Risk management process

3.6.1. Risk Identification

The purpose of risk identification is to find, recognise and describe risks that might help or prevent an organisation achieving its objectives. Relevant, appropriate, and up-to-date information is important in identifying risks (Standards Australia, 2018).

The following factors have been considered by this risk assessment:

- Tangible and intangible sources of risk;
- Causes and events;
- Threats and opportunities;
- Vulnerabilities and capabilities;

- Changes in the external and internal context;
- Indicators or emerging risks;
- The nature and value of assets and resources;
- Consequences and their impacts on objectives;
- Limitations of knowledge and reliability of information;
- Time-related factors; and
- Biases, assumptions, and beliefs of those involved.

3.6.2. Risk Analysis and Evaluation

The purpose of risk analysis is to comprehend the nature of risk and its characteristics, including, where appropriate, the level of risk. Risk analysis can be undertaken with varying degrees of detail and complexity, depending on the purpose of the analysis, the availability and reliability of information and the resources available. Risk analysis techniques can be qualitative, quantitative or a combination of these and should include:

- the likelihood of events and consequences;
- the nature and magnitude of consequences;
- complexity and connectivity;
- time-related factors and volatility;
- the effectiveness of existing controls; and
- sensitivity and confidence levels.

A likelihood of occurrence and severity of consequence rating has been assigned to each identified risk in accordance with the risk matrix detailed in Table 50. Control measures have been developed following the identification of risks to achieve a level of risk that is considered to be an acceptable level, as described in Table 51.

Table 50. Risk matrix

			Consequence			
	Environment	No impact to Environmental Value (EV).	Small-scale impact to EV. Localised impact confined to incident area.	Moderate-scale impact to EV. Localised impact confined to property boundary.	Large-scale impact to EV. Regional area of impact.	Extensive population or community scale impact to EV. Extensive area of impact.
	Community and Reputation	No actual or potential community criticism.	Minor level local community criticism (<week). No reputation impact.	Local community criticism (> week) or one-day community protest. Local company reputation impacted.	State-level community criticism or protest over multiple days/ occasion. State-based company reputation impacted.	National community criticism or large-scale protest. Company reputation and approvals impact. Shareholder intervention or short-term share price impact (< month).
	Financial (A$)	<30K	$30k to 300K	$300k to 3M	$3M to $30M	$30M to $300M
	Compliance EA, legislation, instruments (e.g. tenure licence) or contract.	Administrative non-conformance No regulatory or punitive action.	Non-conformance. Notification/report to; request for information by; and/or administrative/ warning notice from regulator.	Recurring non-conformance. Statutory notice from regulator.	Systemic administrative non-compliance (or one moderate non-conformance). Company charged with an offence or minor penalty/ fine.	Systemic moderate non-conformance (or single material non-conformance). Company charged with an offence with moderate penalty
		1	**2**	**3**	**4**	**5**
Likelihood	**Almost Certain (< 4 months)** Occurs in almost all circumstances OR could occur within days to week. **5**	**Medium (6)**	**High (7)**	**High (8)**	**Very High (9)**	**Very High (10)**

	Likely (4 months – 3 yearly) Occurs in most occurrence OR could occur within weeks to month.	**4**	**Medium (5)**	**Medium (6)**	**High (7)**	**High (8)**	**Very High (9)**
	Occasional (3 - 8 yearly) Has occurred before in OR could occur with months to years.	**3**	**Low (4)**	**Medium (5)**	**Medium (6)**	**High (7)**	**High (8)**
	Possible (8 - 15 yearly) Has occurred elsewhere OR could occur with decades	**2**	**Low (3)**	**Low (4)**	**Medium (5)**	**Medium (6)**	**High (7)**
	Unlikely (15 - 100 yearly) Has occurred elsewhere OR could occur within decades.	**1**	**Low (2)**	**Low (3)**	**Low (4)**	**Medium (5)**	**Medium (6)**

Table 51. Risk scores

Risk Score	Risk Rating	Actions Required
9 – 10	Extreme	Requires immediate action to reduce risk score.
7 – 8	High	Requires an action plan approved by senior management.
5 – 6	Moderate	Specific monitoring and procedures required.
2 – 4	Low	Management through routine procedures and protocols.

Table 52. Risk evaluation

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
RM1 Infrastructure decommissioning and removal	Infrastructure is not adequately identified during planning process	Failure to remove all infrastructure in accordance with schedule. Achievement of RM1 is delayed.	2	3	5	A register of infrastructure is to be developed to track which structures exist in each rehabilitation area. Demolition works to be scoped with area managers to identify all infrastructure.	The proposed actions will ensure the demolition works are correctly scoped and scheduled.	1	3	4	Contractors will return to site to remove all infrastructure.
RM2 Removal of contaminated land	Previously unidentified contamination source discovered.	Financial cost of remediation. Achievement of RM2 is delayed.	3	3	6	Records are to be kept of all spills and other incidents occurring at the Project that might result in contamination. Employees and contractors are to be made aware of their reporting obligations through a Site Induction. Initial consultation with an approved	Disturbance is restricted to approved areas as defined on the EA. Initial contaminated land assessments will identify areas for further investigation and remediation.	2	3	5	Ongoing rehabilitation monitoring will identify presence of previously unidentified contaminants. Any contamination will be investigated and further contaminated land

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
						contaminated land assessor to identify contamination targets for remediation or removal.					sampling/ removal will be conducted as required.
	Contaminated sediment is not removed to an appropriate depth.	Contamination of land and water resources Ongoing cost of remediation Financial cost of remobilising earthworks crew	3	3	6	Conduct validation sampling to determine that contaminant removal has been successful.	To be suitable for a PMLU of low-intensity grazing, contaminated land must be removed from the Contaminated Land Register or the Environmental Management Register. These works must be approved by a suitably qualified person and an approved auditor (under the	2	3	5	Ongoing rehabilitation monitoring will identify presence of previously unidentified contaminants. Any contamination will be investigated and further contaminated land sampling/ removal will be conducted as required

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
							Environmental Protection Act 1999 Act).				
RM3 Landform development and reshaping (RA1)	Final landform not adequately shaped per design.	Reduced safety or instability of landform. Erosion leading to contamination of water ways. Unsuccessfully revegetated.	4	3	7	Landform is assessed as geotechnically stable by a suitably qualified geotechnical engineer	Proposed landform is to be gently sloping, limiting potential for erosion. Little earthworks will be required to achieve profile.	2	3	5	Landform will be reshaped until stability is achieved.
RM4 Landform development and reshaping (RA2)	Final landform not adequately shaped per design.	Reduced safety or instability of landform. Erosion leading to contamination of water ways. Unsuccessfully revegetated.	4	3	7	Landform is assessed as geotechnically stable by a suitably qualified geotechnical engineer	Proposed landform is to be gently sloping, limiting potential for erosion. Little earthworks will be required to achieve profile.	2	3	5	Landform will be reshaped until stability is achieved.
RM5 Landform development and reshaping (RA3)	Final landform not adequately shaped per design.	Reduced safety or instability of landform. Erosion leading to contamination of water ways.	4	3	7	Landform is assessed as geotechnically stable by a suitably qualified	Proposed landform is to be gently sloping, limiting potential for erosion. Little	2	3	5	Landform will be reshaped until stability is achieved.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Unsuccessfully revegetated.				geotechnical engineer	earthworks will be required to achieve profile.				
RM6 Landform development and reshaping (RA4/RA5)	Final landform not adequately shaped per design.	Reduced safety or instability of landform. Erosion leading to contamination of water ways. Unsuccessfully revegetated.	4	3	7	Landform is assessed as geotechnically stable by a suitably qualified geotechnical engineer	Proposed landform is to be gently sloping, limiting potential for erosion. Little earthworks will be required to achieve profile.	2	3	5	Landform will be reshaped until stability is achieved.
	Changes to mine plan resulting in additional PAF waste rock.	Unaccounted for material to be disposed of. Financial cost of waste disposal.	3	3	6	Ongoing mine planning throughout LOM. Materials balance regularly updated. Significant freeboard maintained to allow for TSF disposal.	Early detection of inconsistencies between mine plan and rehabilitation plan will allow adequate opportunity to adjust rehabilitation plan.	2	3	5	PAF will be disposed of in the TSF if additional volume cannot be placed underground.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
	Incorrect waste type utilised in rehabilitation works (PAF v NAF)	Contamination of land and water resources	3	4	7	Material is tested multiple times before being added to the appropriate WRD. Material will be tested prior to use in rehabilitation activities. PAF will be removed completely prior to disturbance to the NAF WRD.	MMG employ a rigorous testing process to minimise risk of incorrect storage within WRD. Process will continue during rehabilitation works. Removing PAF first will reduce likelihood that incorrect material is selected and transported.	2	4	6	Ongoing rehabilitation monitoring will identify presence of previously unidentified contaminants. Any contamination will be investigated and further contaminated land sampling/ removal will be conducted as required.
RM7 Landform development and reshaping (RA6)	Landform instability	Stability of landform not being achieved, meaning the PMLU cannot be achieved.	3	4	7	The construction and maintenance design of the cover system / cap will be certified by an appropriately qualified person.	Performance measured through inspection by suitably qualified person	2	4	6	Landform will be reshaped until stability is achieved.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Greater erosion risk and release of contaminants Wildlife exposure to contaminants Reduced ability to sustain vegetation Impacts to rehabilitation timing and achievement of rehabilitation milestones. Cover compromised by vegetation				AQP will certify that landform has achieved an acceptable factor of safety QAQC testing will be completed post construction Biannual vegetation monitoring will be completed.					
RM8 Landform development and reshaping (RA7)	Landform instability	Reduced safety or instability of landform. Erosion leading to contamination of water ways. Unsuccessfully revegetated.	4	3	7	Landform is assessed as geotechnically stable by a suitably qualified geotechnical engineer	Proposed landform is to be gently sloping, limiting potential for erosion. Little earthworks will be required to achieve profile.	2	3	5	Landform will be reshaped until stability is achieved.
RM9 Surface preparation	Insufficient topsoil	Erosion Unsuccessfully revegetated.	4	3	7	Topsoil will be selectively placed at in 5m wide sections.	The area naturally has low volumes of	3	3	6	Ongoing erosion and vegetation

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Cost of repeating landform reshaping and surface preparation.				Additional topsoil will be obtained from an external source if required.	topsoil. Vegetation has proven to establish successfully on rocky areas with limited topsoil.				monitoring will guide management interventions. Additional topsoil or ameliorants will be applied as required.
	Inappropriate topsoil management whilst stockpiled	Reduced viability of topsoil, limiting plant establishment at rehabilitated sites. Topsoil infested with weed propagules, which will invade rehabilitated sites.	3	2	5	Topsoil is managed as per existing site procedures. Topsoil is recorded in the Topsoil Register and is inspected regularly.	Site has established processes to minimise risk.	2	2	4	Topsoil will be inspected prior to application. Any contaminated topsoil will not be used for rehabilitation.
	Vehicles contaminated with weed seeds used for earthworks.	Weeds invading rehabilitated sites, inhibiting the establishment of desirable species and preventing	3	2	5	Vehicles will be inspected prior to entering site. Vehicles will be cleaned in the site washdown bay if	Site has established processes to minimise risk.	2	2	4	A weed treatment program will be implemented, if required.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		achievement of RM11 and RM12.				weeds or seeds are identified.					
	Heavy rainfall occurring prior to establishment of vegetative cover.	Loss of topsoil Siltation of downstream waterways. Failure of vegetation to establish on eroded surfaces. Cost of reapplying topsoil to eroded surfaces	3	2	5	Earthworks will be completed during the dry season. Earthworks will be scheduled progressively so that areas are exposed for the least amount of time possible.	The area has established wet/dry seasons and works can be scheduled.	2	2	4	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
RM10 Revegetation (native ecosystem)	Natural revegetation unsuccessful	Inability to meet RM11 and RM13	3	2	5	Areas will be monitored annually, for 5 years, and seeded if natural vegetation is unsuccessful	Annual monitoring will allow early detection if seeding is required.	2	2	4	Apply seed as required.
	Heavy rain immediately after seeding.	Loss of topsoil. Siltation of downstream waterways. Failure of vegetation to establish on eroded surfaces.	3	2	5	Low slope gradient in landform design to limit capacity for sediment loss. Surface preparation and sowing is not to take place if heavy rain (>40 mm) is	The area has established wet/dry seasons and works can be scheduled taking this into account.	2	2	4	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Cost of reapplying topsoil and seed to eroded surfaces.				forecast over any one day within the next fortnight.					
	Drought over the first months after planting.	Poor seedling survival and establishment. Increased exposure of bare soil leading to erosion	3	2	5	Planting is to take place in the early wet season, when probability of further rain during seedling establishment is high.	The area has established wet/dry seasons and works can be scheduled taking this into account.	2	2	4	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
	Vehicles and/or footwear contaminated with weed seeds	Weeds invading rehabilitated sites, inhibiting the establishment of desirable species and preventing achievement of RM11 and RM13.	3	2	5	Vehicles will be inspected prior to entering site. Vehicles will be cleaned in the site washdown bay if weeds or seeds are identified.	The site has established controls.	2	2	4	A weed treatment program will be implemented, if required.
	Intruding livestock.	Grazing could lead to poor seedling establishment.	2	2	4	RA1 and RA6 largely inaccessible to cattle due to steep slope. Areas will be fenced.	Fencing will limit cattle access.	1	2	3	Rehabilitation monitoring will guide corrective action (reseeding,

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
											etc) as required.
RM11 Revegetation (grazing)	Natural revegetation unsuccessful	Inability to meet RM12 and RM14	3	2	5	Areas will be monitored annually, for 5 years, and seeded if natural vegetation is unsuccessful	Annual monitoring will allow early detection if seeding is required.	2	2	4	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
	Heavy rain immediately after seeding.	Loss of topsoil. Siltation of downstream waterways. Failure of vegetation to establish on eroded surfaces. Cost of reapplying topsoil and seed to eroded surfaces.	3	2	5	Low slope gradient in landform design to limit capacity for sediment loss. Surface preparation and sowing is not to take place if heavy rain (>40 mm) is forecast over any one day within the next fortnight.	The area has established wet/dry seasons and works can be scheduled taking this into account.	2	2	4	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
	Drought over the first months after planting.	Poor seedling survival and establishment.	3	2	5	Planting is to take place in the early wet season, when probability of further	The area has established wet/dry seasons and works can	2	2	4	Rehabilitation monitoring will guide corrective

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Increased exposure of bare soil leading to erosion				rain during seedling establishment is high.	be scheduled taking this into account.				action (reseeding, etc) as required.
	Vehicles and/or footwear contaminated with weed seeds	Weeds invading rehabilitated sites, inhibiting the establishment of desirable species and preventing achievement of RM12 and RM14.	3	2	5	Vehicles will be inspected prior to entering site. Vehicles will be cleaned in the site washdown bay if weeds or seeds are identified.	The site has established controls.	2	2	4	A weed treatment program will be implemented, if required.
	Intruding livestock.	Grazing could lead to poor seedling establishment.	3	2	5	Areas will be fenced until RM12 is achieved.	Fencing will limit cattle access.	2	2	4	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
RM12 Achievement of surface requirements (native ecosystem)	Weed species dominating native species	Weeds spreading to other rehabilitation areas. Outcompeting native species	3	2	5	Annual monitoring to identify high risk areas.	The site has established controls.	2	2	4	A weed treatment program will be

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Cost of treatment Delay in achieving RM				Weed treatment completed early to minimise outbreak					implemented, if required.
	Revegetation unsuccessful	Erosion Potential weed recruitment Delay in achieving RM Cost of additional seeding	3	3	6	Annual monitoring to high risk areas. Seeding to occur if revegetation is not successful	Annual monitoring will allow early detection if seeding is required.	2	3	5	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
	Persistent seepage from TSF	Contamination of land and water resources Risk to native wildlife accessing as drinking water Cost of contaminated liquid disposal. Delay in achieving RM	2	3	5	Seepage collection pond to remain operational until seepage is not detected. Cover system will be applied to limit rainfall infiltration.	The seepage collection pond is a critical control for this risk. Modelling of both the cover system and groundwater has determined that persistent seepage is a low risk.	2	2	4	Seepage collection will remain. Ongoing monitoring of the cover system, vegetation and water quality will guide correction action as required.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
	Significant erosion	Loss of topsoil. Siltation of downstream waterways. Failure of vegetation to establish on eroded surfaces. Cost of reapplying topsoil and seed to eroded surfaces.	3	2	5	Low slope gradient in landform design to limit capacity for sediment loss. Annual monitoring to identify high risk areas	Monitoring will allow early identification and intervention.	2	2	4	Rehabilitation monitoring will guide corrective action (topsoilling etc) as required.
RM13 Achievement of surface requirements (grazing)	Weed species dominating native species	Weeds spreading to other rehabilitation areas. Outcompeting native species Cost of treatment Delay in achieving RM	3	2	5	Annual monitoring to identify high risk areas. Weed treatment completed early to minimise outbreak	Monitoring will allow early identification and intervention	2	2	4	A weed treatment program will be implemented, if required.
	Revegetation unsuccessful	Erosion Potential weed recruitment Delay in achieving RM Cost of additional seeding	3	3	6	Annual monitoring to high risk areas. Seeding to occur if revegetation is not successful	Annual monitoring will allow early detection if seeding is required.	2	3	5	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
	Significant erosion	Loss of topsoil. Siltation of downstream waterways. Failure of vegetation to establish on eroded surfaces. Cost of reapplying topsoil and seed to eroded surfaces.	3	2	5	Low slope gradient in landform design to limit capacity for sediment loss. Annual monitoring to identify high risk areas	Monitoring will allow early identification and intervention.	2	2	4	Rehabilitation monitoring will guide corrective action (topsoilling etc) as required.
	Intruding livestock.	Grazing could lead to poor seedling establishment.	3	2	5	Areas will be fenced until RM12 is achieved.	Fencing will limit cattle access.	2	2	4	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
RM14 Achievement of post mining land use to a stable condition (native ecosystem)	Weed species dominating native species	Weeds spreading to other rehabilitation areas. Outcompeting native species. Cost of treatment. Delay in achieving RM.	3	2	5	Annual monitoring to identify high risk areas. Weed treatment completed early to minimise outbreak	Monitoring will allow early identification and intervention	2	2	4	A weed treatment program will be implemented, if required.

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
	Revegetation unsuccessful	Erosion. Potential weed recruitment. Delay in achieving RM. Cost of additional seeding.	3	3	6	Annual monitoring of high risk areas. Seeding to occur if revegetation is not successful	Annual monitoring will allow early detection if seeding is required.	2	3	5	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
	Persistent seepage from TSF	Contamination of land and water resources Risk to native wildlife accessing as drinking water Cost of contaminated liquid disposal. Delay in achieving RM	2	3	5	Seepage collection pond to remain operational until seepage is not detected. Cover system will be applied to limit rainfall infiltration.	The seepage collection pond is a critical control for this risk. Modelling of both the cover system and groundwater has determined that persistent seepage is a low risk.	2	2	4	Seepage collection will remain. Ongoing monitoring of the cover system, vegetation and water quality will guide correction action as required.
	Significant erosion	Loss of topsoil. Siltation of downstream waterways.	3	2	5	Low slope gradient in landform design to	Monitoring will allow early	2	2	4	Rehabilitation monitoring will guide

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Failure of vegetation to establish on eroded surfaces. Cost of reapplying topsoil and seed to eroded surfaces.				limit capacity for sediment loss. Annual monitoring to identify high risk areas	identification and intervention.				corrective action (topsoiling etc) as required.
RM15 Achievement of post mining land use to a stable condition (grazing)	Weed species dominating native species	Weeds spreading to other rehabilitation areas. Outcompeting native species Cost of treatment Delay in achieving RM	3	2	5	Annual monitoring to identify high risk areas. Weed treatment completed early to minimise outbreak	Monitoring will allow early identification and intervention	2	2	4	A weed treatment program will be implemented, if required.
	Revegetation unsuccessful	Erosion Potential weed recruitment Delay in achieving RM Cost of additional seeding	3	3	6	Annual monitoring to high risk areas. Seeding to occur if revegetation is not successful	Annual monitoring will allow early detection if seeding is required.	2	3	5	Rehabilitation monitoring will guide corrective action (reseeding, etc) as required.
	Significant erosion	Loss of topsoil. Siltation of downstream waterways.	3	2	5	Low slope gradient in landform design to limit capacity for sediment loss.	Monitoring will allow early identification and intervention.	2	2	4	Rehabilitation monitoring will guide corrective

Rehabilitation Milestone	Hazard	Potential Impact	Risk Rating			Risk Controls	Justification of controls	Residual Risk Rating			Remedial Measures
			L	C	R			L	C	R	
		Failure of vegetation to establish on eroded surfaces. Cost of reapplying topsoil and seed to eroded surfaces.				Annual monitoring to identify high risk areas					action (topsoilling etc) as required.
	Landform doesn't support grazing	Delay in achieving PMLU.	3	4	7	Annual monitoring to determine trajectory of vegetation establishment. Re-seeding as required.	PMLU is consistent with surrounding land use. Monitoring will allow early identification and intervention.	2	4	6	Rehabilitation monitoring will guide corrective action (seeding, etc) as required

3.7. Monitoring and Maintenance

3.7.1. Rehabilitation Monitoring Phases

The Rehabilitation Monitoring Program has been designed to demonstrate that RM14 and RM15 have been achieved. There are three main phases to the Project's rehabilitation monitoring program as displayed in Figure 30.

Figure 30. Rehabilitation monitoring phases

3.7.2. Establishment of Reference Sites

Analogue sites will be used to compare rehabilitation success with regard to groundcover, carrying capacity, weed proportion and species mix. Analogue sites will be established for each SMU to be rehabilitated. Analogue sites will be recorded using GIS and signposted to prevent disturbance during operational activities.

Monitoring of analogue sites will be completed using the same monitoring methods employed at rehabilitation areas, as described below. Monitoring will be completed biannually, in the wet and dry seasons, for the first five years of sites being established. Following this, this monitoring program will be spaced at 5-yearly intervals.

Early monitoring of reference sites will allow site specific milestone criteria to be developed for future rehabilitation works.

3.7.3. Monitoring Program

A Monitoring and Maintenance Program has been developed for the Project in accordance with Section 3.8 of the PRC Plan Guideline. The objective of the monitoring program is to evaluate the progress of rehabilitation towards fulfilling the rehabilitation criteria as well as to implement adaptive management techniques and interventions as required. The program will:

- Compare monitoring results against rehabilitation milestone criteria;
- Determine the trajectory of rehabilitation success;
- Identify areas for improvement;
- Compare rehabilitation areas to analogue sites;
- Assess effectiveness of environmental controls;
- Assess vegetation health;
- Identify areas where seeding or the application of fertilizers/ameliorants may be required;
- Assess existing and potential erosion; and
- Assess native fauna species diversity and the effectiveness of habitat creation for target fauna species.

Landscape function analysis will be used to assess the biophysical functioning of the rehabilitated ecosystems, in terms of soil habitat. These assessments will determine how resilient rehabilitated areas are when posed with possible disturbance, high rainfall events, and various climatic conditions. The process provides a snapshot of rehabilitation performance, and how sustainable vegetation will be long-term.

The success of rehabilitated areas will be determined by continued progression, stability, and self-sustainability, with analogue sites providing a comparative basis.

3.7.3.1.1. Initial Monitoring Program

Initial monitoring will occur approximately 12 months after rehabilitation has commenced to observe the success, identify risks, and develop baseline data. The elements of rehabilitation that will be assessed during this program are:

- Landform and erosion;
- Soils;
- Vegetation;
- Fauna;
- Surface water;
- TSF seepage; and
- Groundwater.

3.7.3.1.1.1. Desktop Monitoring

The initial monitoring program will involve desktop monitoring prior to on-site monitoring work. Using LiDAR and aerial imagery, an understanding of the following can be gained:

- Assessing landform design through a Digital Elevation Model;
- Potential erosion areas to investigate during field surveys; and
- Representative locations to establish permanent monitoring plots in respect to the rehabilitation slope, PMLUs, and accessibility.

3.7.3.1.1.2. Landform and Erosion

As discussed in Section 3.1.28, all soil types identified within the Project, express a low to medium erosion risk. Therefore, on ground monitoring will focus on any high risk areas identified during the desktop monitoring. Due to the potential risk of exposed contaminants, a focus area for erosion monitoring will be the capped surface of the TSF. In addition, the TSF will be monitored for surface ponding and infiltration to determine the effectiveness of the cover system. Monitoring locations will be determined based on the final surface of the TSF on closure.

3.7.3.1.1.3. Soil

A soil monitoring program will be developed for the topsoil stockpiles, prior to use, and will aim to:

- Optimise rehabilitation processes;
- Accurately measure utilisation of stockpile storage and soil reuse; and
- Identify the need and rate of soil amelioration.

Additional insitu sampling may be conducted during initial and major monitoring at areas identified as having low vegetation recruitment.

Samples will be acquired and analysed at an accredited laboratory. The analytes proposed to be tested are detailed in Table 34.

3.7.3.1.1.4. Vegetation

Initial vegetation monitoring will focus on germination success rate of target species, through natural revegetation. Vegetation monitoring will be conducted using the following methods:

- Queensland Herbarium Survey Technique (species richness and tree/shrub densities);
- Ground cover percentage method; and
- Photographic monitoring.

3.7.3.1.1.5. Fauna

MMG currently operates a purple necked rock wallaby monitoring program, with monitoring conducted biannually. This program will continue throughout the rehabilitation period until RM13 is achieved. Presence of the PNRW at RA1 and RA6 will provide evidence of successful rehabilitation.

3.7.3.1.1.6. Surface Waters

Event based monitoring will be conducted at surface water monitoring locations as defined in the EA. These monitoring locations will provide data across the whole site, including downstream of the TSF. Surface water quality results will be compared to ANZECC/ARMCANZ (2000) Table 3.3.4 values for slightly to moderately disturbed aquatic ecosystems to determine rehabilitation success. Compliance will be defined as all results complying with the vales for a minimum of five consecutive years.

The REMP monitoring will continue at locations specified in the REMP design document. Reports will be provided to the DETSI as requested. Downstream locations will be compared to reference sites to assess potential impact from rehabilitated areas.

3.7.3.1.1.7. TSF Seepage

Seepage from the TSF will continue to be collected in the seepage collection pond whilst rehabilitation activities are completed. Once the surface of the TSF is capped, seepage will be pumped to a storage tank before being disposed of at a licenced facility. Seepage rates and volumes will be continuously recorded. Regular water quality samples of seepage, surface waters and groundwaters will be obtained during the initial monitoring round. Visual observations will monitor for the presence of seepage at the toe of the embankments and will inform additional monitoring as needed. Additionally, infiltration will be monitored to assess the potential risks of seepage long term.

3.7.3.1.1.8. Groundwater

Groundwater will continue to be monitored quarterly at locations defined in the EA. These monitoring locations will provide data across the whole site, including downstream of the TSF. Water quality results will be compared to ANZECC/ARMCANZ Table 4.3.2 for livestock drinking water. Compliance will be defined as all results from MB5, MB6, MB9S and MB9D complying with the vales for a minimum of five consecutive years.

3.7.3.1.2. Minor Monitoring Methods

Minor monitoring will continue on a biannual basis (wet and dry) for the first five years following rehabilitation. The minor monitoring methods have been designed with two aims; to quickly identify and resolve issues as well as create a replicable record of the condition and success of rehabilitation. The permanent monitoring points from the initial monitoring program will continue along with any new erosion areas identified during monitoring. The aspects of focus are:

- Landform and erosion;
- Vegetation;
- Surface water;
- TSF seepage; and
- Groundwater.

3.7.3.1.2.1. Desktop Monitoring

The minor monitoring will involve desktop monitoring prior to on-site monitoring work. Through the use of LiDAR and aerial imagery, the following can be achieved:

- Update the Digital Elevation Model;
- Identify new areas of potential sedimentation and/or ponding; and
- Identify new areas of erosion for observation.

3.7.3.1.2.2. Landform and Erosion

Along with the permanent monitoring sites created during the initial program, other points identified during the desktop monitoring may be added. The data to be collected includes the coordinates, estimated topsoil coverage, and erosional process, size, state (active, partly stabilised, or stabilised), and severity.

3.7.3.1.2.3. Vegetation

Vegetation monitoring will continue biannually (wet and dry) as per the initial monitoring methods. At the fixed points determined in the initial program, the acceptance criteria will be utilised as required to determine the level of success and ensure the rehabilitation areas are on a trajectory to meet the milestone criteria.

Preliminary completion criteria are presented in Table 53. Completion criteria will be finalised based on results from monitoring at reference sites during the life of the operation.

Table 53 Preliminary completion criteria summary

Criterion	Completion Score
T1 Height	70% of reference site
Total Native Tree Species	70% of reference site
Shrub Species Richness	70% of reference site
Grass Species Richness	70% of reference site
Forbes and Other Species Richness	70% of reference site
Non-native Plant Cover (%)	<10%
Native Perennial Grass Cover (%)	70% of reference site
Native Forbes and Other Species Cover (%)	70% of reference site
Native Shrubs Cover (%)	25% of reference site
Non-native Grass Cover (%)	<10%
Non-native Forbes and Other Species Cover (%)	<10%
Stems/hectare (tree)	70% of reference site
Stems/hectare (shrub	50% of reference site
Stems/hectare (eucalypt)	25% of reference site

3.7.3.1.2.4. Surface Water

Monitoring of surface waters will continue as per the initial monitoring phase.

3.7.3.1.2.5. TSF Seepage

Monitoring of TSF seepage will continue as per the initial monitoring phase.

3.7.3.1.2.6. Groundwater

Monitoring of ground waters will continue as per the initial monitoring phase.

3.7.3.1.3. Major Monitoring Methods

Major monitoring will occur 5 years following rehabilitation, and every 5 years thereafter until a stable condition is achieved. The purpose for the major monitoring is to assess the performance of the rehabilitation. The points to be monitored will continue from the previous phases as well as any additional erosion areas identified during monitoring. The focus of the major monitoring includes:

- Landform and erosion;
- Soil and spoil;
- Vegetation;
- Surface Water;
- TSF Seepage;
- Groundwater; and
- Grazing Land Suitability Assessment.

3.7.3.1.3.1. Desktop Monitoring

The major monitoring will involve desktop monitoring prior to on-site monitoring work. Through the use of LiDAR and aerial imagery, the following can be gained:

- An understanding of historic conditions through a review of previous monitoring reports;
- Update the Digital Elevation Model and compare against previous models to detect changes; and
- Identify new areas of erosion for field validation.

3.7.3.1.3.2. Landform and Erosion

The focus will be towards assessing erosion at previous monitoring locations as well as any other areas identified during desktop monitoring.

3.7.3.1.3.3. Vegetation

Monitoring will continue as described in the initial monitoring methods.

3.7.3.1.3.4. Grazing Land Suitability Assessment

A land suitability assessment will demonstrate achieving the RM15 milestone criteria for a PMLU of cattle grazing at:

- Year five of the major monitoring to allow vegetation to establish; and
- Each scheduled major monitoring from Year 10+ until the rehabilitation meets the milestone criteria.

3.7.3.1.3.5. Surface Water

Monitoring of surface waters is to continue as per the initial monitoring phase. To achieve the PMLU, downstream water quality is required to meet the ANZECC/ARMCANZ (2000) Table 3.3.4 values for slightly to moderately disturbed aquatic ecosystems for five consecutive years.

3.7.3.1.3.6. TSF Seepage

Monitoring of TSF seepage will continue as per the initial monitoring phase.

3.7.3.1.3.7. Groundwater

Groundwater samples will be collected and analysed to achieve milestone criteria. To achieve the PMLU, groundwater quality is required to meet the ANZECC/ARMCANZ Table 4.3.2 for livestock drinking water for five consecutive years.

3.7.3.1.4. Opportunistic Monitoring

The creeks and drainage lines at the Project are ephemeral therefore inhibiting the ability to collect and assess surface water samples within fixed timings. Resultingly, surface water monitoring is required to be undertaken at nominated points when available and accessible. Monitoring will be conducted during releases as per the existing schedule in the EA.

3.7.4. Maintenance

Monitoring activities may identify rehabilitated areas that required additional maintenance. This could be a result of:

- Climate conditions;
- Invasive species;
- Drainage design;
- Insufficient vegetative cover;
- Surrounding land use influence; and
- Soil health.

Where required, maintenance activities will be planned and conducted to ensure the long term success of rehabilitation. Maintenance may include:

- Management of newly recruited vegetation (addition of fertiliser, re-planting of failed vegetation recruitment) prior to its establishment within the ecosystem;
- Repair eroded areas and damage drainage systems;
- Improved management of surface water runoff through modifying landforms or structures;
- Upkeep of water management structures;
- Removing drainage that is not needed for long-term stability; and
- Replacing and repairing fences and signage (where probable).

It is expected that maintenance will be more intensive in the first years following closure and will gradually decrease as PLMUs begin to establish.

3.7.5. Analysis, Recording, and Reporting

All monitoring will occur in accordance with relevant Queensland Guidelines including the Queensland Monitoring and Sampling Manual. This includes appropriately qualified personnel collecting and analysing the samples and data. The data will be analysed to identify trends, changes, anomalies, and to track progress. Throughout the process, the data and achievements will be assessed against the milestone criteria and remedial actions will occur where necessary.

The relevant data will be stored and processed within internal geospatial and document management systems.

3.7.6. Quality Assurance

All staff undertaking monitoring and reporting activities will be suitably qualified for that task. Quality assurance / quality control (QAQC) methodologies will be followed and acted upon should breaches in QAQC procedures occur.

Samples collected will be sent to a NATA accredited laboratory for analysis. For surface water and groundwater samples, at a minimum, for every 10 sites sampled, one field blank, travel blank, and duplicate sample will be taken.

Results from this monitoring program will provide information for future and post-mine closure monitoring requirements.

The monitoring and maintenance allows for a repetitive execution-verification-monitoring QAQC approach to ensure rehabilitation areas progress and achieve the milestone criteria.

3.7.7. Review

This Plan will be reviewed by a SQP should an amendment to the PRCP be made or under timed renewal of the PRCP. In the context of monitoring, a review of the plan must consider:

- Environmental performance;
- Rehabilitation objectives and indicators;
- Environmental inspection outcomes;
- Changes in relevant legislation, policy and guidelines;
- Changes in the mine plan; and
- Rehabilitation completion criteria.

3.7.8. EA Relinquishment

Prior to certification of progressive rehabilitation for part of the Project, or acceptance of EA surrender for part or the whole of the Project tenure, DETSI must be satisfied with the rehabilitation. The decision is based on either a final rehabilitation report (section 264 of the EP Act) for the whole Project tenure or a part being surrendered, or a progressive rehabilitation report for part of the Project (section 318Z of the EP Act).

The Proponent is required to prepare either of the above, including a compliance statement, and submit to DETSI for assessment. Relevant rehabilitation requirements (section 318Z or section 268 of the Ep Act) will be considered by DETSI when deciding whether to certify progressive rehabilitation or to approve surrender application. A post-relinquishment plan will also need to be developed by the proponent to assist with ongoing land management beyond the surrender of the Project tenure.

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Appendix A: PRCP Schedule

Progressive Rehabilitation and Closure Plan Schedule template

Instructions

General Instructions:

- **This form can be used for completing a PRCP schedule for the submission of a progressive rehabilitation and closure plan (PRC plan).**
- **See the PRCP schedule section of the PRC plan guideline (ESR/2019/4964) for further information requirements.**

- A default value of one (1) Rehabilitation Area (RA) is represented by one RA sheets below (RA1).
- A default value of one (1) Improvement Area (IA) is represented by one IA sheet below (IA1).

- To record additional RAs for your project make a copy of the RA sheet below and update it to the relevant RA number (i.e. RA2).
- To record additional IAs for your project make a copy of the IA sheet below and update it to the relevant IA number (i.e. IA2).
- To remove the IA sheet if there is no IA for your project, delete the IA sheet below.

- Each RA and IA sheet contains **two separate excel tables** (yellow and blue) for recording the time-based rehabilitation milestones.
- Add a new column or row to each table as required for your information requirements.

- Two (2) separate sheets below exist for recording the "Rehabilitation Area Milestones" and "Improvement Area Milestones".
- Delete the Improvement Area Milestone sheet if it does not apply to your project.
- Delete additional rows in either sheet if they do not apply to your project.
- See the PRC plan guideline for a list of reference milestones and further information for developing additional site-specific milestones where appropriate.

Further Instructions when inputting PMLUs

Headings under Rehabilitation Area (RA) sheets

Rehabilitation area - The rehabilitation area must align with the spatial information included in the rehabilitation planning part of the PRC plan. This area must have the same PMLU and same milestones applied to the whole area.

Relevant activities - The relevant activities must align with the activities identified in the rehabilitation planning part of the PRC plan. The relevant activities are those undertaken within the rehabilitation area prior to land becoming available for rehabilitation.

Total size of rehabilitation area (ha) - Total size of rehabilitation area in hectares.

Commencement of first milestone - The applicant must nominate a date for when the first milestone for the rehabilitation area will commence. The milestone reference for the first milestone must be included in the heading.

PMLU - The PMLU must align with those identified in the rehabilitation planning part of the PRC plan and in the proposed final site design.

Date area is available - The PRCP schedule must identify when land within the rehabilitation area becomes available for rehabilitation. If the whole rehabilitation area becomes available at once there should be only one date. If the rehabilitation areas becomes available progressively there should be multiple dates. These dates should reflect the information provided in

the rehabilitation planning part of the PRC plan.

Cumulative area available (ha) - The PRCP schedule must identify the area of land within the rehabilitation area that will become available at a given time.

Milestone completed by - The PRCP schedule must identify completion dates for milestones to be completed.

Cumulative area achieved (ha) - The PRCP schedule must show how progressive rehabilitation is being achieved over the life of the mine. This section must reflect the proposed rehabilitation work required for the rehabilitation area to achieve stable condition. The milestone reference to be included refers back to the Rehabilitation Area Milestones sheet with the detailed milestone criteria. The milestones must be achieved consecutively.

Headings under Rehabilitation Area Milestones sheet

Rehabilitation milestone & Milestone criteria - The "rehabilitation milestone" is a short description of the rehabilitation activities. The "milestone criteria" must be able to demonstrate achievement of the milestone.

Further Instructions when inputting NUMAs

Headings under Improvement Area (IA) sheets

Improvement area - The improvement area must align with the spatial information included in the rehabilitation planning part of the PRC plan. This area must have the same NUMA and same milestones applied to the whole area.

Relevant activities - The relevant activities must align with the activities identified in the rehabilitation planning part of the PRC plan. The relevant activities are those undertaken within the improvement area prior to land becoming available for improvement.

Total size (ha) - Total size of improvement area in hectares.

Commencement of first milestone - The applicant must nominate a date for when the first milestone for the improvement area will commence. The milestone reference for the first milestone must be included in the heading.

NUMA - The NUMA must align with those identified in the rehabilitation planning part of the PRC plan and in the proposed final site design.

Date area is available - The PRCP schedule must identify when land within the improvement area becomes available for improvement. If the whole improvement area becomes available at once there should be only one date. If the improvement areas becomes available progressively there should be multiple dates. These dates should reflect the information provided in the rehabilitation planning part of the PRC plan.

Cumulative area available (ha) - The PRCP schedule must identify the area of land within the improvement area that will become available at a given time.

Milestone completed by - The PRCP schedule must identify completion dates for milestones to be completed.

Cumulative area achieved (ha) - The PRCP schedule must show how progressive improvement is being achieved over the life of the mine. This section must reflect the proposed management work required for the improvement area to achieve sufficient improvement. The milestone reference refers back to the Improvement Area Milestones sheet with the detailed milestone criteria. The milestones must be achieved consecutively.

Headings under Improvement Area Milestones sheet

Post-mining land uses (PMLU)										
Rehabilitation area	RA1									
Relevant activities	Ancillary infrastructure and services									
Total rehabilitation area size (ha)	19.76									
Commencement of first milestone: RM1	1-Jan-44									
PMLU	Native ecosystem									
Date area is available	1/01/44	1/01/46	1/01/47	1/01/49	1/01/55					
Cumulative area available (ha)	19.76	19.76	19.76	19.76	19.76					
Milestone completed by	10/12/45	10/12/46	10/12/48	10/12/54	10/12/60					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	19.76									
RM2		19.76								
RM3		19.76								
RM9		19.76								
RM10			19.76							
RM12				19.76						
RM14					19.76					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA2									
Relevant activities	Borrow pits and stockpiles									
Total rehabilitation area size (ha)	43.84									
Commencement of first milestone: RM4	1-Jan-44									
PMLU	Low intensity grazing									
Date area is available	1/01/50	1/01/51	1/01/56							
Cumulative area available (ha)	43.84	43.84	43.84							
Milestone completed by	10/12/50	10/12/55	10/12/60							
Milestone Reference	**Cumulative area achieved (ha)**									
RM4	43.84									
RM9	43.84									
RM11	43.84									
RM13		43.84								
RM15			43.84							

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA3									
Relevant activities	Dams and diversion structures									
Total rehabilitation area size (ha)	32.28									
Commencement of first milestone: RM1	1-Jan-48									
PMLU	Low intensity grazing									
Date area is available	1/01/51	1/01/52	1/01/57	1/01/58	1/01/63					
Cumulative area available (ha)	32.28	32.28	32.28	32.28	32.28					
Milestone completed by	10/12/51	10/12/56	10/12/57	10/12/62	10/12/67					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	32.28									
RM2	32.28									
RM5		32.28								
RM9		32.28								
RM11			32.28							
RM13				32.28						
RM15					32.28					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA4									
Relevant activities	Mineralised waste									
Total rehabilitation area size (ha)	22.56									
Commencement of first milestone:RM2	1-Jan-44									
PMLU	Low intensity grazing									
Date area is available	1/01/48	1/01/51	1/01/52	1/01/53	1/01/58					
Cumulative area available (ha)	22.56	22.56	22.56	22.56	22.56					
Milestone completed by	10/12/50	10/12/51	10/12/52	10/12/57	10/12/62					
Milestone Reference	**Cumulative area achieved (ha)**									
RM2	22.56									
RM6		22.56								
RM9		22.56								
RM11			22.56							
RM13				22.56						
RM15					22.56					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA5									
Relevant activities	Mining and processing areas									
Total rehabilitation area size (ha)	180.78									
Commencement of first milestone:RM2	1-Jan-44									
PMLU	Low intensity grazing									
Date area is available	1/01/44	1/01/45	1/01/46	1/01/46	1/01/49	1/01/50	1/01/51	1/01/55		
Cumulative area available (ha)	124.2	124.2	180.78	180.78	180.78	180.78	180.78	180.78		
Milestone completed by	10/12/44	10/12/45	10/12/48	10/12/50	10/12/49	10/12/54	10/12/55	10/12/59		
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	124.2		86.58							
RM2	124.2		86.58							
RM6	124.2		86.58							
RM9		124.2			86.58					
RM11		124.2			86.58					
RM13				124.2		86.58				
RM15							124.2	86.58		

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA6									
Relevant activities	Tailings Storage Facility (TSF)									
Total rehabilitation area size (ha)	109.88									
Commencement of first milestone: RM1	1-Jan-44									
PMLU	Native ecosystem									
Date area is available	1/01/44	1/01/48	1/01/51	1/01/53	1/01/58					
Cumulative area available (ha)	109.88	109.88	109.88	109.88	109.88					
Milestone completed by	10/12/47	10/12/50	10/12/52	10/12/57	10/12/70					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	109.88									
RM7		109.88								
RM9			109.88							
RM10			109.88							
RM12				109.88						
RM14					109.88					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Post-mining land uses (PMLU)										
Rehabilitation area	RA7									
Relevant activities	Renewable energy infrastructure									
Total rehabilitation area size (ha)	67.07									
Commencement of first milestone: RM1	1-Jan-44									
PMLU	Native ecosystem									
Date area is available	1/01/44	1/01/45	1/01/46	1/01/47	1/01/50					
Cumulative area available (ha)	67.69	67.69	67.69	67.69	67.69					
Milestone completed by	10/12/44	10/12/45	10/12/46	10/12/49	10/12/54					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	67.07									
RM2		67.07								
RM8		67.07								
RM9			67.07							
RM10			67.07							
RM12				67.07						
RM14					67.07					

1) Insert new columns to the yellow table to include further rehabilitation milestone dates.
2) Insert new columns to the blue table to match rehabilitation milestone dates.
3) Insert new rows to the blue table to include additional rehabilitation milestone references.
4) Insert the relevant number in the "Milestone reference" column (i.e. RM1).

Milestone reference	Rehabilitation milestone	Milestone criteria
RM1	Infrastructure decommissioning and removal	For all areas: a) All buildings and associated infrastructure are dismantled and removed offsite. b) All hardstand and concrete areas are decommissioned and removed. c) Fences are removed. d) All pipelines are removed. e) Powerlines and supporting electrical infrastructure (above and below ground) are removed. f) Roads removed (with the exception of those being retained for future site access). g) Waste is removed. h) Drillholes, sediment ponds and sumps decommissioned. i) Machinery/ equipment not required for rehabilitation removed from site. For RA7: j) All infrastructure is decommissioned and removed from site in accordance with EODMP under the supervision of an AQP
RM2	Removal of contaminated land	a) Contaminated land assessment is completed by a suitably qualified person. b) Any identified contaminated material is removed from the mine domain and disposed of at a licenced facility. c) Validation sampling determines that contaminant removal has been successful. d) The validation sampling report is accepted by a suitably qualified Contaminated Land Auditor stating that contamination removal has been successful.
RM3	Landform development and reshaping - RA1	a) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. b) Landform is ripped parallel to contour. c) Features such as large woody debris or boulders are situated to provide suitable habitat for the Purple Neck Rock Wallaby. d) RA1 is determined to be geotechnically stable by a suitably qualified geotechnical engineer.
RM4	Landform development and reshaping - RA2	a) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. b) Landform is ripped parallel to contour. c) RA2 determined to be geotechnically stable by a suitably qualified geotechnical engineer.
RM5	Landform development and reshaping - RA3	a) General earthworks completed. b) HPDE Liner removed. c) Dams filled with NAF or other suitable material. Material placed in 500mm lifts, watered and compacted. d) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. e) RA3 determined to be geotechnically stable by a suitably qualified geotechnical engineer.
RM6	Landform development and reshaping - RA4/RA5	a) Removal of waste rock. PAF material is disposed of underground. NAF material utilised in rehabilitation. b) Major earthworks are completed. c) Landform is shaped to be gently sloping, characteristic of the natural landform with natural drainage lines reinstated. d) Land reshaped to final landform design with suitable material as assessed by AQP and as per EODMP, where required. e) RA4/RA5 is determined to be geotechnically stable by a suitably qualified geotechnical engineer.

RM7	Landform development and reshaping - RA6	a) The construction of the cover system / cap has been certified by an appropriately qualified person as being consistent with the cover design. b) QAQC testing is completed post construction at a rate of at least 1 sample per ha and confirms depth of layers and permeability is to specified designs and no PAF material is present within the cover system. c) Primary monitoring locations have been established in representative locations recommended as an outcome of the trial mentioned in Condition PRCP5(e) and include: I. An automated meteorological station that records the following: rainfall (tipping bucket), i. evaporation, ii. relative humidity, iii. wind strength, iv. wind direction, and v. air temperature. II. piezometers within the tailings and capillary break layer, III. automated in situ water content and suction sensors in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals (except in the capillary break), IV. temperature sensor in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals, V. a lysimeter. d) Secondary monitoring locations have been established in representative locations recommended as an outcome of the trial mentioned in Condition PRCP5(e) and include in each layer of the cover system and in the tailings below the cover system: I. piezometers within the tailings and capillary break layer, II. automated in situ water content sensors in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals (except in the capillary break). e) Temperature sensor in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals. All sensors are calibrated to each material type using the manufacturers specifications. f) Lysimeters and associated drainage collection and monitoring system are installed in at least 3 locations that are recommended as an outcome of the trial mentioned in Condition PRCP5(e). g) Sediment capture flumes have been installed and calibrated at the base of the TSF embankment. h) All monitoring equipment has been installed and calibrated by an appropriately qualified person. i) Slopes of TSF surface have a grade of <1.5% j) Certification by an AQP that landform has been constructed according to the design and has achieved an acceptable factor of safety. k) Spillway is reinstated at RL 242.1m. Spillway has an approximate length of 330m and a longtitudinal grade of 2.0%. l) TSF is assessed as geotechnically stable by a suitably qualified geotechnical engineer. m) Features such as large woody debris or boulders are present to provide suitable habitat for the Purple Neck Rock Wallaby. n) TSF surface has been shaped to prevent ponding and concentration of surface water flow. o) Spillway is designed and constructed to support peak flood flow velocity. p) Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y. q) Erosion rilling is <0.2m. r) No surface ponding. s) Installation of erosion and sediment control structures that comply with International Erosion Control Association (IECA).
RM8	Landform development and reshaping - RA7	a) Land reshaped to final landform design with suitable material as assessed by AQP and as per EODMP. b) Features such as large woody debris or boulders are situated to provide suitable habitat for the Purple Neck Rock Wallaby. c) RA7 is determined to be geotechnically stable by a suitably qualified geotechnical engineer.
RM9	Surface preparation	a) Deep ripping of compacted surfaces, at least 300mm into soil profile, where required and avoiding habitat features associated with RM3 and RM8. b) An assessment of the need for soil amelioration undertaken and soil ameliorants such as fertiliser, gypsum and/or organic matter have been applied at rates determined by an appropriately qualified person. c) Topsoil placement of 0.1 - 0.2 m
RM10	Revegetation (native ecosystem)	a) Seeding rate of 4 – 10 kg/ha is applied. b) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2 and 1.7.7 on RA1 including *Eucalyptus leucophloia, Corymbia terminalis, Corymbia capricornia* with a groundcover of *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus,Themeda triandra, Triodia pungens* . c) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2 and 1.7.7 on RA6 including *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus,Themeda triandra, Triodia pungens* . d) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2a/1.7.7a and RE1.11.3a/1.3.13a on RA7, including the terrestrial species of *Eucalyptus leucophloia, Corymbia terminalis* and *Corymbia capricornia* with a groundcover of *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus, Themeda triandra* and *Triodia pungens.* e) Direct seeding species mix on RA7 including riparian species of *Eucalyptus camaldulensis, Corymbia capricornia, Sporobolus australasicus* , Melaleuca species, Lophostemon species and other suitable wetland groundcover species in riparian vegetation zones. f) Deep rooting vegetation such as Eucalyptus Spp not present on RA6. g) Groundcover >50%.
RM11	Revegetation (grazing)	a) Direct seeding is applied at a rate of 4 – 10 kg/ha. b) Direct seeding of native species including *Eucalyptus leucophloia, Corymbia capricornia, Terminalia aridicola, Corymbia terminalis, Triodia pungens, Eucalyptus pruinose, Eremophila longifolia, Atalaya hemiglauca, Acacia chisholmi,i Atalaya hemiglauca, Carissa lanceolata* as well as appropriate 3P grass species to support the PMLU. c) Pasture vegetation seeding creates cover >30%.

RM12	Achievement of surface requirements (native ecosystem)	For all areas: a) Weed species in densities less than 10% total coverage. b) Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y. c) Vegetation cover 70%. d) Species used in revegetation in RM10 remain present and showing evidence of natural recruitment. e) Surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly to moderately disturbed). f) Stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low. g) Quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA. h) Soil testing indicates the following parameters are met: I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth). For RA6: i) There is no evidence of water ponding on the surface of the TSF. j) Continuous recording demonstrates seepage volume is decreasing. k) Seepage is collected and disposed of at an appropriately licensed facility. l) In-situ permeability and surface infiltration are not significant deacreasing compared with initial rates based on statisical analysis. For RA7: m) Certification from AQP that all actions required in EODMP to achieve surface requirements have been completed. n) All temporary erosion and sediment control and stormwater management structures have been removed. o) No erosion classified as “moderate” or “severe”3. p) Riparian monitoring is undertaken every year5, which shows a progressive improvement in the following attributes; tree species richness, bank stability, recruitment and projected foliage cover, or is similar to, representative reference ephemeral waterways in the region q) Rehabilitated watercourses are stable and do not create any upstream or downstream impacts, as certified by an AQP.
RM13	Achievement of surface requirements (grazing)	a) Weed species in densities less than 10% total coverage. b) Pasture covers has reached 70% of surface area. c) Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y. d) Surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly disturbed). e) Stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low. f) Quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA. g) Soil testing indicates the following parameters are met: I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth). For RA5: h) Certification from AQP that all actions required in EODMP to achieve surface requirements have been completed.

RM14	Achievement of post-mining land use to a stable condition (native ecosystem)	For all areas: a) Vegetation cover exceeds 70% of the surface area. b) All species used in RM10 show natural recruitment. c) Weed species in densities less than 10% total coverage. d) Native fauna observed or indicators of these species have been recorded. e) There is no evidence of seepage occurring within the mining tenure. f) Certification from an REPQ that the domain has achieved stable condition.4 g) Certification from an AQP that the landform achieved a factor of safety 1.5. h) All results from surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly disturbed) for a minimum of 5 consecutive years.1 i) All results from stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low for a minimum of 5 consecutive years. j) All results from quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA for a minimum of 5 consecutive years. k) Soil testing undertaken at yearly intervals indicates the following parameters are met: I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth). For RA1: l) No evidence of erosion classified as 'Severe'3. m) No active erosion present as demonstrated by no increase in erosion ratings3 over time. For RA6: n) There is no evidence of water ponding on the surface of the TSF. o) Average erosion rate of <5 t/ha/y. p) No evidence of erosion classified as 'moderate' or 'severe'. q) No evidence of salt rise through the cover system of the TSF. r) In-situ permeability and surface infiltration are not significantly decreasing compared with initial rates based on statistical analysis. s) Results of monitoring gathered from primary and secondary monitoring stations established in RM7 demonstrate the following has been maintained for a minimum of 10 years: I. Hydraulic conductivity of the cover system is less than 1 x 10-8 m/s for at least 10 years, II. Net percolation through the cover into the tailings has been reduced to <5% of rainfall for at least 10 years as measured by primary and secondary monitoring locations and lysimeters, III. Water content of the reduced permeability layer is maintained above 85% over a 10 year period, IV. Temperature within the tailings has not increased over a 10 year period, V. Volumetric water content of tailings does not respond to rainfall events. For RA7: t) Certification by AQP that all actions as required in the EODMP to achieve a stable condition have been completed.
RM15	Achievement of post-mining land use to a stable condition (	a) Weed species in densities less than 10% total coverage. b) Vegetation cover has reached 70%. c) All established species show natural recruitment. d) Land suitability assessment by an appropriately qualified person certifies land has achieved a post-mine land suitability2 of 42 or better. e) Minimum of 4 palatable perennial pasture species and 2 shade tree species established. f) No evidence of erosion classified as 'Severe'3. g) No active erosion present as demonstrated by no increase in erosion ratings3 over time. h) There is no evidence of seepage occurring within the mining tenure. i) Certification from an REPQ that the domain has achieved stable condition.4 j) Certification from an AQP that the landform achieved a factor of safety 1.5. k) All results from surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly to moderately disturbed) for a minimum of 5 consecutive years.1 l) All results from stream sediment at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with limits set for low risk and no adverse effects in ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low for a minimum of 5 consecutive years. m) All results from quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA for a minimum of 5 consecutive years. n) Soil testing undertaken at yearly intervals indicates the following parameters are met: PAWC >50 at Red Plain and Pocket soil types, I. Rootzone EC <0.15mS/cm, II. Soil pH <9 and >6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) <5% (at 0-10cm depth), IV. Carrying capacity is suitable to support a sustainable level of grazing. For RA5: o) Certification by AQP that all actions as required in the EODMP to achieve a stable condition have been completed.

1) Insert new rows below the table to record more Rehabilitation Area Milestones for the project

2) Ensure all Rehabilitation Milestones recorded in this table align with those included in the RA sheets in this form.
3) See the PRCP guideline before developing site-specific Rehabilitation Area Milestones

Milestone reference	Management milestone	Milestone criteria
MM1		
MM2		
MM3		
MM4		
MM5		
MM6		
MM7		
MM8		
MM9		
MM10		

1) Insert new rows below the table to record more Improvement Area Milestones for the project
2) Ensure all Management Milestones recorded in this table align with those included in the IA sheets in this form.
3) See the PRCP guideline before developing site-specific Improvement Area Milestones

Appendix B: DRM Community and Social Performance Standard

COMMUNITY AND SOCIAL PERFORMANCE

WORK QUALITY REQUIREMENT

DUGALD RIVER MINE

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1 PURPOSE

The purpose of this Work Quality Requirement (WQR) is to provide an overview of MMG's Dugald River Mine (DRM) social performance activities and to explain their significance in meeting local community expectations as well as MMG standards and international obligations. It also outlines how DRM's social performance reporting frameworks are to be used to inform and guide MMG's interactions with local/host communities (Cloncurry, Kalkadoon Traditional Owners and the North West Minerals Province which includes Mount Isa).

Recognising the 'people aspect' of MMG's business and committing to strong social performance is critical to delivering on MMG's vision *'To build the world's most respected mining company'* and meeting the MMG Social Performance Standard.

MMG also adheres to international best practice, with relevant International Council of Mining and Metals (ICMM) membership commitments including:

- Principle 3: Respect human rights and the interest, cultures, customs and values of employees and communities affected by our activities.
- Principle 9: Pursue continual improvement in social performance and contribute to the social, economic and institutional development of host countries and communities. ICMM members commit to support effective management of local grievances. This is supported by meaningful engagement with local people, taking care to include women, vulnerable or marginalised groups.
- Principle 10: Proactively engage key stakeholders on sustainable development challenges and opportunities in an open and transparent manner, effectively report and independently verify progress and performance.

MMG additionally commits to align all social investment to the first six United Nations Sustainable Development Goals (UN SDGs). These include: no poverty; zero hunger; good health and wellbeing; quality education; gender equality; and clean water and sanitation.

This WQR document summarises the practical actions that MMG's DRM takes to ensure all necessary compliance in respect of the local context. Respectful efforts to minimise adverse impacts and maximise benefits in local communities also help MMG maintain its intangible, but important, social licence to operate.

Nº	Document Title and Link	Document Type
1.	International Council on Mining & Metals – https://www.icmm.com/	Website
2.	United Nations Sustainable Development Goals https://sdgs.un.org/goals	Website

2 SCOPE

This document applies to all DRM People and all activities controlled or managed by MMG or where stipulated to be in partnership with MMG. It addresses how the Social Performance Standard is met by DRM, and supports assurance of the standard, which is to be conducted periodically in line with the MMG Assurance Framework.

Nº	Document Title and Link	Document Type
1.	MMG Social Performance Standard - http://mmglibrary.myintranet.local/otcs/cs.exe?func=ll&objId=12975735&objAction=download	Standard
2.	MMG Assurance Framework - https://mmglibrary.mmg.com/otcs/llisapi.dll?func=ll&objId=40863121&objAction=download&viewType=1	Framework

3 ACRONYMS AND ABBREVIATIONS

LIST OF ACRONYMS AND ABBREVIATIONS			
DRM	Dugald River Mine	EIS	Environmental Impact Statement
ICMM	International Council on Mining & Metals	KPIs	Key Performance Indicators
SBS	Socio-economic Baseline Study	SIMP	Socio-economic Impact Management Plan
SMP	Stakeholder Management Plan	SIOA	Socio-economic Impact and Opportunities Assessment
SIP	Social Investment Plan	The EA	Environmental Authority EPML00731213
UNSDGs	United Nations Sustainable Development Goals	WQR	Work Quality Requirement

4 LAND ACCESS AND CULTURAL HERITAGE

All activities controlled by MMG's DRM are established and operated on lands owned or leased by MMG and secured through processes that respect legal and traditional rights of landholders.

4.1 LAND ACCESS AND ENVIRONMENTAL AUTHORITY

Activities at MMG DRM is authorised under the *Mineral Resources Act 1989*, and the *Environmental Protection Act 1994*. This is reflected in Environmental Authority EPML00731213 (the EA). The EA sets the minimums standards for environmental protection. MMG then has a series of procedures and work quality requirements to ensure obligations required under the EA are met.

The EA requires that MMG's DRM consult, promote and maintain easily accessible lines of communication between residents, stakeholders and landowners. MMG facilitates this by hosting regular community consultation meetings (Community Consultative Group and Kalkadoon meetings both occur within no more than 6 months intervals A26). Contact details are also provided on the MMG website (www.mmg.com), and in the window of MMG's Cloncurry office as follows:

General Enquiries/Site Contact
Phone: +61 7 4442 0630
Email: dr_siteadmin@mmg.com

Community Issues/Grievances
Phone: +61 1800 532 007
Email: dugaldrivercsp@mmg.com

Nº	Document Title and Link	Document Type
1.	DRM Environmental Authority EPML00731213 - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/15153694	Environmental Authority
2.	Mineral Resources Act 1989 - https://www.legislation.qld.gov.au/view/html/inforce/current/act-1989-110	Legislation
3.	Environmental Protection Act 1994 - https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-1994-062	Legislation

4.2 CULTURAL HERITAGE MANAGEMENT

MMG's DRM values and respects local cultures and traditions, particularly that of the Kalkadoon Traditional Owners. Cultural Heritage agreements for DRM between MMG and the Kalkadoon People have been designed to comply with the *Queensland Aboriginal Cultural Heritage Act 2003, The Queensland Heritage Act 1992 and Torres Strait Islander Cultural Heritage Act 2003.* These are reflected in the ancillary agreement between Oz Minerals/MMG and the Kalkadoon People and the cultural heritage management procedure.

These documents define the base standards MMG's DRM must adhere to in complying with the agreements and legislation.

Nº	Document Title and Link	Document Type
1.	Oz Minerals/MMG and Kalkadoon Agreement - https://mmglibrary.mmg.com/otcs/cs.exe/app/nodes/1663383	Agreement
2.	DRM Cultural Heritage Management Procedure - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/39260027	Procedure
3.	Queensland Aboriginal Cultural Heritage Act 2003 - https://www.legislation.qld.gov.au/view/html/inforce/current/act-2003-079	Legislation
4.	The Queensland Heritage Act 1992 - https://www.legislation.qld.gov.au/view/html/inforce/current/act-1992-009	Legislation
5.	Torres Strait Islander Cultural Heritage Act 2003 - https://www.legislation.qld.gov.au/view/html/inforce/current/act-2003-080	Legislation

5 SOCIAL BASELINE STUDIES AND SOCIAL IMPACT AND OPPORTUNITIES

A socio-economic baseline study (SBS) and socio-economic impact and opportunities assessment (SIOA) were completed by Nation Partners in 2019 to comply with MMG's Social Performance Standard, which requires these reports are updated at least every 5 years (in line with international best practice). The Nation Partners reports build on, and provide an update to, those prepared in 2010/11 by AustralAsian Resource Consultants, as part of DRM's Environmental Impact Statement (EIS) under the *Environmental Protection Act 1994*.

The SBS and SIOA have slightly different focuses as explained below, although collectively identify demographic aspects, issues and perceptions of stakeholders and interested parties from communities local to DRM. The SBS provides rich and important contextual information about the local communities, however the SIOA is the key report of interest from a social performance perspective and in the eyes of regulators because it focuses on the meaningful management of socio-economic impacts and opportunities associated with DRM. This helps build earnest project support from local communities and in turn, a social licence to operate.

5.1 SOCIAL BASELINE STUDY

The SBS prepared for MMG by Nation Partners in 2019 profiles the key socio-economic and cultural characteristics of regional and local communities which interface with MMG's DRM. The focus of the SBS is on objectively investigating past, current and projected socio-economic data. This helps MMG understand the community dynamics that existed prior to, and independent of, DRM versus those which appear to have been influenced by the project. The SBS therefore informs the SIOA by providing insights into the community's likely vulnerability to project influences and potentially its ability to adapt to change. SBS data also provides benchmark conditions against which potential social impacts can subsequently be measured and monitored over time. Furthermore, the findings of the SBS are very valuable because they help MMG's DRM understand who their local communities are relative to other sites, and inform the design and nature of DRM's stakeholder engagement and social investment activities so they are culturally and contextually appropriate.

Nº	Document Title and Link	Document Type
1.	Dugald River Mine – Social Baseline Study - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/38399043	Report
2.	Environmental Protection Act 1994 - https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-1994-062	Legislation

5.2 SOCIO ECONOMIC IMPACTS AND OPORTUNITIES

The SIOA prepared for MMG by Nation Partners in 2019 reports on project-related socio-economic impacts and opportunities on surrounding local and regional study communities. It covers the identification, analysis, assessment, management and monitoring of a project's social and economic impacts, both positive and negative. In contrast to the SBS, the SIOA draws on baseline data in conjunction with community engagement feedback regarding the project and comparable project experiences elsewhere to analyse key issues as assessable social and economic impacts and opportunities associated with DRM. The SIOA includes impact management measures and impact monitoring and is typically accompanied with a supporting socio-economic impact management plan (SIMP). Nation Partners prepared a DRM SIMP in 2019. SIMPs have long been considered international best practice, although are now mandatory in Queensland whenever an EIS process is triggered for large resource projects. This is due to the introduction of the *Strong and Sustainable Resource Communities Act 2017* which mandates use of the Queensland Government's 2018 Social Impact Assessment Guidelines. These guidelines were followed when preparing the SIOA and SIMP.

Nº	Document Title and Link	Document Type
1.	Dugald River Mine – Social Impacts and Opportunities - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/38439710	Report
2.	Environmental Protection Act 1994 -*1994* https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-1994-062	Legislation

3.	Strong and Sustainable Resource Communities Act 2017 - https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2017-028	Legislation
4.	Queensland 2018 Social Impact Assessment Guidelines - https://www.statedevelopment.qld.gov.au/coordinator-general/strong-and-sustainable-resource-communities/social-impact-assessment	Guidelines
5.	Dugald River Mine – Socio-Economic Impact Management Plan - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/39097377	Plan

6 SOCIAL DEVELOPMENT AND COMMUNITY ENGAGEMENT

Dugald River Mine is committed to the future of our local/host communities thorough supporting education and skills development for future generations as well as preserving the history of our region's through infrastructure and legacy preservation. Social investments, social commitments and community engagement tools are used to achieve these outcomes which will create MMG's long term positive legacy.

6.1 SOCIAL INVESTMENT

A DRM Social Investment Plan (SIP) was prepared by Nation Partners in 2019 to create improved processes for managing MMG's social investment, which is defined to incorporate multi-stakeholder partnerships, social development programs, sponsorships and community contributions (including employee volunteering). The SIP outlines community goals for Cloncurry and Kalkadoon (distilled from community engagement feedback), local and regional government planning directives and MMG's business drivers and sustainability objectives. These are integrated into social investment criteria to promote maximum shared value for community, government and MMG. The SIP contains a practical tool to apply the criteria and allow social investment proposals to be objectively evaluated to better determine how available funding can best be utilised to positively contribute to the social and economic development of the area. MMG have also updated MMG's DRM Sponsorship Program Application Kit form, which helps community members preparing a proposal to clearly demonstrate the anticipate benefit and any shared value across stakeholder groups.

MMG's DRM develop a yearly social development investment budget, aligned with the Social Performance Standard and the DRM Social Investment Plan, and track progress. Borealis is to be used to store social investment and sponsorship proposals, decisions, agreements, and evaluations, and report on key milestones and community contributions (cash and in-kind), to ensure reporting is based on DRM's total social investment. Investments are to be assessed using appropriate metrics where possible to evaluate whether anticipated benefits have materialised (See SIMP for monitoring and evaluation guidance).

Nº	Document Title and Link	Document Type
1.	Dugald River Mine - Social Investment Plan - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/38439397	Plan
2.	MMG Sponsorship Program – Application Kit http://www.mmg.com/en/Our-Operations/Mining-operations/Dugald-River.aspx	Form
3.	Dugald River Mine – Socio-Economic Impact Management Plan https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/39097377	Plan

6.2 SOCIAL COMMITMENTS

The DRM Social Commitments and Agreements Procedure outlines the processes and requirements for commitment and agreement making, and for establishing and maintaining the DRM site-level Social Commitments and Agreements Register through Borealis (MMG's stakeholder management system). A commitment is defined as a pledge, promise and/or public or private statement of intent to do something for someone on behalf of MMG while an Agreement is a decision or arrangement between MMG and one or more stakeholders. More detailed interpretations of these terms are provided in the procedure. Designed for internal use, the procedure ensures that commitments are made with due consideration of the potential benefits and risks and are appropriately authorised. It also holds MMG's personnel accountable for commitments and agreements made internally as well as those made with, and for, external stakeholders.

Nº	Document Title and Link	Document Type
1.	Dugald River Mine - Social Commitments and Agreements Procedure - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/6952270]	Procedure

6.3 COMMUNITY ENGAGEMENT

A Stakeholder Management Plan (SMP) was prepared by Nation Partners for MMG in 2020 to guide communications with stakeholders and manage relationships across the lifecycle of the DRM, with a focus on operations. It provides a framework for comprehensive and strategic planning of community engagement activities. It also supports long-term improvements to the social performance of the DRM, enhancing MMG's reputation among local communities and helping the company build and maintain a social license to operate.

Prepared in alignment with ICMM principles and the International Association for Public Participation Australasia (IAP2) Spectrum, the SMP identifies key stakeholders impacted by, or with an interest in, the DRM, and outlines areas of interest for each stakeholder group and the likely extent of the engagement. Stakeholder groups include local communities, marginalised and vulnerable groups, affected individuals and landholders, local government, local opinion leaders, health and education providers, community groups and non-government organisations. The SMP identifies tailored communications methods and tools relevant for engaging different stakeholders. Stakeholder grievance management processes are also outlined and a monitoring and evaluation framework is included to support continual improvement.
Nation Partners additionally prepared a Community Engagement Plan in 2019 to guide targeted community engagement activities occurring in support of the social performance reporting being undertaken at that time.

All stakeholder engagement activities and mapping are to be captured in Borealis.

Nº	Document Title and Link	Document Type
1.	Dugald River Mine Stakeholder Management Plan	Plan
2.	Dugald River Mine – Community Engagement Plan - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/30361782	Plan

7 LOCAL EMPLOYMENT AND LOCAL SUPPLY

7.1 LOCAL EMPLOYMENT

The DRM Local Employment Framework describes the MMG processes and procedures used to manage local employment at the DRM, and outlines associated benefits. It has been established in response to concerns raised by the community in 2019 in relation to the relatively low levels of local employment at the mine, and a perceived lack of commitment to change this.

MMG is committed to supporting its people to live locally, having established a variety of incentives and initiatives to encourage greater uptake of employment among the existing local community, and attract current and future DRM employees to move to the local area. The framework has been developed to articulate DRM's commitment to promoting the growth of its locally based workforce. The document highlights the package of benefits available to local employees, and MMG's broader initiatives intended to enhance the education and long-term employability of the local population and offset some of the key barriers that often deter people from living in a remote community (i.e., to encourage population growth in the region).

The DRM Local Employment Framework assists with compliance against Part 2, Section 6 of the Strong and Sustainable Resource Communities Act 2017 which states Prohibition on 100% fly-in fly-out workers for large resource projects close to local communities.

Nº	Document Title and Link	Document Type
1.	Dugald River Mine Local Employment Framework – Contact HR Department	Framework
2.	Strong and Sustainable Resource Communities Act 2017 - https://www.legislation.qld.gov.au/view/pdf/inforce/current/act-2017-028	Legislation

7.2 LOCAL SUPPLY

DRM is committed to the regions in which we operate and endeavours to establish positive engagements with the communities in close proximity to our assets. As part of DRM's procurement strategy, we aim to develop sustainable supply options in our host communities. MMG's Dugald River Local Supply Management Plan communicates the DRM policies and measures designed to maximise local procurement opportunities. This document includes an action plan and discussion of how DRM's Sourcing and Contracting process involves MMG routinely undertaking an assessment of prospective and existing suppliers to understand their capabilities. These suppliers are provided with information regarding DRM's goods and service needs and the typical terms of engagement. MMG selects suppliers which meet required standards across safety, quality and commercial criteria. Where local suppliers demonstrate these attributes, MMG provides them with opportunities to supply DRM.

Nº	Document Title and Link	Document Type
1.	Dugald River Local Supply Management Plan - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/36043146	Procedure

8 STAKEHOLDER GRIEVANCES AND SOCIAL INCIDENTS

DRM's grievance mechanism is a tool to strengthen engagement with local stakeholders, build trust and stakeholder support for its operations and demonstrate a commitment to respecting and upholding human rights. Through identifying potential and actual impacts, including human rights impacts, DRM can critically examine its operations and implement appropriate controls. Maintaining collaborative and positive relationships with our stakeholders is critical to the long-term success of DRM. All grievances received through the mechanism are to be responded to in a timely manner and processed through, and stored in, Borealis.

Nº	Document Title and Link	Document Type
1.	Dugald River Mine - Grievance Procedure - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/6991881	Procedure

9 SOCIAL PERFORMANCE COMPETENCY

MMG's DRM has committed to conducting a site-specific Social Performance Competency Assessment every two years for all Social Development and Community Relations employees, to identify competency gaps and training requirements, these gaps will then be loaded against employees My Commitment & My Development goals. Testing was last routinely completed in 2020 by MMG's corporate team. MMG's DRM is currently investigating alternative and more thorough systems of competency testing for application in 2022.

10 MONITORING AND EVALUATION

In line with its ICMM membership commitment to continual improvement in social performance, MMG's DRM recognises the importance of monitoring and evaluation. Nation Partners prepared the aforementioned SIMP and SIP reports which explicitly address monitoring and evaluation from a social performance perspective.

The SIMP provides a practical framework for the implementation of the social impact mitigation and opportunity enhancement measures outlined in the SIOA, including an overview of associated monitoring and evaluation activities. The SIMP details appropriate Key Performance Indicators (KPIs) and monitoring mechanisms to measure the extent to which each mitigation or enhancement measure implemented by MMG is successful in achieving its intended outcome.

The SIP outlines how social investment can be assessed using metrics which evaluate whether anticipated community and business benefits have materialised and other strategic goals have been satisfied. Monitoring and evaluation of the social investments (cash and in-kind) against their objectives and designated KPIs including relevant UN SDG/s occurs in Borealis. Stakeholder surveys are key in obtaining up-to-date and unbiased feedback. Nation Partners investigated DRM's social performance with surveys in 2019, while MMG regularly surveys stakeholders on its social investments to monitor and evaluate success and to support continual improvement.

Nº	Document Title and Link	Document Type
1.	Dugald River Mine – Socio-Economic Impact Management Plan https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/39097377	Plan
2.	Dugald River Mine - Social Investment Plan - https://mmglibrary.mmg.com/otcs/llisapi.dll/app/nodes/38439397	Plan

Appendix C: DRM Community Engagement Plan

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Dugald River Draft Community Engagement Plan

Prepared for MMG by
Nation Partners

24 May 2019

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Document title
Dugald River Draft Community Engagement Plan

Version
[0.0]

Date
May 2019

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File name
Dugald River Draft CEP v1.0

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Dugald River Community Engagement Plan

1. Introduction

Nation Partners has been engaged to undertake a suite of social performance related tasks for the Dugald River project and has prepared the following community engagement plan (CEP) to identify the communications and consultation activities required to support this work.

Dugald River mine is a zinc and lead mine located in north-western Queensland (QLD) approximately 65 kilometres northwest of Cloncurry and approximately 85 kilometres north-east of Mount Isa. It is among the top 10 largest zinc mines globally and has an expected lifespan of 25 years. During this time, it is anticipated the mine will annually process about 170,000 tonnes of zinc in zinc concentrate, plus by-products.

MMG submitted a final Environmental Impact Statement (EIS) for the project in December 2010, which was approved by the Department of Environment and Resource Management in November 2011. Construction began in August 2015 and was completed in late 2017, with first production of finished zinc concentrate leaving Dugald River on 8 November 2017. The mine successfully achieved commercial production in May 2018.

In light of the project's recent transition from construction to operation and a number of resourcing changes at the site, it is considered an opportune time to undertake targeted community and stakeholder engagement to support the updating of key social performance documents and plans.

2. Purpose and Objectives

2.1 The CEP

This CEP has been prepared to guide targeted community and stakeholder engagement in support of the suite of Dugald River social performance work being undertaken by Nation Partners to satisfy the requirements of the MMG Social Performance Standard. Nation Partners will conduct targeted community and stakeholder engagement to inform:

- a revised Social Baseline Study (SBS)
- a revised Social Impact and Opportunity Assessment (SIOA)
- a revised Social Impact Management Plan (SIMP)
- a Social Investment Plan (SIP)
- an updated Local Employment Management Plan (LEMP).

The CEP provides a framework for comprehensive and strategic planning of community engagement activities designed to:

- embody a best practice approach (see section 3)
- encourage improved levels of participation in project community engagement activities
- demonstrate respect, build trust and strengthen MMG's reputation (i.e., social licence to operate)
- obtain clear and structured feedback which is directly applicable to the social performance reports
- facilitate the development of practical and effective social management systems for application across the life of the project in collaboration with the community, and ideally with their final endorsement/approval.

2.2 Community and stakeholder engagement

Targeted community and stakeholder engagement is a critical input to the development of the social performance reporting. It is undertaken to:

- understand who is likely to be impacted and how
- establish the values and socio-economic characteristics of potentially affected communities

- identify and evaluate potential social impacts (positive and negative)
- develop management measures to mitigate adverse impacts and enhance positive impacts
- support monitoring and evaluation reporting, including outcomes and key social performance indicators.

Community and stakeholder engagement helps generate up-to-date qualitative research, which assists to fill information gaps in desktop research and validate or occasionally identify discrepancies in statistical data. As local stakeholders have a first-hand appreciation of the local context and how socio-economic conditions have evolved over time due to a variety of influences it makes sense to test preliminary findings and recommendations with the community before drawing any final conclusions.

Community and stakeholder engagement will also facilitate meaningful community input into the mitigation design process as well as some form of stakeholder endorsement or agreement on the outcomes of the updated social performance reporting. Local communities usually value the opportunity to be involved in developing solutions to issues affecting them, and are well placed to apply their local knowledge to advise what likely will and won't work in terms of mitigation strategies, benefit enhancement measures and monitoring activities.

3. Approach

This CEP has been prepared in accordance with the core values and basic principles of good practice of the International Association for Public Participation Australasia (IAP2).

The engagement process will aim to be:

- targeted at the appropriate stakeholders and focused on relevant topics
- early enough for feedback to be meaningfully considered
- informed with relevant information disseminated in advance
- meaningful in that content is clearly understandable and culturally appropriate
- supportive of a two-way exchange in information
- gender-inclusive and sufficiently diverse to reflect the stakeholder base
- free from coercion
- documented with follow up processes.

A wide range of potential key stakeholders will be contacted and informed about this work, and invited to participate. In general, those groups most directly and significantly affected will be encouraged, and naturally have more incentive, to be the most involved in applicable aspects of the social performance work. Equally where project interest, and impacts to, stakeholders are marginal, stakeholders informed of this social performance work may elect to not participate further. See Table 1 for the IAP2 Public Participation Spectrum, with the engagement of potential stakeholders on the Dugald River project expected to range anywhere from inform through to collaborate if stakeholders take an active role in the development and design of social impact mitigation and monitoring plans.

Table 1 IAP2 Public Participation Spectrum

IAP2 Public Participation Spectrum

Developed by the International Association for Public Participation

INCREASING LEVEL OF PUBLIC IMPACT

INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
Public Participation Goal:	**Public Participation Goal:**	**Public Participation Goal:**	**Public Participation Goal:**	**Public Participation Goal:**
To provide the public with balanced and objective information to assist them in understanding the problems, alternatives and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public issues and concerns are consistently understood and considered.	To partner with the public in each aspect of the decision including the development of alternatives and the identification of the preferred solution.	To place final decision-making in the hands of the public.
Promise to the Public:	**Promise to the Public:**	**Promise to the Public:**	**Promise to the Public:**	**Promise to the Public:**
We will keep You informed.	We will keep you informed, listen to and acknowledge concerns and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and issues are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for direct advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
Example Tools:	**Example Tools:**	**Example Tools:**	**Example Tools:**	**Example Tools:**
• Fact sheets • Web Sites • Open houses	• Public comment • Focus groups • Surveys • Public meetings	• Workshops • Deliberate polling	• Citizen Advisory Committees • Consensus-building • Participatory decision-making	• Citizen juries • Ballots • Delegated decisions

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A core principle integral to our approach will be to clearly define which aspects of the process stakeholders are being asked to contribute to and/or be involved in for the social performance work, and what is negotiable and not negotiable with respect to decision-making.

There are two rounds of face-to-face engagement planned, with the first being dedicated to building a greater understanding of the local communities and uncovering the full extent of relevant project-related social impacts and opportunities, and the second focused on refining concepts for mitigation, monitoring and social investment initiatives. The second round will also seek to gain stakeholder agreement/endorsement on the reporting deliverables, particularly the SIMP. Given this work is being driven by internal standards rather than regulatory requirements, the endorsement process will likely be relatively informal, documented in terms of participation, inputs and general feedback provided throughout the engagement process.

For this scope of work, targeted community and stakeholder engagement will adopt standard and well-established techniques and approaches, that stakeholders are likely to be comfortable with and which do not rely on overly complicated technology. Engagement methods will include:

- **phone introductions/interviews**, to be undertaken as an initial step with all key stakeholders and followed up with additional phone interviews, face-to-face interviews or focus groups as requested (see below). During the initial interviews, we will verify project interest and confirm what further engagement will entail with each stakeholder.
- **email,** to provide further information for key stakeholders following initial phone introductions, and for notifying low influence/interest potential key stakeholders of this work, an inviting them to participate if of interest. Email will be used for stakeholder updates, reminders, and to share draft documentation and facilitate feedback when explicitly requested by stakeholders.
- **face-to-face interviews** with key stakeholders who could not be reached via phone or who requested an in-person meeting as a follow up to the initial phone interview.
- **face-to-face focus group sessions** with multiple stakeholders from the same group or with common interests (e.g. councils).

Given it is difficult to anticipate the exact amount of time that will be spent on each community engagement activity, and based on the 45 stakeholder groups identified, we have made allowances for:

- 18 initial phone interviews (30 minutes each) supplemented with 12 follow up calls (30 minutes)
- 12 face-to-face interviews (1 hour each)
- 5 focus group sessions (1 hour each)
- 18 emails (personally tailored, although sometimes incorporating standardised group email type content taking 15 minutes each)

We plan to be flexible in our approach, allowing for two people to be on phone calls for any potentially controversial stakeholders, and to spread the time allocated across activities to wherever most demand exists. For example, if focus groups end up taking longer than anticipated, we will look to borrow time from activities where budgeted time has not been fully utilised.

As part of operating flexibly, we have contingency plans in place to ensure the engagement has a sufficiently wide reach. For example, in the event that a key stakeholder is unable or would prefer not to participate in the proposed engagement via phone interviews, then face-to-face interviews and/or focus sessions will be arranged. We will do our best to accommodate and cater to the requests of the key stakeholders through comprehensive and early planning.

The social performance activities being completed by Nation Partners are community centric in nature in that they are primarily focused on identifying, managing and monitoring impacts on, and opportunities for, the community as opposed to MMG as a business. That said, feedback from community and stakeholder engagement is likely to provide useful insights into how community and social impacts in turn represent risks and opportunities for the project and MMG.

4. Resources

Nation Partners proposes to send two of our team members to Cloncurry to undertake face-to-face interviews and targeted focus group sessions in order to:

- allow one person to lead the engagement and the other to support and scribe feedback
- help to formalise the process and demonstrate commitment, making stakeholders feel valued
- reduce the likelihood of any stakeholders subsequently developing differing versions of events and accounts of what was said and agreed upon.

For each of the two rounds of engagement, one Nation Partners team member will fly from Melbourne and the other from Brisbane, both for a three day stay in Mount Isa and Cloncurry, with shared vehicle hire.

Nation Partners will require access to the Cloncurry Community Information Centre/MMG Project Office over the period of time that the face-to-face engagement is to occur, with some form of basic catering to be provided by MMG (e.g. coffee/tea and biscuits).

5. Stakeholder and issues identification

This section identifies a list of potential key stakeholders along with possible issues/interests they may have in the Dugald River project and the social performance work being undertaken. A stakeholder is defined as any individual, group of individuals, organisation or political entity with an interest in the outcome of a decision. Stakeholders may be, or perceive they may be, affected directly or indirectly by the outcome of a decision.

Early identification of stakeholders enhances the consultation process by enabling more time for planning, stakeholder notifications and tailoring of the engagement approach as appropriate. It therefore supports greater participation, greater efficiencies and an improved likelihood of generating desired outcomes/outputs.

Potential stakeholders have been profiled where an interest in, issue with or capacity to influence the project and planned social performance work has been identified. The proposed list of stakeholders embodies a good cross-representation of the community, and has been developed using the draft SIMP prepared by ARC in 2011 coupled with recent feedback from MMG. Notably, due to government restructures since the ARC report was prepared, many key government stakeholders who expressed interest in the project and made submissions during the EIS process now hold different names.

The list of potential project related social issues and impact areas of interest to the stakeholders was developed as part of scoping activities, having been drawn primarily from the 2010 Social and Economic Impact Assessment and the 2011 and 2015 Social Impact Management Plans for the Dugald River project.

Stakeholder groups have been ranked according to their likely influence/interest in the project in accordance with the criteria presented in Table 2. Table 3 summarises potential stakeholder groups by social issue/impact area, with a more detailed breakdown of the social issues/impacts available in Appendix A.

Table 2 Criteria for ranking stakeholders by Project influence/interest

High influence or interest in the project and the commissioned social performance work
Medium influence or interest in the project and commissioned the social performance work
Low influence or interest in the project and the commissioned social performance work

Table 3 Potential key stakeholder by social issues/ impact areas

Potential stakeholder groups	Key social issue/impact area
Local landholders and land users on neighbouring land • Mount Roseby Homestead	• Land use • Environment • Traffic
Indigenous groups and traditional owners • Kalkadoon Native Title Aboriginal Corporation – Registered Native Title Bodies Corporate • the Mitakoodi Aboriginal Corporation • Carpentaria Land Council Aboriginal Corporation • Queensland South Native Title Services	• Economic development and benefit • Training and employment • Community values and heritage • Land use
Councils • Cloncurry Shire Council • Townsville City Council • Mount Isa City Council	• Economic development and benefit • Training and employment • Housing • FIFO lifestyle • Environment • Social profile • Community values and heritage • Cumulative impacts • Community services

	• Traffic
State Departments • State Development, Manufacturing, Infrastructure and Planning • Aboriginal and Torres Strait Islander Partnerships • Housing and Public Works • Employment, Small Business and Training • Communities, Disability Services and Seniors • Child Safety, Youth and Women • Transport and Main Roads • Fire and Emergency Services • Education • Natural Resources, Mines and Energy • Police • Health • Agriculture and Fisheries • Innovation, Tourism, Industry Development and the Commonwealth Games	• Economic development and benefit • Training and employment • Environment • Cumulative impacts • Community services
Other emergency services • Queensland Ambulance Service • State Emergency Service • CareFlight	• Cumulative impacts • Community services
Non-governmental organisations • Southern Gulf Natural Resource Management	• Environment • Cumulative impacts
Industry groups and businesses • Construction, Forestry, Mining and Energy Union • Multi-Skill Centre • Glencore • CuDeco Limited • Copper Mountain Mining Corporation • CuString • CS Energy • Ergon Energy • Sunwater • Local Chambers of Commerce • Queensland Resources Council • Townsville Enterprise • Mount Isa to Townsville Economic Development Zone	• Economic development and benefit • Training and employment • Cumulative impacts
Community and underrepresented groups • Cloncurry Justice Association • Country Women's Association • Rotary Club of Cloncurry • Lions Club of Cloncurry • Cloncurry and District Historical and Museum Society • Sisters of the North	• Economic development and benefit • Community values and heritage • Social profile • Cumulative impacts
Local residents • Cloncurry and surrounding areas	• Economic development and benefit • Training and employment • Housing • Environment • Social profile • Community values and heritage • Cumulative impacts • Community services • Traffic
Dugald River mine employees	• Economic development and benefit • Training and employment • FIFO lifestyle

6. Information requirements from stakeholders

Nation Partners has drafted an SBS report and is in the process of drafting a SIOA using desktop information. We have reviewed the information available and identified gaps and in some cases anomalies in the data and literature which require further investigation directly with stakeholders (see Table 3). In order to support the engagement being of the most value, we plan to discuss the preliminary findings of our work (i.e. from the SBS and SIOA) with stakeholders, and use the identified topics in Table 4 to formulate insightful questions helpful to completing the key deliverables.

Table 4 Information needs from community and stakeholder engagement

SBS Requirements	SIOA, SIMP and Social Investment Requirements*
Additional information on the existing or baseline conditions, with particular focus on: • Underlying factors driving fluctuations in the population over time and its overall decline • Understanding the volatility of the local unemployment rate and recent increase (as of December 2018) • Exploring the connection between the opening and closing of mines on local employment levels • Investigate the above average turnover of local businesses • Confirming the assumption that average incomes for the Cloncurry Local Government Area (LGA) and Indigenous population of Cloncurry LGA are due to the presence of well-paid mining industry employment opportunities • Understanding the extent to which volunteering levels correlate with local community pride and whether there is any explanation for differences between Cloncurry LGA and the Indigenous population of Cloncurry LGA • Investigating the nature and magnitude of disadvantage as an issue in the community, in light of the Index of Socio-Economic Disadvantage reported for the community • Investigating the above average level of developmentally vulnerable children reported to be entering school • Confirming the assumption that lower than average education levels yet high levels of income in the community, result from low skill and high pay mining jobs • Further investigating disparity between Indigenous and non-Indigenous education, employment and income • Uncovering what the high level of “other” dwelling structures in the community incorporates • Exploring the fundamentals of the local housing rental market and the fluctuations in rental prices over time • Investigating mobility/ the transience of the population	Confirm relevance/ significance of impacts identified to date and adequacy of current management and mitigation and monitoring requirements with focus on: • Evaluating local and regional economic benefit, including lost opportunities due to FIFO workforce • Understanding expectations for community investment • Assessing the benefit of training, graduate studies, vacation, scholarship and employment opportunities for local community members • Understanding the positive and negative aspects of FIFO lifestyle for relevant Dugald River mine employees • Exploring impacts to community culture, values and lifestyle due to FIFO workforce • Investigating impacts on land use for nearby residents and Native Title claimants • Understanding the environmental impacts (noise, dust, vibration, traffic) of the project, particularly in reference to nearby landholders and the community • Exploring the trend of local residents gaining employment and transferring to FIFO leading to a reduction in local population • Understanding impact to the values and lifestyle of the local community, including effect on social order • Understanding impact to Indigenous community culture • Investigating cumulative impacts across the majority of described impacts • Discussing project impacts on community services and traffic

SBS Requirements	SIOA, SIMP and Social Investment Requirements*
• Gaining insights into the local culture, values and lifestyle (including Kalkadoon) • Understanding the drivers and details regarding the elevated rate of reported offences in the area and any links to the project workforce • Confirming any land use changes	

* Note this list is very preliminary in nature given many of these reports are not yet drafted or in very preliminary draft form.

7. Proposed methodology

Step 1: MMG review stakeholder list and engagement approach

Nation Partners requests that MMG review and confirm the adequacy and appropriateness of the list of potential key stakeholders profiled above in Table 3, in addition to the proposed approach and timelines set out in this plan and provide feedback. We anticipate that further refinements may occur following the initial round of phone interviews (i.e., with some stakeholders listed potentially indicating that they do not need or desire to be further involved as stakeholders).

See Appendix B for a table which profiles potential key stakeholders, their contact details and planned methods of engagement, noting that we will operate flexibly and adjust our approach and methods of engagement to suit stakeholder preferences wherever possible.

Step 2: Coordinate dates for face-to-face engagement

Nation Partners is keen to lock in dates for face-to-face community and stakeholder engagement as soon as possible to ensure team availability. In consideration of the proposed project delivery schedule, the preexisting commitments of team members and being conscious to avoid school holidays[1], we have proposed that the first visit occur the week starting Monday 17 June (from Wednesday 19 June to Friday 21 June). We suggest that the second trip occur in late August the week starting Monday 19 August or Monday 26 August to allow for stakeholder and community engagement on the full spectrum of social performance reports being prepared, and in particular the SIMP and SIP.

Step 3: Nation Partners attend Community Consultative Committee (CCC) and Kalkadoon meetings

Given the importance of providing MMG's stakeholders with timely and relevant information, Nation Partners prepared some PowerPoint slides (Appendix C) about the work being conducted and the planned engagement activities which were shared with attendees of the Kalkadoon and CCC meetings on 23 May 2019. Introducing the Nation Partners team and this work is expected to help ensure stakeholders are well aware of, and informed, about this work with maximum opportunity to participate. This step will has provided a foundation for engagement to commence with these key stakeholders imminently.

Step 4: Make initial contact with potential key stakeholders

Nation Partners will phone stakeholders to confirm the contact information we hold is correct, introduce ourselves and this scope of work, confirm stakeholder interest levels, and set up a telephone interview time and/or face-to-face interview time. In some instances, stakeholders may be open to participating in an interview at the time of the initial introductory call, while others will likely schedule it in for another time. Flexibility is at the heart of our approach and therefore we will attempt to cater to the preferences of all stakeholders.

In addition to making an introductory phone call, we also propose to send all stakeholders an email following up, to summarise the project information and confirm any agreed future time for a phone or face-to-face

[1]QLD school holiday no-go consultation periods include (5 April – 23 April, 28 June -15 July, and 20 September – 8 October)

interview or focus group. See Appendix D for a template email, which we would tailor slightly depending the type of stakeholder and the nature of the initial communication.

For low influence/interest stakeholders, email will be the primary form of engagement, with stakeholders notified about the social performance work in progress and invited to get in touch/ participate if desired. See Appendix E for a proposed standardised template email, which we would tailor slightly for some stakeholders as appropriate.

Step 5: Undertake round 1 phone interviews

We will attempt to do phone interviews with as many stakeholders as possible, and if this falls through or there are still gaps at the end of these interviews, we can subsequently undertake a face-to-face interview or follow up by email or further phone interviews. In general, each call with include an introduction of Nation Partners and this scope of work (in high level detail only and to the extent required depending on the nature of any previous introductory call), an overview of some of our main findings from preliminary phase of reporting, and a number of questions aimed to expand our understanding of some of the baseline conditions and also impacts from a local perspective. The phone interviews will vary by stakeholder depending on their interests/influence and the information gaps (see Table 4) of relevance to given stakeholders. We will also make sure to express our and MMG's gratitude for the time and participation offered by stakeholders, invite any questions and provide next steps/ a plan for follow up.

Step 6: Undertake round 1 face-to-face Interviews and focus group sessions

Round 1 face-to-face interviews will be similar in structure to round 1 phone interviews detailed above, except that they will be held in person. We will plan to bring some copies of the preliminary reports in the event that stakeholders request to view them, and to talk through any anomalies (i.e. point to graphs).

While the focus group sessions will be similar to the above, they will likely be a little more formal in structure and we will have a few power point slides available to use if desired. Depending on attendance levels, and how receptive the stakeholders are to responding to questions with an audience, we may opt to provide printed handouts with areas we are seeking input and encourage stakeholders to get in touch for personal interviews or to give feedback privately. We will run focus groups with cultural sensitivity and in an agile manner, adjusting our approach as we lead the engagement to get the most value out of it.

Step 7: Draft summary report and integrate feedback into reporting

Nation Partners will draft a report summarising the findings of community engagement and integrate these into the SBS, SIOA and SIMP as appropriate.

Step 8: Undertake round 2 phone interviews

Once the reporting has progressed further, we will undertake a second round of phone interviews, primarily to demonstrate how the initial inputs have been used and to present the proposed mitigations, social investments and monitoring plans to stakeholders.

We will consult with MMG on any new mitigation and social investment initiatives we are recommending before they are discussed during these interviews, to ensure they are realistic options and something MMG is open to committing to. Equally if new mitigations are raised through the engagement process by stakeholders, we will invite conversation to understand why something has been proposed but be very careful in how we discuss any such recommendations. Our messaging will be that we appreciate all inputs and suggestions, and will investigate recommendations further and discuss them with MMG before a decision can be made about whether they will become formally adopted as an MMG commitment in the SIMP. This is very important so that we effectively temper expectations and do not end up putting MMG in a position of seeming to over promise and under deliver.

Step 9: Undertake round 2 face-to-face Interviews and focus group sessions

Round 2 face-to-face interviews will also be similar to the round 2 phone interviews described above with the focus on mitigations, social investment initiatives and monitoring. We will use any learnings from round 1 to improve the focus group sessions. We will provide printed hand-outs summarising the main items we would like input and feedback on, and once again if individuals are uncomfortable providing feedback as part of a group, we will invite stakeholders to follow up with us individually.

Step 10: Finalise engagement summary report and integrate feedback into reporting

Nation Partners will add to and finalise the report summarising the findings of community engagement and integrate relevant findings into the SIOA, SIMP, SIP and LEMP as appropriate.

8. Engagement schedule

Activity	Purpose	Timeframe
MMG review draft CEP	• Ensure approach is aligned with MMG's expectation for stakeholder engagement • Confirm proposed messaging to stakeholders • Approve materials for CCC and Kalkadoon meetings	w/c 20 May 2019
CCC meeting • Includes short presentation on social performance work • JM and OW to dial-in to introduce themselves and the work	• Introduce Nation Partners and the social performance work • Ensure the CCC are fully briefed and know what to expect for upcoming engagement	23 May 2019
Kalkadoon Native Title Aboriginal Corporation (KNTAC) meeting • Includes short presentation on social performance work	• Introduce Nation Partners and the social performance work • Ensure the KNTAC are fully briefed and know what to expect for upcoming engagement	23 May 2019
Initial contact with stakeholders • Phone call, supplemented with email for medium and high influence/interest stakeholders • Email only to most low influence/interest stakeholders • Refer to Appendix B for list of	Introductory phone call: • Confirm contact information is correct • Introduce Nation Partners and the social performance work • Confirm stakeholder interest levels • Set time for phone and/or face-to-face interview, or undertake during call if desired Email follow-up: • Summarise project information • Confirm time for future engagement (phone, face-to-face, focus group) Alternate introductory email: • Introduce Nation Partners and the social performance work	w/c 27 May 2019

stakeholders and contact details	• Invite stakeholder to get in contact if interested in learning more/ participating	
Round 1 phone interviews	• Provide overview of main findings from preliminary phase of reporting • Expand understanding of baseline conditions and impacts from a local perspective	w/c 3 June 2019 and 10 June 2019
Evaluation and gap assessment of round 1 phone interviews	• Determine any gaps from phone interviews and confirm follow-up requirements (face-to-face or focus sessions)	w/c 10 June 2019
Round 1 face-to-face interview and focus group sessions	• Provide overview of main findings from preliminary phase of reporting • Expand understanding of baseline conditions and impacts from a local perspective Focus group sessions: • Capture a specific group's perspective on baseline conditions and impacts	w/c 17 June 2019
Draft summary report and integrate feedback into reporting	• Provide MMG with a summary of findings from Round 1 • Increase usefulness and relevance of SBS, SIOA and SIMP by integrating up-to-date qualitative information	w/c 24 June 2019 – 22 July 2019
Round 2 phone interviews	• Demonstrate how feedback captured during Round 1 has been used • Present proposed mitigations, social investments and monitoring plans to stakeholders	w/c 29 July 2019 and w/c 5 August 2019
Evaluation and gap assessment of round 2 phone interviews	• Determine any gaps from phone interviews and confirm follow-up requirements (face-to-face or focus sessions)	w/c 12 August 2019
Round 2 face-to-face interview and focus group sessions	• Demonstrate how feedback captured during round 1 has been used • Present proposed mitigations, social investments and monitoring plans to stakeholders and invite further feedback	w/c 19 August 2019 OR w/c 26 August 2019
Finalise engagement summary report and integrate feedback into reporting	• Provide MMG with a final summary of all findings • Increase usefulness and relevance of SIOA, SIMP, SIP and LEMP by integrating up-to-date qualitative information	w/c 2 September 2019 – w/c 9 September 2019 *(may start earlier depending on above)*
Close-the-loop with stakeholders • Via email	• Thank stakeholders for participating in the process and provide information around what their outputs will be / has been used for	w/c 9 September 2019

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Appendices

Appendix A - Issues Scoping

Table 1 outlines impact areas identified as part of the 2010 Social and Economic Impact Assessment and the 2011 and 2015 Social Impact Management Plans for the Dugald River Project.

Table 1 Key social impact areas

Impact	2010 SEIA	2011 SIMP	2015 SIMP
Economic Development and Benefit			
Positive impact on regional economic development	X	X	
Local economic benefit via investment, purchasing of consumables and use of certain service industries	X		X
Economic benefit via payment of royalties and taxes to QLD Government	X		
Lost opportunity for/ reduced local economic benefit to some services in Cloncurry due to large FIFO workforce	X		X
Increased expectation for community investment			X
Intercity rivalries (Mount Isa and Cloncurry) for mine derived benefits			X
Training and Employment			
Training and employment opportunities for local Indigenous and non-indigenous people	X	X	
Training, graduate studies, vacation work and scholarship programs provided to employees and students	X		
Housing			
Minimal impact to accommodation and housing market in Cloncurry due to FIFO workforce	X		
Impact on short-term accommodation		X	
FIFO lifestyle			
Positive aspects of FIFO lifestyle including more quality family and leisure time, and financial incentives	X		

Impact	2010 SEIA	2011 SIMP	2015 SIMP
Negative aspects of FIFO lifestyle including extended absences from families and insufficient rest for employees	X	X	
Reduced community participation in Cloncurry due to FIFO workforce			X
Land use			
Impact on land for nearby residents, including reduction of grazing area due to the Project infrastructure footprint	X	X	X
Impact on land for Native Title claimants	X	X	X
Environment			
Potential impact to the liveability and quality of lifestyle for nearby landholders and community	X	X	
Environmental impacts including noise, vibration, dust, lighting and visual amenity		X	X
Impact on local water security			X
Increase in uncontrolled pests and feral flora in Project area			X
Increase in noise, dust, traffic from Cloncurry load out facility			X
Increase in dust, noise, traffic at Townsville Port			X
Impact of mine closure		X	
Social profile			
Minimal impact expected on population size and structure of Cloncurry	X		
No contribution to population growth or diversity in Cloncurry due to FIFO nature of the work	X		
Local employees gain employment and transfer to FIFO leading to a reduction in local population*			
Community values and heritage			
Continuing tradition of mining playing a major role in the historical and cultural background of Cloncurry	X		

Impact	2010 SEIA	2011 SIMP	2015 SIMP
Negative impact on social amenity, community values and lifestyle		X	
Impact to Indigenous cultural heritage	X	X	X
Impact to historical cultural heritage			X
Impact to social order		X	
Cumulative impacts			
General cumulative impacts across majority of described impacts	X	X	
Impact to services without active social contribution to town	X		
Increased house and rental prices	X		
Spike in antisocial behaviour such a crime, vandalism and alcoholism	X		X
Community services			
Impact to health services		X	
Impact to education		X	
Impact to emergency services		X	
Expectation that commercial airline services will remain due to the Project			X
Traffic			
Impact on public safety on highway and roads		X	
Increased road traffic from mining operations			X

Appendix B – Proposed Stakeholder engagement method

Table 2 Stakeholder contact details and anticipated method of engagement

Stakeholder	Contact details	CCC Member?	Anticipated engagement method
Mount Roseby Homestead landowners	**Harold and Catherine McMillan** 0427 425 904 mtroseby@bigpond.com	Yes	Phone call, supplemented with email. Phone interviews and/or face-to-face interviews/focus groups with residents of all affiliated homesteads invited.
Corella Park Station landowners	**Anthony and Jane McMillan** 0417 799 063 corellapark@reachnet.com.au	Yes	Phone call, supplemented with email. Phone interviews and/or face-to-face interviews/ focus groups combined at Mount Roseby Homestead.
Landowners (pastoralists)	**Mark and Chelsea McMillan** *MMG to provide*	Yes	Phone call, supplemented with email. Phone interviews and/or face-to-face interviews/focus groups combined at Mount Roseby Homestead.
	Allan and Brooke Adby (07) 4742 1227		Phone call, supplemented with email. Phone interviews and/or face-to-face interviews/focus groups (on request).
	David and Tracy Corbett (07) 4742 1085		Phone call, supplemented with email. Phone interview and/or face-to-face interviews/focus groups (on request).
Kalkadoon Native Title Aboriginal Corporation	**Virginia Mayo** (Board Member) **Kurt** (Board Member) **Dorsey** (Board Member) **Jenny** (Board Member) (07) 4749 2766 admin@kalkadoonpbc.com.au 109 Barkly Highway, Mount Isa QLD 4825 (office address)	Yes	Phone call, supplemented with email. Two focus group sessions plus interviews as specified.
	Dorothea Seumanutafa (admin support) Same as above	No	N/A – will liaise with to facilitate engagement with board members

Stakeholder	Contact details	CCC Member?	Anticipated engagement method
Queensland South Native Title Services	**Kelly Thomas-Greer** (Assistant Legal Manager) (07) 3224 1200 kelly.thomasgreer@qsnts.com.au Level 10, 307 Queen Street, Brisbane QLD 4000 (head office address)	No	Phone call, supplemented with email. Phone interview/s.
Mitakoodi Aboriginal Coroproation	**Beverly Wardrop** (Manager) (07) 4742 1208 mitakoodi@gmail.com 55 King Street, Cloncurry QLD 4824	No	Phone call, supplemented with email. Phone interviews and/or face-to-face interviews/ focus groups.
Carpentaria Land Council Aboriginal Corporation	Cairns Office: (07) 4041 3833 info@clcac.com.au PO Box 6662 Cairns QLD 4870	No	Email introducing SP work. Phone interview/s on request.
Cloncurry Shire Council	**Greg Campbell** (Mayor) 0484 829 444 Mayor@cloncurry.qld.gov.au **David Bezuidenhout** (CEO) 0439 294 747 DavidB@cloncurry.qld.gov.au 38-46 Daintree Street, Cloncurry (office address)	Yes	Phone call/s, supplemented with email/s. Focus group sessions plus interviews as specified.
	Dane Swalling (Deputy Mayor) 0408 019 691 crdswalling@cloncurry.qld.gov.au 38-46 Daintree Street, Cloncurry (office address)	No	Invite to focus group sessions
Mount Isa City Council	**Joyce McCulloch** (Mayor) mayorjoyce@mountisa.qld.gov.au **Sharon Ibardolaza** (CEO) SharonI@mountisa.qld.gov.au (07) 4747 3200 23 West Street, Mount Isa QLD 4825 (office address)	Yes	Phone calls, supplemented with emails. Face to-face interviews/ focus groups.

Stakeholder	Contact details	CCC Member?	Anticipated engagement method
Townsville City Council	**Jenny Hill** (Mayor) jenny.Hill@townsville.qld.gov.au **Mike Chiodo** (CEO) Mike.Chiodo@townsville.qld.gov.au 13 48 10 103 Walker Street, Townville QLD 4810 (office address)	No	Phone calls, supplemented with emails. Phone interview/s.
Department of State Development, Manufacturing, Infrastructure and Planning	**Tammy Parry** (Regional Director) (07) 4747 3909 tammy.parry@dsdmip.qld.gov.au **Darren Cleland** (Executive Regional Director) 0417 007 571 darren.cleland@dsdmip.qld.gov.au PO Box 15009, City East QLD 4002	Yes	Phone calls, supplemented with emails. Phone interview/s.
Department of Environment and Science	**Ingrid Fomiatti Minnesma** (Director Minerals) 0412 588 475 ingrid.fomiattiminnesma@des.qld.gov.au GPO Box 2454, Brisbane QLD 4001	No	Email introducing SP work. Phone interview/s on request.
Department of Transport and Main Roads	**Mark Desira** (Inspector of Mines – Occupational Hygiene) 0467 808 736 mark.desira@dnrme.qld.gov.au **Andrew Hobbs** (Director) 0405 506 019 Andrew.r.hobbs@tmr@qld.gov.au **Sandra Voll** (Program Support Office, North West) (07) 4769 3249 Sandra.G.Voll@tmr.qld.gov.au PO Box 673 Fortitude Valley QLD 4006	No	Email/s introducing SP work. Phone interview/s on request.

Stakeholder	Contact details	CCC Member?	Anticipated engagement method
Department of Aboriginal and Torres Strait Islander Partnerships	13 74 68 enquiries@datsip.qld.gov.au PO Box 15397 City East QLD 4002	No	Email introducing SP work. Phone interview/s on request.
Department of Housing and Public Works	13 74 68 DirectorGeneral@hpw.qld.gov.au GPO Box 2457 Brisbane QLD 4001	No	Email introducing SP work. Phone interview/s on request.
Department of Employment, Small Business and Training	13 74 68 info@desbt.qld.gov.au PO Box 15033 City East Brisbane QLD 4002	No	Email introducing SP work. Phone interview/s on request.
Department of Communities, Disability Services and Seniors	13 74 68 1 William Street, Brisbane QLD 4000	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Department of Child Safety, Youth and Women	13 74 68 1 William Street, Brisbane QLD 4000	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Queensland Fire and Emergency Services	13 74 68 QFESEnquiries@qfes.qld.gov.au GPO Box 1425, Brisbane QLD 4001	No	Email introducing SP work. Phone interview/s on request.
Department of Education	13 74 68 PO Box 15033, City East QLD 4002	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Department of Natural Resources, Mines and Energy	North West Region (07) 4747 2158 isamines@dnrme.qld.gov.au PO Box 334, Mount Isa QLD 4825	No	Email introducing SP work. Phone interview/s on request.
Queensland Police	131 444 (07) 3055 6206 GPO Box 1440, Brisbane QLD 4000	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Queensland Health	13 74 68 GPO Box 48, Brisbane QLD 4001	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Department of Agriculture and Fisheries	13 25 23 info@daf.qld.gov.au GPO Box 46, Brisbane QLD 4001	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.

Stakeholder	Contact details	CCC Member?	Anticipated engagement method
Innovation, Tourism, Industry Development and the Commonwealth Games	13 74 68 PO Box 15168, City East QLD 4002	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Queensland Ambulance Service	13 74 68 GPO Box 1425 Brisbane QLD 4001	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
State Emergency Service	(07) 4743 2601 SESNR.Admin@qfes.qld.gov.au 1/173 Camooweal Street, Mount Isa QLD 4825 Note: Cloncurry Office in Alice Street	No	Email introducing SP work. Phone interview/s on request.
CareFlight	Mount Isa and the North West Region (07) 4743 0937 1/24 West Street, Mount Isa QLD 4825	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Southern Gulf Natural Resource Management	(07) 4743 1888 admin@southerngulf.com.au PO Box 2211, Mount Isa QLD 4825	No	Email introducing SP work. Phone interview/s on request.
Construction, Forestry, Mining and Energy Union	CFMEU Brisbane (07) 3231 4600 qntqueries@cfmeu.org 16 Campbell Street, Bowen Hills QLD 4006	No	Email introducing SP work. Phone interview/s on request.
Multi-Skill Centre	(07) 4742 2887 paul@multiskillcentre.com.au 32-36 Short Street, Cloncurry QLD	No	Phone call, supplemented with email. Phone interviews or face-to-face interviews (on request)
Glencore	Glencore Brisbane (07) 3833 8500 10/160 Ann Street, Brisbane QLD 4000	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
CuDeco Limited	(07) 4742 4800 cloncurry@cudeco.com.au Corella Park Road, Cloncurry QLD 4824	No	Email introducing SP work. Phone interview/s on request.
Copper Mountain Mining Corporation	(08) 9485 2929 1/2 Kings Park Road, West Perth WA 6005	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.

Stakeholder	Contact details	CCC Member?	Anticipated engagement method
CuString	No contact information currently available (project soon to go through EIS process, so expected in near future)	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
CS Energy	(07) 3854 7777 PO Box 2227, Fortitude Valley BC QLD 4006	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Ergon Energy	13 74 66 PO Box 1090 Townsville QLD 4810	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Sunwater	(07) 3120 0000 9/515 St Pauls Terrace, Fortitude Valley QLD 4006	No	Phone call to get correct contact email. Email introducing SP work. Phone interview/s on request.
Local Business Network Cloncurry	Contact via Council (07) 4742 4100 council@cloncurry.qld.gov.au 38-46 Daintree Street, Cloncurry QLD 4824	No	Phone call, supplemented with email. Phone interview or face-to-face interview (on request)
Queensland Resources Council	**Ian Macfarlene** (CEO) (07) 3295 9560 info@qrc.org.au 13/133 Mary Street, Brisbane QLD 4000	No	Email introducing SP work. Phone interview/s on request.
Townsville Enterprise	**Patricia O'Callaghan** (CEO) (07) 4726 2733 patricia.ocallaghan@tel.com.au PO Box 1043, Townsville QLD 4810	No	Email introducing SP work. Phone interview/s on request.
Mount Isa to Townsville Economic Development Zone	**David Glasson** (President) **Glen Graham** (CEO) (07) 4743 3488 0428 781 594 ceo@mitez.com.au PO Box 1258, Mount Isa QLD 4825	No	Phone call, supplemented with email. Phone interview/s.
Cloncurry Justice Association	**Judith Ontronen** (Manager) (07) 4742 0846 cloncurryjustice@bigpond.com	No	Email introducing SP work. Phone interview/s on request.

Stakeholder	Contact details	CCC Member?	Anticipated engagement method
	12 Ramsay Street, Cloncurry QLD 4824		
Country Women's Association	**Sarah Harvey** (President) 0414 187 052 cloncurrycwa@gmail.com	No	Phone call, supplemented with email. Phone interview or face-to-face interview (on request).
Rotary Club of Cloncurry	(02) 8894 9800 Matilda Highway, Cloncurry QLD 4824	No	Email introducing SP work. Phone interview/s on request.
Cloncurry Lions Club	1800 655 201 PO Box 279, Cloncurry QLD 4824	No	Email introducing SP work. Phone interview/s on request.
Cloncurry and District Historical and Museum Society	**John Walton** (President) 0429 664 907 gail.wipaki@bigpond.com	No	Email introducing SP work. Phone interview/s on request.
Eagles Football Club	**John and Susan Swalling** 0428 421 573 wallingcnj@gmail.com	Yes	Phone call, supplemented with email. Phone interview or face-to-face interview (on request).
Cloncurry Merry Muster	**Janessa Bidgood** 0429 855 734 outbackauctions@bigpond.com	Yes	Email introducing SP work. Phone interview/s on request.
Sisters of the North	Susan Dowling 0429 467 300 susanldowling@gmail.com	Yes	Email introducing SP work. Phone interview/s on request.
Bowls Club	**Kevin Wherman (Bungie)** 0409 476 978 adm@krcontracting.com.au **Damien McGee** 0418 713 608 manager@ozecool.com	Yes	Email introducing SP work. Phone interview/s on request.
Local residents in Cloncurry and surrounding areas	n/a	n/a	Option to provide information about social performance work on Cloncurry Council website and community facebook page if desired
Dugald River mine employees	n/a	n/a	Employee survey

Appendix C – Slide Pack for Community Consultative Group Meeting (and Kalkadoon meeting)

Appendix D – Proposed messaging to Stakeholders (Follow-up email template)

Dear <insert name here>,

Thank you for your time on the phone <earlier, yesterday etc.>. As discussed, we have contacted you regarding work we are undertaking to support the social performance of the Dugald River mine, a zinc-lead-silver mine owned and operated by MMG 65 kilometres northwest of Cloncurry.

Nation Partners have been engaged to complete a number of social performance tasks (including a social baseline study, a social impact and opportunity assessment, a Social Impact Management Plan and a Social Investment Plan) which will support MMG to enhance the management of social impacts associated with the Dugald River mine on an ongoing basis, and benefit the local communities through positive social and economic development.

As discussed, we would like to engage with you to help us better understand the existing socio-economic characteristics of local communities, and investigate how these communities are impacted by the operation of Dugald River project or likely to be impacted in futures phases, both positively and negatively. We are also seeking input on social impact management and monitoring systems being developed for the Dugald River mine.

We would like to invite you to participate in a <phone> interview on <date> at <time>. If this does not suit, please contact us on the details below and we would be happy to arrange an alternative time. Please also get in touch if you have any questions or would like any further information on the work we are undertaking.

Thank you in advance for your participation. Your local knowledge will help us build our understanding of the issues and considerations unique to this area, and contribute to the long-term improvement of the social performance of the Dugald River mine.

We look forward to speaking to you soon.

Kind regards,

Appendix E – Proposed messaging to Stakeholders (Primary engagement email for low influence/interest stakeholders)

Dear <inset name here>,

We are writing to you regarding work we are undertaking to support the social performance of the Dugald River mine, a zinc-lead-silver mine located 65 kilometres north-west of Cloncurry in north-western Queensland. The mine is owned and operated by MMG, the world's second largest producer of zinc and a substantial producer of copper, lead, gold and silver.

With construction of the mine now complete, and the achievement of commercial production having occurred in May 2018, MMG is seeking to update key documents and plans to contribute to the long-term improvement of the social performance of the Dugald River mine.

To complete this work, MMG have engaged Nation Partners - a trusted consultancy that provides solutions to complex problems and offer a wealth of local and international experience undertaking social performance activities on mining projects. We will be completing the following tasks:

- Preparing a social baseline study
- Creating a social impact and opportunity assessment
- Developing a Social Impact Management Plan
- Developing a Social Investment Plan

These documents and plans will support MMG to enhance the management of social impacts associated with the Dugald River mine on an ongoing basis, and benefit local communities through positive social and economic development.

You have been identified as a stakeholder who may have an interest in the work we are undertaking. We would like to engage with stakeholders who can help us better understand the existing socio-economic characteristics of local communities, and investigate how these communities are impacted by the operation of Dugald River project or likely to be impacted in futures phases, both positively and negatively. We are also seeking input on social impact management and monitoring systems being developed for the Dugald River mine.

If you are interested in participating in the community and stakeholder engagement to support this work, or would like more information, please contact us on the details below.

We look forward to speaking to you soon.

Kind regards,

Appendix D: Dugald River TSF Stage 3 Detailed Design Report

REPORT

MMG Dugald River
ABN: 19 083 405 556

Dugald River Mine
Tailings Storage Facility – Stage 3
Raise Detailed Design Report

250542-R04 REV 0
FEBRUARY 2026

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Document Control

Project Name:	Dugald River Mine
Project Number:	250542-R04
Document Title:	Tailings Storage Facility – Stage 3 Raise Design Basis Report
File Location:	S:\Dugald\250542 - TSF Raise Design\Documents\R04 - Detailed Design\250542-R04 (Rev0).docx

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
A	Draft Issue	23/09/2025	JL	DMR / CN
0	Final Issue	06/02/2026	JL	DMR

Issue Register

Distribution List	Date
MMG Dugald River	6/2/2026

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EXECUTIVE SUMMARY

General

The Dugald River Mine (DRM) is operated by MMG Limited (MMG), and is located in north-western Queensland, approximately 65 kilometres north-west of Cloncurry and 85 kilometres north-east of Mt Isa.

MMG have engaged ATC Williams (ATCW) to produce a detailed design for a raise to the existing Dugald River Tailings Storage Facility (TSF), hereafter referred to as the 'Stage 3 Detailed Design'.

This design report documents the design basis, assumptions, and analyses that have informed the Stage 3 Detailed Design process.

The main work elements involved in the Stage 3 TSF raise are as follows:

- Downstream raising of the existing TSF embankment by 9.25 m to a crest level of RL 253.5 m;
- Excavation of a new spillway approximately 250 m north of the TSF embankment;
- Construction of a new seepage collection system downstream of the TSF embankment;
- Construction of a discharge bund on the northern side of the impoundment (approx. 9.5 m in height);
- Construction of a haul road to the west of the TSF (excavated materials to be the primary rockfill source for embankment construction);
- Construction of four access roads to the discharge points; and
- Relocation of the Return Water System and construction of a new access platform.

Basis of Design

The key objective of the Stage 3 TSF is to store a total tailings quantity of 22.3 Mt over 27 years (total mine life), based on the latest production forecast provided to ATCW by MMG, dated February 2026.

Tailings characterisation testwork has shown the material to be a low plasticity silt/clay, with a particle density (specific gravity) of approximately 2.96. An overall in-situ density (OID) of 1.35 t/m^3 has conservatively been adopted on the basis of the achieved densities for the existing Stage 2 TSF. Based on the assumed density, the required overall TSF capacity is thus 16.5 Mm^3.

The decant water accumulating within the TSF is to be re-utilised within the process plant, with water returned via a pontoon-mounted pumping station installed within the TSF.

The design has been prepared to comply with all relevant Queensland regulatory requirements, national guidelines, and global standards.

Consequence Category Assessment

A dam break assessment was conducted to assess the failure impacts and associated Consequence Categories for the Stage 3 TSF. The results of the Stage 3 dam break assessment indicate that the dam break flows will initially propagate westward through the unnamed tributary of Cabbage Tree Creek until intersecting the Cabbage Tree Creek drainage path.

The results indicate that the proposed diversion drain and flood protection levee around the third party "Little Eva" Pit are capable of diverting the majority of the mobilised flood volumes away from the Little Eva Pit. The results indicate that some minor overtopping of the proposed flood protection levee is anticipated at the northern extents where the crest of the proposed flood protection levee is at its lowest.

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After being diverted away from the Little Eva Pit, the dam break flows continue northwards along the Cabbage Tree Creek before joining the Leichardt River at the Cabbage Tree Creek-Leichardt River confluence.

The maximum Population at Risk (PAR) and Potential Loss of Life (PLL) are estimated to occur during daytime periods, in which a PAR of 10.23 and a PLL of 0.29 have been estimated.

Table E1 presents a summary of the adopted Consequence Categories on the basis of the dam break outcomes.

TABLE E1 – CONSEQUENCE CATEGORY SUMMARY

Methodology	Scenario	Base Case
DETSI	Failure to Contain – Seepage	**Low**
	Failure to Contain – Overtopping	**Significant**
	Dam Break	**High**
ANCOLD	Dam Failure	**High C**
	Environmental Spill	**Low**
GISTM	Consequence Classification	**High**

TSF Embankment

The existing TSF embankment will be downstream raised and continue the existing Stage 2 zoning configuration of:

- Bituminous Geomembrane (BGM) Liner on the upstream face;
- Zone 2B Liner Support;
- Zone 2C Granular Filter; and
- Zone 3A and 3B Rockfill.

The rockfill seepage collection drain at the base of the existing embankment will be continued through the base of the embankment raise.

A reinforced concrete toe plinth will be constructed within a trench at the upstream toe of the embankment, upon which the BGM liner will later be anchored. The plinth will also act as the surface through which contact and foundation grouting works will be conducted.

The foundation grouting will be conducted at regular intervals along the length of the plinth to a minimum depth of 6 m, in order to intersect and grout any potential deeper sources of foundation seepage beneath the TSF Embankment.

Shallow depth contact grouting beneath the plinth will be conducted to minimise the extent of seepage beneath the plinth/foundation rock interface.

The new seepage collection system will consist of the construction of a rockfill seepage collection drain within the lowest point of the embankment foundations, connecting with a seepage interception trench at the downstream toe. HDPE drain pipes will be placed within the seepage collection drain to facilitate drainage.

The downstream seepage interception trench will have a circular concrete seepage monitoring chamber (precast concrete soakwell) installed and will have Concrete Canvas liners placed on the base and downstream wall of the excavation. After installation of the soakwell and Concrete Canvas liner, the trenches will be backfilled with Zone 3C rockfill and will be wrapped in geotextile.

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Tailings Management

Tailings discharge is proposed to continue from the northern and southern ends of the valley on a rotational basis across five discharge points, such that the low point of the tailings beach where the decant pond forms, is maintained in the centre of the valley.

The objective is to maximise sub-aerial deposition, and to rotate deposition to fill the TSF by way of a series of thin layers that form gently sloping beaches that support near laminar flow, therefore enabling deposition of solids. Water liberated from the tailings through the deposition phase drains towards the Decant Pond located at the centre of the facility to concentrate bleed and surface water runoff in a location area where it can be easily recovered.

Tailings deposition modelling for the Stage 3 raise indicates that the Stage 3 TSF will provide a total tailings capacity of **26.2 Mt**. Hence the proposed 9.25 m embankment raise provides a tailings storage capacity that exceeds the requirements set out by the forecasted production estimates. However, it is noted that the estimated tailings capacity is subject to change based on the size of the decant pond and achieved tailings beach slopes.

Water Management

DETSI requires that for a “High” Consequence Category dam for “dam failure”, the TSF must have available a sufficient volume on 1st November of any year to store the Design Storage Allowance (DSA) of 1,500 ML. This equates to a maximum reservoir level of RL 249.8 m as of the 1st November on any given year.

DETSI also requires that for a “Significant” Consequence Category dam for “failure to contain – overtopping”, all reasonable efforts shall be made to provide for the Extreme Storm Storage (ESS) of 953 ML at all times. This equates to a Mandatory Reporting Level (MRL) of RL 249.54 m.

Probabilistic water balance modelling carried out for the Stage 3 raise indicate that neither the Stage 3 DSA Reporting Level nor MRL are estimated to be exceeded during operational life of the facility.

The governing requirements for the spillway capacity are those required by ANCOLD, which require the Stage 3 emergency spillway to be designed to pass the greater of the 1:100,000 AEP flood plus wave run-up from the 1:10 AEP wind; and the Probable Maximum Flood (PMF). The results of the hydraulic spillway modelling indicate that the proposed spillway geometry satisfies both of these criteria.

Stability and Deformations

The results of slope stability assessments confirm that the proposed Stage 3 TSF geometry satisfy ANCOLD criteria.

Empirical deformation modelling indicates that the expected maximum crest settlements resulting from the design earthquake would be less than 15 mm. The available freeboard (either tailings or pond freeboard) is expected to significantly exceed this.

Quantitative Risk Assessment

The overall Total Annual Probability of Failure for the Stage 3 TSF embankment is estimated to be 5.5E-08. This meets the USBR Risk Guidelines (2019) criteria of not greater than 1E-04.

The total societal risk due to failure of the Stage 3 TSF is assessed to be 5.2E-09. This satisfies the ANCOLD societal risk criteria for new dams or major augmentations of not greater than 1E-04.

The Individual Risk imposed by the Stage 3 TSF is estimated to be 1.0E-09. The Individual Risk estimate satisfies the ANCOLD criteria for new dams or major augmentations (not greater than 1E-05).

The risk assessment and As Low a Reasonably Practicable (ALARP) assessment outcomes indicate that the Stage 3 TSF societal risk profile is lower than the ANCOLD limit of tolerability to an extend determined to be “ALARP”.

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Closure and Rehabilitation

The general approach to closure will incorporate a low water flux cover system that includes a capillary break, sealing layer, waste rock layer and revegetated topsoil. Four cover options have been proposed to be modelled to assess their relative performance regarding net percolation and to determine which option(s) would meet the closure objectives.

Rehabilitation of the embankment will comprise flattening the batter from 1.5H:1V to 6.5H:1V, undertaken by pushing excess fill material from the crest of the embankment to fill the downstream toe of the embankment.

The conceptual general arrangement for the final drainage of the rehabilitated TSF is to reprofile the final landform into drainage channels that allow for a self-shedding closure landform whilst also minimising erosion.

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1 INTRODUCTION

The Dugald River Mine (DRM) is operated by MMG Limited (MMG), and is located in north-western Queensland, approximately 65 kilometres north-west of Cloncurry and 85 kilometres north-east of Mt Isa.

MMG have engaged ATC Williams (ATCW) to produce a detailed design for a raise to the existing Dugald River Tailings Storage Facility (TSF), hereafter referred to as the 'Stage 3 Detailed Design'.

This design report documents the design basis, assumptions, and analyses that have informed the Stage 3 Detailed Design process.

2 PROJECT BACKGROUND

2.1 Site Description

The DRM is located approximately 85 km north-east of Mt Isa and 65 km north-west of Cloncurry in Queensland's north-west. The TSF is within a natural valley located within the Knapdale Range, a large formation of outcropping quartzite on the western side of the mine lease. The valley is approximately 4 km northwest of the DRM process plant.

The natural formation of the Knapdale Range valley, which is within the DRM lease boundary, is employed to assist with the containment of the tailings and process water. The TSF Embankment completes the containment area west of the Knapdale Range valley.

2.2 Existing TSF

2.2.1 Purpose & Components

The deposit at DRM is majority zinc-lead based with some copper mineralisation. The main purpose of the TSF is to provide storage of tailings, processed at the DRM process plant. The tailings comprise process water, finely ground rock particles and metals that cannot be economically extracted during mineral processing of the zinc-lead ore.

DRM utilise tailings paste backfill of underground mine stopes on an ongoing basis. Tailings are either transferred to the paste plant (when backfill is required) or are pumped to the TSF via a 4 km long pipeline.

Another function of the TSF is to provide temporary water storage for mineral processing and various other mining activities (dust sprays, mine service water streams, etc.). The water stored within the TSF originates from decant (bleed) water emerging from the deposited tailings, as well as from rainfall runoff from the catchment area.

The existing TSF (Stage 2) consists of the following infrastructure:

- The 37 m high TSF embankment, which is a water-retaining structure comprising a zoned rockfill and granular material with an impermeable bituminous geomembrane (BGM) liner;
- An emergency spillway excavated into the rock on the northern abutment of the TSF Embankment, with a base width of 10 m;
- A seepage collection pond constructed downstream of the TSF Embankment, to monitor and collect foundation seepage before it discharges off-site;
- The tailings delivery system, comprising the pumping station, steel pipelines, HDPE pipelines, spill containment ponds and end-point discharges;
- An evaporator system, comprising two evaporator units, a pump station, weather station, and HDPE pipelines; and
- Return water system (RWS), comprising a skid-mounted pump, floating offtake, and a discharge pipeline to pump water from the TSF decant water pond, which forms over the deposited tailings centrally within the TSF. The skid-mounted decant pump transfers water to

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a booster pump station on the east side of the TSF, from where it is pumped back to the Process Plant.

2.2.2 Design & Construction

The design of the TSF makes use of the inherent characteristics of the Knapdale Range valley, located northwest of the mine area and process plant.

Tailings are pumped uphill to the TSF from the process plant along the mine village access road.

Discharge occurs at the northern and southern ends of the valley on a rotational basis, such that the low point of the tailings beach where the decant pond forms, is maintained in the centre of the valley. An access road links the eastern side of the TSF to the mine village access road, which the decant return pipeline follows.

Containment of the tailings and process water is almost entirely provided by the valley topography, with the main retaining feature being the TSF embankment. The TSF embankment is required to close the valley outlet on the western side.

The embankment was designed and constructed as a water-retaining structure, due to the location of the decant pond adjacent to the embankment upstream face. Further details regarding the dam design are provided in ATCW's May 2016 Design Report **[1]**.

TSF Embankment civil construction works occurred from June 2016 to June 2017, with only non-civil works completed thereafter. A two-stage construction was initially intended, with the Starter Embankment (Stage 1) constructed to RL 233.4 m, followed by a further raise (Stage 2) to RL 244.25 m.

In August 2016, MMG decided to combine the Stage 1 and Stage 2 Works and construct the TSF Embankment to its final (i.e., Stage 2) height. Details of the dam construction are provided in ATCW's July 2017 Construction Report **[2]**.

2.2.3 Embankment Details

The Stage 2 TSF Embankment is a zoned granular and rockfill embankment, with a waterproofing bituminous geomembrane (BGM) liner fitted on the upstream face, and a fully-intercepting foundation grout curtain at the upstream toe.

The bulk of the embankment is formed by weathered quartzite rockfill materials (Zone 3A and 3B), with sandy and clayey granular filter material (Zone 2B and 2C) forming the upstream face to support the BGM liner. The rockfill materials were sourced from a quarry within the TSF impoundment, whilst granular and low permeability materials were sourced from alluvial and colluvial deposits in the valley floor and surrounding foothill areas. The embankment foundations were stripped of all alluvial and loose colluvial deposits to reveal weathered quartzite rock. A rockfill seepage collection drain was constructed in the embankment foundation, which discharges into the seepage collection pond directly downstream of the Stage 2 TSF Embankment.

For the waterproofing element of the Stage 2 TSF Embankment, a reinforced elastomeric BGM was installed on the upstream face. The BGM proprietary material is Axter COLETANCHE ES3 HFA SBS elastomeric modified bituminous geomembrane (high friction angle variant), with a nominal thickness of 4.8 mm. The BGM is anchored at the embankment toe to a reinforced concrete plinth, which also acts as the grout cap for the foundation grout curtain. At the crest, the BGM is anchored via a mass concrete ballast beam. Although the BGM liner is designed to prevent seepage into the embankment, the upstream embankment zones (Zone 2A and 2B) provide a protective filter preventing tailings migration in the event of a leak in the BGM liner.

The BGM is protected from bushfire damage at the abutments and rockfalls along the plinth toe by a covering layer of a geocomposite called "Concrete Canvas".

Nine survey monitoring points are installed on the crest and downstream bench of the TSF embankment.

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2.3 Previous Studies

In 2024, MMG engaged ATCW to investigate raise options to the TSF. As part of the study, tailings beach modelling was undertaken for two production cases; a production scenario of 13.1 Mt of tailings over 16 years; and another of 21.0 Mt over 27 years **[3]**.

Following submission of the report and discussions between ATCW and MMG, MMG advised their preference of proceeding with a concept design for a 9.25 m embankment raise to a level of RL 253.5 m (Stage 3). The concept design report was prepared in September 2024 **[4]**.

3 DESIGN OVERVIEW

The main work elements involved in the Stage 3 TSF raise are as follows:

- Downstream raising of the existing TSF embankment by 9.25 m to a crest level of RL 253.5 m;
- Excavation of a new spillway approximately 250 m north of the TSF embankment;
- Construction of a new seepage collection system downstream of the TSF embankment;
- Construction of a discharge bund on the northern side of the impoundment (approx. 9.5 m in height);
- Construction of a haul road to the west of the TSF (excavated materials to be the primary rockfill source for embankment construction);
- Construction of four access roads to the discharge points; and
- Relocation of the Return Water System and construction of a new access platform.

A general layout of the works is provided on **Figure 1**.

4 BASIS OF DESIGN

4.1 Overview

The key objectives of the DRM TSF are summarised as follows:

- Safe and stable containment of tailings and process water;
- Safe management of decant and rainfall runoff;
- Collection and temporary storage of runoff during the wet season for use in the process plant; and
- Operating the TSF on a zero-discharge basis.

4.2 Guidelines and Standards

The design of the Dugald River TSF has been undertaken in accordance with the following regulatory requirements, national guidelines, and global standards:

Regulatory Requirements

- Queensland Department of Environment, Tourism, Science and Innovation (DETSI) (2024) Manual for Assessing Consequence Categories and Hydraulic Performance of Structures, ESR/2016/1933, Version 5.03 **[5]**

National Guidelines

- ANCOLD (2019) Guideline on Tailings Dams – Planning, Design, Construction, Operation and Closure **[6]**
- ANCOLD (2019) Guidelines for Design of Dams and Appurtenant Structures for Earthquake **[7]**

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- ANCOLD (2012) Guidelines on the Consequence Categories for Dams **[8]**

Global Standards

- ICMM (2020) Global Industry Standard on Tailings Management (GISTM) **[9]**

4.3 Tailings Tonnage

For detailed design purposes, the staging and rate of filling of the TSF have been based on a total tailings quantity of 22.3 Mt over 27 years based on the latest production forecast provided to ATCW by MMG, dated February 2026 and reproduced in **Table 4.1**.

TABLE 4.1 – TAILINGS PRODUCTION FORECAST (FEBRUARY 2026)

Source	Year	Tailings to TSF (Mt)	
		Annual	Cumulative
Actuals	**2017**	0.231	0.231
	2018	1.243	1.474
	2019	1.066	2.540
	2020	0.807	3.347
	2021	0.819	4.166
	2022	0.827	4.993
	2023	0.835	5.828
	2024	0.854	6.681
Forecast	**2025**	0.928	7.609
	2026	0.858	8.467
	2027	0.861	9.329
	2028	0.784	10.113
	2029	0.893	11.006
	2030	1.002	12.008
	2031	0.786	12.794
	2032	0.806	13.600
	2033	0.791	14.391
	2034	0.773	15.165
	2035	0.781	15.946
	2036	0.775	16.721
	2037	0.772	17.493
	2038	0.779	18.272
	2039	0.824	19.096
	2040	0.827	19.923
	2041	0.891	20.814
	2042	0.820	21.634
	2043	0.709	22.343

4.4 Design Criteria Summary

The design requirements for the DRM TSF, as defined by DETSI **[5]**, ANCOLD **[6]**, and GISTM **[9]** are summarised in **Table 4.2**.

TABLE 4.2 – DESIGN CRITERIA SUMMARY

Item	Criteria Description	Criteria Requirement		
1		**DETSI**	Failure to Contain – Seepage	**Low**

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Item	Criteria Description	Criteria Requirement		
	Consequence Category (Refer **Section 7**)		Failure to Contain – Overtopping	**Significant**
			Dam Break	**High**
		ANCOLD	Dam Failure	**High C**
			Environmental Spill	**Low**
		GISTM	Consequence Classification	**High**
2	Embankment Stability Minimum Factor of Safety (FoS)	**Loading Condition**	**Criteria**	**Material Strength Parameters**
		Static Long Term	FoS ≥ 1.5	Drained (Effective) Strength
		Static Short Term (loss of containment)	FoS ≥ 1.5	Undrained Strength
		Static Short Term (no loss of containment)	FoS ≥ 1.3	Undrained Strength
		Post-seismic /Liquefaction	FoS ≥ 1.0	Post-liquefied strength / residual strength for materials that are potentially liquefiable and 20% reduction in peak shear strength for the materials that are not liquefiable
3	Seismic Criteria	Operating Basis Earthquake (OBE) – 1 in 475 AEP to 1 in 1,000 AEP (ANCOLD) Safety Evaluation Earthquake (SEE) – 1 in 2,000 AEP (ANCOLD) Operations and Closure – 1 in 2,475 AEP (GISTM)		
4	Wet Season Storage Allowance	Design Storage Allowance (DSA) – 1:20 AEP wet season runoff (DETSI) Design Storage Allowance (DSA) – 1:5 AEP wet season runoff (ANCOLD)		
5	Extreme Storm Storage Allowance	Extreme Storm Storage (ESS) – 1:10 AEP, 72-hr (DETSI) Extreme Storm Storage (ESS) – Determine by risk assessment (ANCOLD)		
6	Contingency Freeboard	Wave run-up from 1:10 AEP wind (DETSI) Nil wave run-up and nil additional freeboard (ANCOLD)		
7	Spillway Criteria	1:1,000 AEP to 1:100,000 AEP plus wave run-up for 1:10 AEP wind (DETSI) 1:100,000 AEP plus wave run-up for 1:10 AEP wind (ANCOLD); and PMF 1:2,475 AEP (GISTM)		

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5 SITE CHARACTERISATION

5.1 Topography

The Knapdale valley is some 3 km long and is generally less than 500 m wide within the tailings and decant water storage area. The sides of the valley are generally steep, ranging from 1.5:1 (horiz:vert) at the southern end, to 3.5:1 in the north. The valley floor, by comparison, is relatively flat, with its level ranging from a low point of RL 207 m at the base of the TSF Embankment, to RL 235 m at the southern end (approximately a 1 % slope). The Knapdale Valley has a perimeter level generally in excess of RL 260 m.

The valley has a catchment area of 338 hectares. The eastern side of the catchment extends across the Knapdale plateau some 700 m, whilst the western side ridgeline rises more abruptly before dropping down to the western toe of the range.

The single drainage outlet (TSF Embankment location) is a relatively narrow valley approximately mid-way along the western side. This valley extends some 600 m before reaching the western extent of the range and discharging into the Cabbage Tree Creek catchment.

5.2 Geology

The DRM project is located within the Mary Kathleen Zone of the Eastern Foldbelt of the Mt Isa Inlier, on Proterozoic sandstone, siltstone and quartzite. Based on the BMR Quamby Sheet 6957, 1980 Regional Geology Sheet, the 14 km long, 3 km wide Knapdale Range consists of Knapdale Quartzite of the Mount Albert Group, which overlie the Corella Formation calc-silicates. Separating the quartzite from the Corella Formation is a low angle, mylonitic thrust fault **[10]**.

The quartzite is a massive formation of medium grained, pink-grey metamorphosed sandstone, striking predominantly north-south with a dip of foliation angle in the range of 60 to 80 degrees to the west. There are no known faults running through the valley.

A specific assessment of the Knapdale Valley structural geology was conducted by ATCW in 2011, as documented in Appendix A of **[1]**.

5.3 Hydrogeology

An assessment of the hydrogeology of the Dugald River site and the groundwater aspects of the proposed mine development were conducted by Rob Lait and Associates in 2011 **[11]**. The following is a summary:

- There are no significant aquifers within the Knapdale Quartzite. The mylonitic fault which separates the quartzite from the Corella Formation to the east is considered to form a low permeability groundwater disconnect.
- Minor perched zones occur in the upper 10 m of the quartzite formation where unloading fractures occur. However, due to the nature of the quartzite formation, the groundwater exists only locally in the fissures within the rock mass. Below this depth, the formation is massive and unfractured.
- From permeability tests conducted in the Knapdale Valley TSF floor, the potential for leachate infiltration into the Knapdale Quartzite is considered low. Therefore, the potential for groundwater contamination is low. These tests are summarised below:
  - Average permeability of shallow (6 m to 10 m) bores = 8×10^{-8} m/s
  - Average permeability of deep (18 m to 30 m) bores = 5×10^{-9} m/s
- As with the Knapdale Range, the utilisation of groundwater within the Cabbage Tree Creek catchment area to the west has been very limited. However, the lack of production bores or wells in the area suggests it is a poor groundwater resource.

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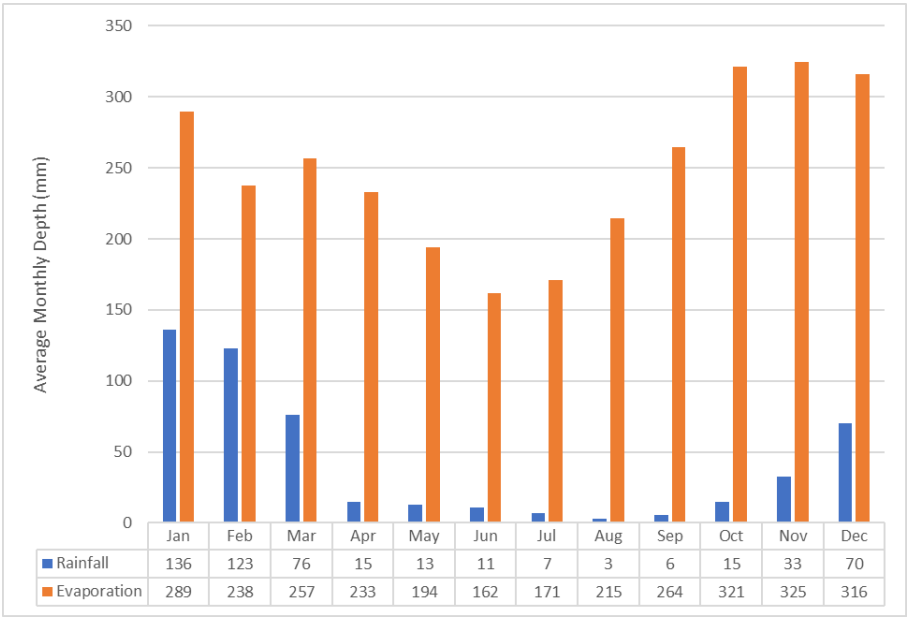
5.4 Climate Statistics

Highly variable rainfall occurs over the summer/wet season, which is typically hot and humid. Data obtained from the SILO Data Drill **[12]** from 01/01/1889 to 14/11/2022 indicates that the mean annual rainfall for the region is 503 mm, and the mean annual evaporation for the region is 2,991 mm. The highest monthly rainfall occurs generally over November to March, as illustrated in **Graph 5.1**. The lowest monthly rainfall occurs in the dry winter months of April to October. **Graph 5.1** indicates that monthly evaporation rates exceed rainfall year-round at the DRM site.

GRAPH 5.1 – RAINFALL AND EVAPORATION GRAPH



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	136	123	76	15	13	11	7	3	6	15	33	70
Evaporation	289	238	257	233	194	162	171	215	264	321	325	316

5.5 Design Rainfall

Estimates of the design rainfall intensities and depths for the 1 in 1 to the 1 in 2000 Annual Exceedance Probabilities (AEP) have been determined from the Bureau of Meteorology (BoM) Design Rainfall Database **[13] [14]**. The Intensity-Frequency-Duration (IFD) curves are presented in **Graph 5.2** with select AEP rainfall depths summarised in **Table 5.1**.

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GRAPH 5.2 – RAINFALL INTENSITY-FREQUENCY-DURATION CURVES

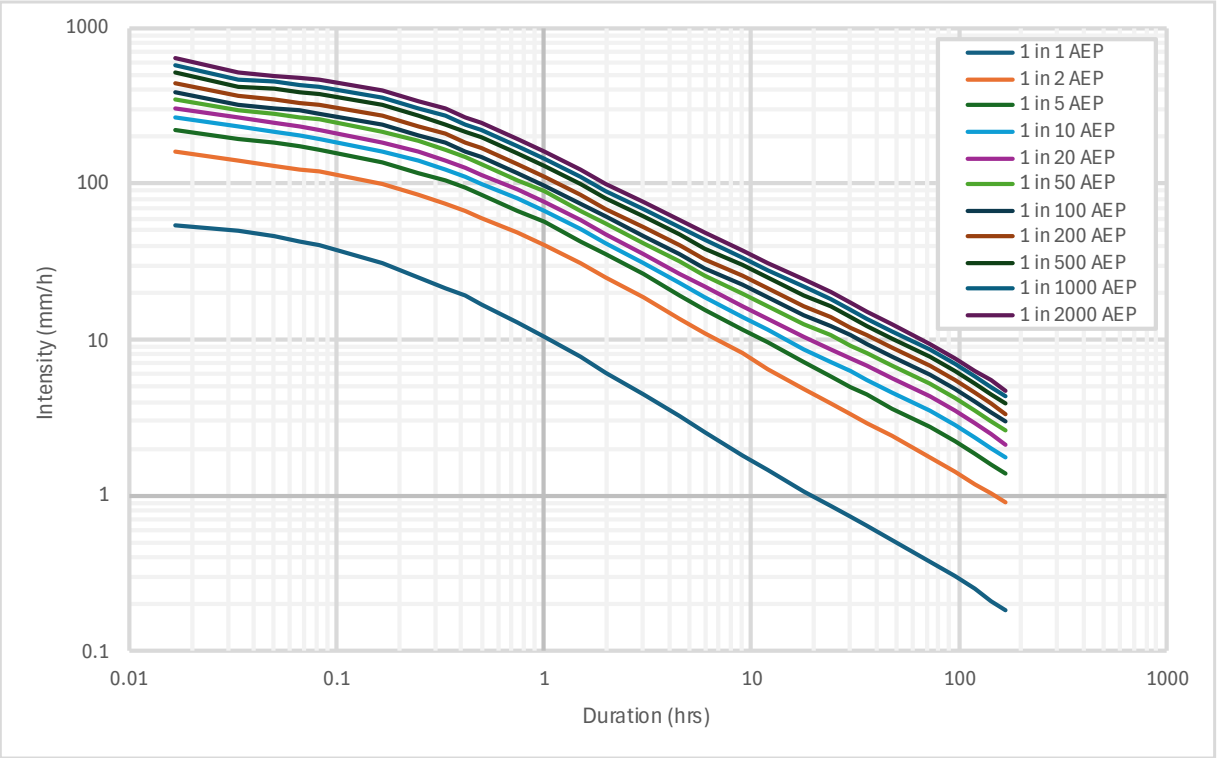

TABLE 5.1 – DESIGN RAINFALL DEPTHS

Duration (hrs)	Depth (mm)			
	1 in 10	1 in 100	1 in 1,000	1 in 2,000
0.25	35	52	77	86
0.5	50	74	110	122
0.75	60	87	129	144
1	67	97	144	160
2	83	122	181	201
3	94	138	206	229
4	101	151	226	252
5	107	163	244	272
6	113	173	260	290
9	127	200	301	335
12	138	222	334	373
24	173	291	434	482
48	221	378	542	596
72	252	430	616	676
120	284	483	695	763
144	290	494	713	784
168	293	499	722	795

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5.6 Extreme Rainfall

The extreme rainfall depths for short durations (up to 6 hours) and long durations (up to 72 hours) have been estimated in accordance with the Australian Rainfall and Runoff (ARR) Guidelines **[15]** and BoM estimation methods (**[16] [17]**).

The Probable Maximum Precipitation (PMP) depths for event durations between 0.25 hours and 6 hours have been estimated in accordance with the Generalised Short Duration Method (GSDM) **[16]**, whilst the PMP depths for durations up to 120 hours have been estimated in accordance with the Generalised Tropical Storm Method (GTSMR) **[17]**.

Estimates of the 1 in 10,000 AEP and 1 in 100,000 AEP events have been interpolated between the 1 in 1000 AEP, 1 in 2000 AEP, and PMP rainfall events based upon the procedure outlined in Siriwardena (1998) **[18]**. The resultant rainfall estimates are summarised in **Table 5.2**.

TABLE 5.2 – EXTREME RAINFALL DEPTHS

Duration (hrs)	Depth (mm)		
	1 in 10,000	1 in 100,000	PMP
0.25	108	142	200
0.5	153	201	290
0.75	183	246	370
1	202	272	430
2	255	355	650
3	292	410	780
4	324	459	890
5	349	497	980
6	373	530	1040
12	477	654	1080
24	606	798	1150
36	677	899	1420
48	739	987	1650
72	838	1138	2080
96	906	1239	2330
120	948	1298	2450

5.7 Climate Change Adjusted Rainfall Depths

A climate change study was carried out in April 2025 **[19]** by ATCW to adjust the design rainfall depths based on the latest ARR guidance **[15]**. The adjustments are based on a medium Shared Socioeconomic Pathway (SSP2-4.5) and are applicable for the year 2040.

The adjusted rainfall depths for select AEPs are presented in **Table 5.3**.

TABLE 5.3 – CLIMATE CHANGE ADJUSTED RAINFALL DEPTHS (YEAR 2040)

Duration (hrs)	Depth (mm)					
	1 in 10	1 in 100	1 in 1,000	1 in 10,000	1 in 100,000	PMP
0.25	43	63	94	132	173	244
0.5	61	90	134	187	245	354
0.75	73	106	157	224	300	451

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Duration (hrs)	Depth (mm)					
	1 in 10	1 in 100	1 in 1,000	1 in 10,000	1 in 100,000	PMP
1	81	118	176	247	332	525
2	99	145	215	304	422	774
3	109	161	241	342	479	913
4	118	176	263	377	534	1037
5	124	188	282	404	574	1132
6	130	199	299	429	609	1196
12	156	251	377	539	739	1220
24	194	326	486	678	893	1288
36	224	381	551	758	1006	1590
48	248	423	607	828	1106	1848
72	282	482	690	939	1274	2330
96	305	519	744	1015	1387	2610
120	318	541	778	1062	1453	2744

5.8 Wind

Wind direction and speed data over the period 2001 to 2025 was obtained from the BoM for Cloncurry Airport (weather station ID 29141) **[13]**. Wave development is a function of sustained winds rather than short duration gusts, so it was important to distinguish maximum 10 minute wind speeds from the higher speed gusts. In total, hourly 10 minute maximum wind speeds and orientations were analysed for the period 2001 to 2025.

Table 5.4 summarises the annual maximum recorded wind gusts in the NE-N, E, and SE-S directions.

To obtain the 1:10 AEP wind speed in each direction, lognormal probabilistic distributions were fitted to the obtained data. The estimated 1:10 AEP wind speeds are presented in **Table 5.5**. Winds blowing from the SW, W and NW directions were not considered in the assessment as it was determined that these would not induce any wave actions due to the orientation of the embankment.

TABLE 5.4 – MAXIMUM WIND SPEED SUMMARY

Year	Maximum Wind Speed (km/h)			
	All Directions	NE-N	E	SE-S
2001	61.2	29.5	37.1	61.2
2002	74.2	42.5	42.5	46.4
2003	79.6	44.3	79.6	70.2
2004	64.8	50	64.8	53.6
2005	64.8	46.4	53.6	61.2
2006	76	42.5	76	64.8
2007	70.2	53.6	53.6	63
2008	51.8	44.3	48.2	48.2
2009	63	42.5	50	63
2010	55.4	55.4	46.4	50
2011	68.4	68.4	61.2	51.8
2012	64.8	46.4	57.2	64.8
2013	63	59.4	63	53.6

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Year	Maximum Wind Speed (km/h)			
	All Directions	NE-N	E	SE-S
2014	85.3	46.4	57.2	64.8
2015	59.4	42.5	57.2	46.4
2016	57.2	42.5	55.4	57.2
2017	72.4	53.6	57.2	72.4
2018	81.4	42.5	76	81.4
2019	76	50	57.2	76
2020	72.4	50	50	48.2
2021	72.4	63	48.2	72.4
2022	76	40.7	66.6	72.4
2023	64.8	37.1	42.5	48.2
2024	68.4	50	51.8	68.4
2025	83.2	55.4	61.2	64.8
Maximum Recorded	85.3	68.4	79.6	81.4

TABLE 5.5 – 1 IN 10 AEP WIND SPEED SUMMARY

Wind Speed (km/h)	NE-N	E	SE-S
1 in 10 Wind Speed	59	71	75

5.9 Seismicity

A probabilistic seismic hazard assessment (PSHA) of the region was conducted by the Seismology Research Centre (SRC) in 2008.

An updated PSHA of the Dugald River TSF was conducted by ATCW in June 2024 **[20]**. The calculated site peak ground accelerations (PGA) for different return periods are presented in **Table 5.6**.

TABLE 5.6 – PGA AS A FUNCTION OF RETURN PERIOD

Return Periods	PGA (g)
475 yr	0.0029
1,000 yr	0.0063
2,000 yr	0.0123
2,475 yr	0.0146
5,000 yr	0.0252
10,000 yr	0.0408

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6 TAILINGS CHARACTERISATION

6.1 Tailings Classification

ATCW has completed numerous tailings characterisation testing on the Dugald River tailings. The laboratory testing included basic characterisation tests (particle density, plasticity) and specialised tailings testing (initial and shrinkage limit density, rheology, Rowe Cell consolidation).

A summary of the outcomes from the characterisation testing is presented in **Table 6.1**. The tailings laboratory testing report for the 2025 round of testing is provided in **Appendix A.**

TABLE 6.1 – TAILINGS CLASSIFICATION SUMMARY

Parameter	2008 [21] Flocculated Pb/Zn Bulk Float Tailings Sample	2015 [22] Flocculated Zn Tailings	2025 [23] Flocculated Tailings
Specific Gravity	2.96	2.97	2.96
Liquid Limit	21	19	28
Plastic Limit	15	19	16
Plasticity Index	6	0	12
Unified Soil Classification	Low plasticity silt	Low plasticity silt	Low plasticity clay
Segregation Threshold	46% solids	47% solids	40% solids
Initial Settled Density	1.08 – 1.2 t/m^3	1.22 t/m^3	1.15 t/m^3
Shrinkage Limit Density	1.63 t/m^3	1.67 t/m^3	1.80 t/m^3

6.2 Tailings Design Density

For design purposes, the Overall In-situ Density (OID) is used to estimate the required capacity of the TSF. A summary of the OID achieved to May 2025 for the existing Stage 2 TSF since commissioning is provided in **Table 6.2**. As of May 2025, an OID of 1.37 t/m^3 was estimated.

However, during the period October 2020 to November 2022 the OID was estimated to be at or below the assumed design density of 1.35 t/m^3. The OID is predicted to improve over time due to the increasing TSF beach area, relative to the decant pond extents, and the commensurate lower rate of rise and greater beach area exposed to evaporative drying.

Notwithstanding this, an OID of 1.35 t/m^3 has been adopted for this study.

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TABLE 6.2 – ACHIEVED OVERALL IN-SITU DENSITY FOR DRM TSF TAILINGS

Date of Survey	Cumulative Tonnage (t)	Consumed Volume (m^3)	OID (t/m^3)
1 October 2017	-	-	-
15 November 2018	1,300,147	821,009	1.58
18 December 2018	1,414,455	860,749	1.64
5 September 2019	2,190,879	1,546,332	1.42
10 December 2019	2,466,392	1,687,963	1.46
17 June 2020	2,919,453	2,136,524	1.37
7 October 2020	3,139,253	2,324,235	1.35
24 February 2021	3,482,931	2,748,000	1.27
17 June 2021	3,710,134	2,707,600	1.37
21 October 2021	4,010,833	3,031,591	1.32
17 February 2022	4,247,083	3,380,188	1.26
21 June 2022	4,492,636	3,485,576	1.29
3 November 2022	4,815,770	3,600,769	1.34
20 April 2023	5,191,174	3,428,600	1.51
18 July 2023	5,402,969	3,777,616	1.43
16 October 2023	5,642,483	3,827,303	1.47
24 January 2024	5,881,315	3,857,903	1.52
25 April 2024	6,127,224	4,256,699	1.44
18 July 2024	6,244,662	4,665,573	1.34
13 October 2024	6,446,990	4,672,253	1.38
21 January 2025	6,728,680	4,958,387	1.36
21 May 2025	7,032,385	5,141,381	1.37

6.3 Tailings Geochemistry

A review of the available geochemical monitoring data for the DRM tailings was carried out by ATCW in 2024 **[24]**, which involved an assessment of 215 discrete samples which were collected by MMG

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between October 2018 and April 2024 and dispatched to an independent laboratory for testing. Test work included:

- Net Acid Production Potential (NAPP);
- Maximum Potential Acidity (MPA);
- Acid Neutralising Capacity (ANC);
- Net Acid Generation (NAG);
- Total Zinc;
- Total Lead;
- Total Sulphur; and
- Chromium Reducible Sulphur (CRS).

Summary statistics for the complete dataset is shown in **Table 6.3**. The small variation between the median and mean values indicate that the properties of the tailings are generally stable.

TABLE 6.3 – TAILINGS GEOCHEMISTRY SUMMARY STATISTICS

Test	NAPP (kg H2SO4/t)	ANC (kg H2SO4 equiv./t)	MPA (kg H2SO4 equiv./t)	Total Zinc (mg/kg)	Total Lead (mg/kg)	Total Sulphur (%)
Count	201	201	204	199	199	204
Median	231	51	285	13,800	3,610	9
Mean	231	52	285	14,197	3,725	9
Standard Deviation	37	18	32	5,059	951	1

6.4 Liquefaction Potential

Based upon the tailings particle size distribution and tailings characteristics reported in **Section 6.1**, the tailings are a fine grained silt/clay of low plasticity.

The criteria published by Boulanger **[25]** show that a fine-grained silt tailings with Plasticity Index less than 5 will be potentially liquefiable when saturated. Therefore, the DRM tailings are conservatively assessed to be potentially liquefiable on the basis of the results of the laboratory testing (**Section 6.1**).

7 CONSEQUENCE CATEGORY ASSESSMENT

7.1 Overview

In order to ensure regulatory compliance with DETSI, an assessment of failure impacts and associated Consequence Categories has been completed for the Stage 3 TSF. The review has been completed in accordance with the DETSI, “Manual for assessing consequence categories and hydraulic performance of structures”, referred to herein as “the Manual” **[5]**. An assessment of the Consequence Category to ANCOLD **[8]** and GISTM guidelines **[9]** has also been carried out.

In accordance with the Manual, all dams associated with the operation of an environmentally regulated activity must have their Consequence Category assessment based on the potential environmental harm that would result from potential failure event scenarios. The Consequence Category will determine whether the structure is a Regulated Structure. A structure is only a Regulated Structure where the Consequence Category for the structure is ‘Significant’ or ‘High’.

7.2 Dam Break Assessment

7.2.1 Overview

In order to assess the impacts of a TSF Embankment failure on the downstream receiving environment, a dam break assessment was completed for the Stage 3 TSF configuration. This assessment is documented in **Appendix B** and is summarised in the following sections.

7.2.2 Downstream Receiving Area

The TSF Embankment is located within a narrow gully which drains the Knapdale Range valley impoundment into an unnamed tributary of Cabbage Tree Creek. Cabbage Tree Creek is located in the Leichardt River Basin, which discharges north to the Gulf of Carpentaria. Apart from Cabbage Tree Creek, the downstream receiving area is considered generally flat, with a slight gradient dropping in a south to north direction.

A local access road is located approximately 5 km to the north of the TSF Embankment. This road is on an east west alignment, connecting Burke Development Rd to Lake Julius.

The nearest third-party asset is a future proposed mining project, owned by Harmony Gold Mining Co. Ltd. (Harmony). The project will consist of a mining pit, called “Little Eva” Pit, approximately 14 km downstream of the DRM TSF Embankment and in close proximity to Cabbage Tree Creek. The Little Eva Pit infrastructure is proposed to include a diversion drain and a flood protection levee designed to divert the flood levels recorded during the extreme, 2009 wet season Cabbage Tree Creek flood event **[26]**.

7.2.3 Modelled Scenarios

The selection of the dam break scenarios to be modelled have been based upon the credible failure modes identified in the Failure Mode and Effects Analysis (FMEA) process (**Section 15.3**).

Dam break modelling was carried out for a hypothetical Sunny Day Failure (SDF) mechanism. Under this scenario, it was assumed that global instability failure occurs causing significant deformation of the embankment and a loss of freeboard. Water begins overtopping the embankment, resulting in gradual erosion of the embankment crest. The loss of confining stress also causes static liquefaction of the tailings, which begin overtopping the embankment once the crest erodes to the level of the tailings. The release of water and liquefied tailings is into a dry downstream environment.

7.2.4 Breach Characteristics

The embankment breach was assumed to occur at the location coincident with the greatest embankment height in order to maximise the potential release volumes. This corresponds to the centre of the Stage 3 TSF.

The breach depth was limited to approximately two-thirds of the embankment height for the following reasons:

1. The identified credible failure mode relates to overtopping and progressive erosion of the crest, rather than a global failure of the entire structure, such as an instability failure through the foundation;
2. The embankment will be constructed predominantly from quarried quartzite rockfill and lined with a Bituminous Geomembrane Liner, and therefore will be less susceptible to erosion;
3. A portion of the liquefied tailings is assumed to mobilise and continue the breach propagation, however it is expected that a point of equilibrium will be reached with increased depth as higher strength, more consolidated tailings are exposed;
4. The embankment will be approximately 130 m wide at the base of the breach; and
5. A portion of the mobilised tailings and embankment materials will likely be deposited against the downstream toe of the embankment, providing additional resistance against continued breach propagation to the full height.

A sensitivity assessment was also carried out assuming a full-height breach to understand the potential increase in the failure impact.

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The adopted breach parameters are summarised in **Table 7.1** based on the estimated release volumes detailed in **Section 7.2.7**.

TABLE 7.1 – EMBANKMENT BREACH PARAMETERS

Parameter	SDF
Breach Base Level	RL 221.5 m
Breach Height	32.0 m
Average Breach Width	82.6 m
Breach Side Slopes	1H:1V
Breach Development Time	0.56 hrs (34 mins)

7.2.5 Tailings Parameters

The tailings parameters adopted for the dam break assessments are summarised in **Table 7.2**.

TABLE 7.2 – ADOPTED TAILINGS PARAMETERS FOR DAM BREAK ASSESSMENTS

Parameter	Description	Value
G_S	Solids specific gravity	2.97
ρ_d	In-situ dry density	1.35 t/m^3
S_u	Undrained, post-liquefaction shear strength ratio	0.07
C_w	Initial solids concentration (by weight)	71.2%

7.2.6 Tailings Rheology

The tailings rheological parameters define the non-Newtonian flow characteristics of the liquefied tailings, and have been obtained from the following laboratory testing which have been completed in ATCW's Melbourne laboratory:

- Bob and Cup Rheology Test
- Shear Vane with Shrinkage Limit Density Testing

The exponential relationships between the Bingham Plastic yield stress and the Bingham Plastic viscosity versus solids concentration is presented in **Graph 7.1** and **Graph 7.2**.

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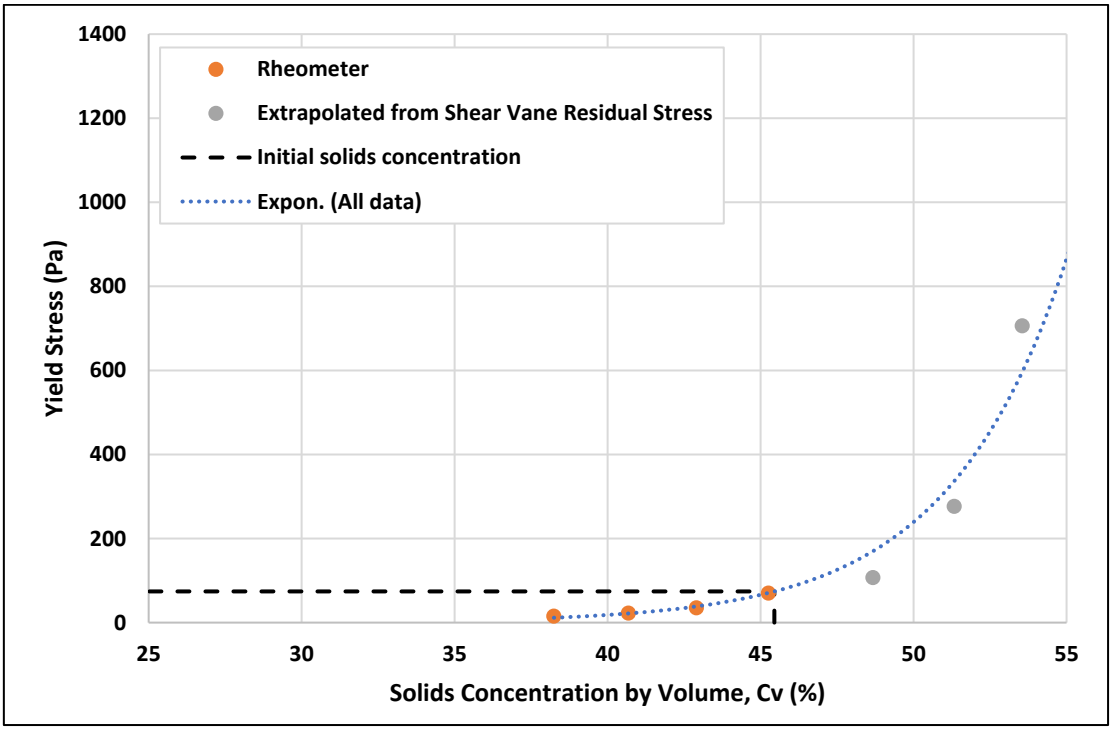
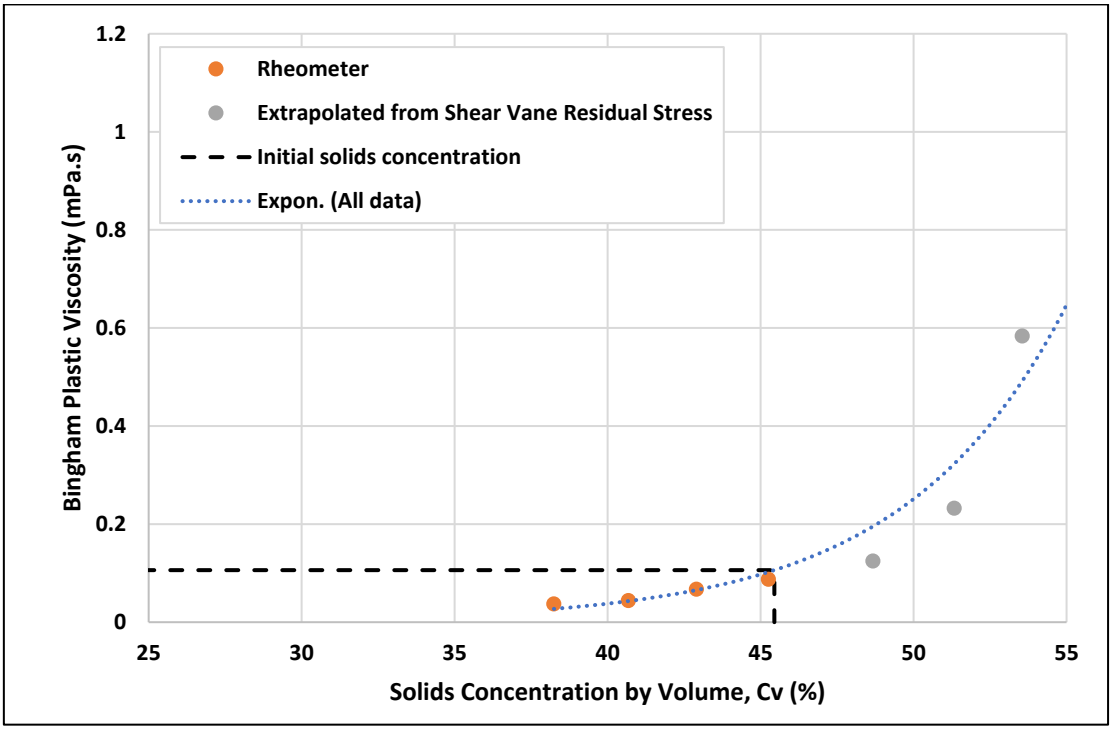
GRAPH 7.1 – BINGHAM PLASTIC YIELD STRESS



GRAPH 7.2 – BINGHAM PLASTIC VISCOSITY



7.2.7 Dam Break Release Volumes

The estimated water release volume was determined as the volume of stored water above the assumed breach base. The reservoir volume prior to the dam break was conservatively assumed to be at the spillway invert level to represent that maximum potential impact.

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The tailings release volume was estimated by predicting a residual post-failure slope of the tailings backscarp based on Infinite Slope Theory **[27]**. This is estimated to be 3.3% based upon the tailings parameters listed in **Table 7.2**. The tailings material located above the tailings backscarp is assessed as the mobilised failure volume.

The assumed release volumes are summarised in **Table 7.3**.

TABLE 7.3 – ASSUMED DAM BREAK RELEASE VOLUMES

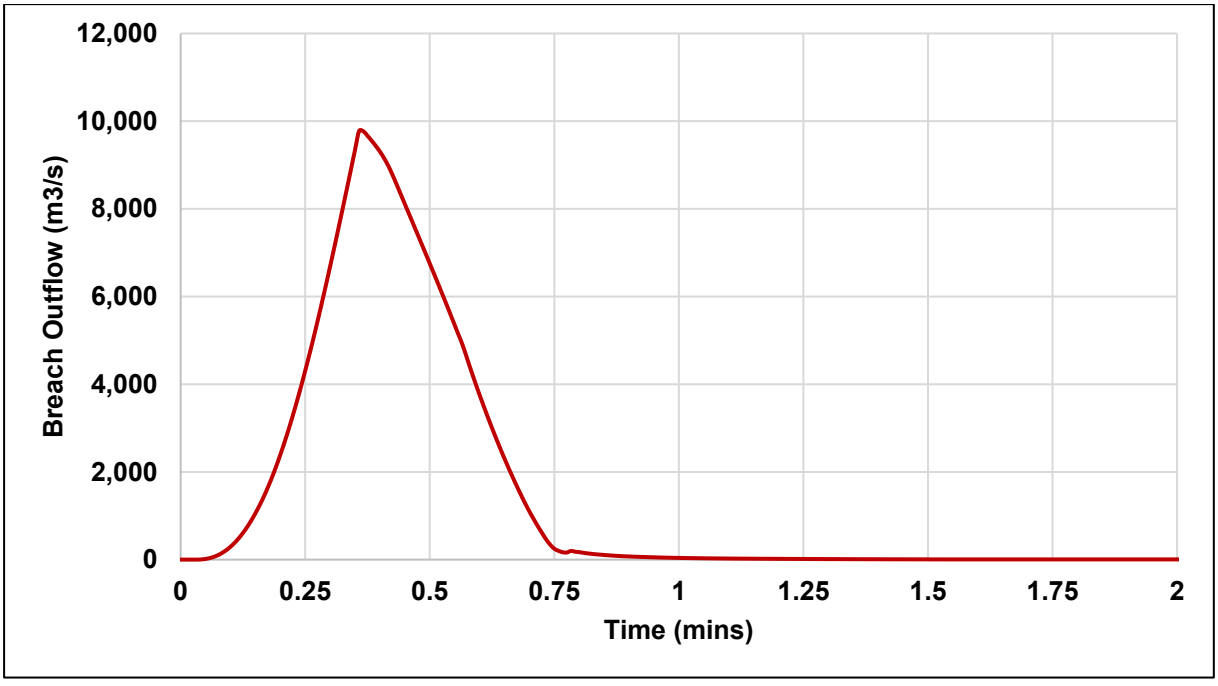
Parameter	SDF
Tailings Release Volume	3,859,700 m3
Water Release Volume	7,248,500 m3

7.2.8 Breach Hydrograph

The breach hydrograph has been developed in hydraulic modelling software HEC-RAS. This method idealises the tailings breach hydrograph as water flow. ATCW considers this to be conservative and appropriate, particularly given that the majority of the dam break flows are expected to comprise water.

A plot of the assumed breach hydrograph is presented in **Graph 7.3**.

GRAPH 7.3 – DAM BREAK HYDROGRAPH



7.2.9 Modelling Outcomes

The results of the Stage 3 dam break assessment indicate that the dam break flows will initially propagate westward through the unnamed tributary of Cabbage Tree Creek until intersecting the Cabbage Tree Creek drainage path. It is noted that the dam break flows may inundate multiple drainage paths before turning into Cabbage Tree Creek and flowing northwards towards the Little Eva Pit.

The results indicate that the proposed diversion drain and flood protection levee around Little Eva Pit are capable of diverting the majority of the mobilised flood volumes away from the Little Eva Pit. The results indicate that some minor overtopping of the proposed flood protection levee is anticipated at the northern extents where the crest of the proposed flood protection levee is at its lowest.

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After being diverted away from the Little Eva Pit, the dam break flows continue northwards along the Cabbage Tree Creek before joining the Leichardt River at the Cabbage Tree Creek-Leichardt River confluence.

7.2.10 Sensitivity Analysis

As part of the Stage 3 dam break assessments, a sensitivity analysis was carried out by assuming a full-height embankment breach. This assumption results in the release of approximately 11.4 Mm^3 of liquefied tailings (comprising approximately 83% of the Stage 3 storage volume).

The results of the sensitivity assessment indicate that the dam break flows follow a similar flow path to the Base Case assessment, but with a wider footprint along both the unnamed Tributary of Cabbage Tree Creek and Cabbage Tree Creek itself.

The results indicate that the addition of the liquefied tailings results in significant overtopping of the proposed Little Eva Pit flood protection levee. It is therefore evident that the performance of the Little Eva Pit flood protection levee is sensitive to the mobilised tailings volume (and by extension the assumed breach depth).

7.3 Consequence Category

7.3.1 Guidelines and Considerations

As part of the Stage 3 dam break assessment (**Appendix B**), consequence category assessments have been carried out in accordance with the following methodologies:

- DETSI **[5]** - three separate scenarios for which different design criteria apply:
  - Failure to Contain (seepage) – sets the required containment and detection measures;
  - Failure to Contain (overtopping) – sets the required flood management criteria (i.e., Design Storage Allowance and Mandatory Reporting Level); and
  - Dam Break – sets the required spillway capacity.
- ANCOLD **[6]** – two separate scenarios for which different design criteria apply:
  - Dam Failure – sets the required spillway capacity and seismic design ground motions; and
  - Environmental Spill – sets the required flood management criteria (i.e., Design Storage Allowance, Extreme Storm Storage Allowance and Contingency Freeboard).
- GISTM **[9]**
  - Dam Failure – sets the required earthquake and flood management criteria, differentiating between active care and passive care.

The DETSI CCA is used as the basis for obtaining regulatory approvals for the TSF, and generates hydrological and hydraulic design criteria, provided they meet or exceed the requirements of ANCOLD. The ANCOLD CCA is used by MMG for internal business risk ranking and application of critical controls, whilst the GISTM CCA is assessed to demonstrate compliance with the GISTM.

The consequence category assessment is documented in **Appendix B** and is summarised in the following sections.

7.3.2 Population at Risk (PAR)

Based on the ANCOLD guidelines **[8]**, the PAR is considered to be “all those persons who would be directly exposed to floodwaters within the dam break affected zone if they took no action to evacuate”

The ANCOLD and GISTM assessments consider both internal (i.e. MMG personnel) and external populations; whilst the DESI assessments only consider third-party (external) populations.

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The assessment of PAR has been based on information provided by MMG and considers the proportion of time the individual or group can be expected to be exposed to the dam break inundation area. Separate PAR estimates have been carried out for Day and Night periods.

MMG have advised that the potential PAR will comprise those listed in **Table 7.4**. The time-weighted estimate of the PAR is summarised in **Table 7.5**.

TABLE 7.4 – POTENTIAL POPULATIONS AT RISK

Task	No. People	Frequency (day time)	Frequency (night time)
Daily Inspections	1 person	1 hrs per inspection, once per day	Day shift only
Weekly Inspections	2 people	2 hrs per inspection, once per week	Day shift only
Monthly Inspections	1 person	2 hrs per inspection, once per month	Day shift only
Annual Surveillance Inspections	5 people	10 hrs per inspection, once per year	Day shift only
SCP Pump Maintenance	2 people	2 hrs a week	Day shift only
Environmental Sampling	2 people	2 hrs, once per month 3 hrs, once per quarter	Day shift only
Land Owner Inspections	1 person	6 hrs, twice per year	Day shift only
Drilling	2 people	12 hrs, once per year	Day shift only
Ad hoc Inspections	2 people	2 hrs, once per month	Day shift only
Little Eva Pit[1]	10 people	12 hrs shift	Day shift and night shift

Note 1: Conservative assumptions due to limited available information.

TABLE 7.5 – ESTIMATED POPULATION AT RISK

Task	Frequency	People Hours/Week	
		Day Time	Night Time
Daily Inspections	1 person x 1 hrs per inspection x once per day	7.000	-
Weekly Inspections	2 people x 2 hrs per inspection x once per week	4.000	-
Monthly Inspections	1 person x 2 hrs per inspection x once per month	0.462	-
Annual Surveillance Inspections	5 people x 10 hrs per inspection x once per year	0.962	-
SCP Pump Maintenance	2 people x 2 hrs a week	4.000	-
Environmental Sampling	(2 people x 2 hrs x once per month) + (2 people x 3 hrs x once per quarter)	1.385	-

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Task	Frequency	People Hours/Week	
		Day Time	Night Time
Land Owner Inspections	1 person x 6 hrs x twice per year	0.231	-
Drilling	2 people x 12 hrs x once per year	0.462	-
Ad hoc Inspections	2 people x 2 hrs x once per month	0.923	-
Little Eva Pit	10 people x 12 hrs	840.000	840.000
	Total People Hours/Week	859.424	840.000
	Total Hours per Week	84	84
	Equivalent PAR (Time-Weighted)	**10.231**	**10.000**

7.3.3 Potential Loss of Life (PLL)

Estimates of the PLL have been carried out in accordance with ANCOLD **[28]**. As recommended by ANCOLD, the RCEM approach **[29]** has been used to estimate the PLL.

The fatality rates and Weighted PLL for each population is summarised in **Table 7.6**.

TABLE 7.6 – ESTIMATED POTENTIAL LOSS OF LIFE

Task	People Hours/Week	Weighted PAR		Fatality Rate	Weighted PLL	
		Day	Night		Day	Night
Daily Inspections	7.000	0.083	-	0.8	0.067	-
Weekly Inspections	4.000	0.048	-	0.8	0.038	-
Monthly Inspections	0.462	0.005	-	0.8	0.004	-
Annual Surveillance Inspections	0.962	0.011	-	0.8	0.009	-
SCP Pump Maintenance	4.000	0.048	-	0.8	0.038	-
Environmental Sampling	1.385	0.016	-	0.8	0.013	-
Land Owner Inspections	0.231	0.003	-	0.8	0.002	-
Drilling	0.462	0.005	-	0.8	0.004	-
Ad hoc Inspections	0.924	0.011	-	0.8	0.009	-
Little Eva Pit	840.000	10.000	10.000	0.01	0.100	0.100
	Total PAR	**10.231**	**10.000**	**Total PLL**	**0.285**	**0.100**

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7.3.4 Consequence Category Summary

A detailed Consequence Category assessment was carried out and is documented in **Appendix B**. A summary of the assigned Consequence Categories is provided in **Table 7.7**.

TABLE 7.7 – CONSEQUENCE CATEGORY SUMMARY

Methodology	Scenario	Base Case
DETSI	Failure to Contain - Seepage	**Low**
	Failure to Contain – Overtopping	**Significant**
	Dam Break	**High**
ANCOLD	Dam Failure	**High C**
	Environmental Spill	**Low**
GISTM	Consequence Classification	**High**

It is noted that the definition of the ANCOLD 'Environmental Spill' consequence category is broadly equivalent to the DETSI 'Failure to Contain – Overtopping' consequence category, particularly as both relate to the consequences of spilling of water from the dam during a flood event or extreme wet weather period.

However, the DETSI 'Failure to Contain – Overtopping' consequence category has been assessed as 'Significant', whilst the ANCOLD 'Environmental Spill' consequence category has been assessed as 'Low'. This discrepancy is driven by the difference in assessment methodologies.

The DETSI assessment nominates a 'Significant' general environmental harm, which thus drives the overall 'Failure to Contain – Overtopping' consequence category of 'Significant'. The ANCOLD assessment nominates a 'Significant' Severity of Damage and Loss (driven by environmental impacts), but considers the low Potential Loss of Life (PLL) to assign the 'Environmental Spill' consequence category of 'Low'.

8 TAILINGS MANAGEMENT

8.1 Deposition Strategy

Tailings discharge is proposed to continue from the northern and southern ends of the valley on a rotational basis, such that the low point of the tailings beach where the decant pond forms, is maintained in the centre of the valley.

Five discharge points are proposed as follows:

- Northern Discharge Point 1 (ND1);
- Northern Discharge Point 2 (ND2);
- Southern Discharge Point 1 (SD1);
- Southern Discharge Point 2 (SD2); and
- Southern Discharge Point 3 (SD3).

In order to optimise the tailings storage capacity within the TSF and maintain operability of the RWS, tailings deposition is proposed to be managed in accordance with the following principles.

- Tailings Discharge Solids Concentration -

  Discharge of tailings at or above the target solids concentration (52 – 55% w/w) results in predominantly sub-aerial (above water) deposition. Solids deposited at higher elevations are

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more likely to drain bleed water and desiccate, thus supporting the development of higher OID.

Discharge of tailings with solids concentrations lower than the target will travel further down the beach before deposition occurs. Tailings that deposit on the lower or flatter sections of beach or sub-aqueously (under water) are slower to consolidate and therefore make for a less efficient storage.

- Sub-aerial Discharge & Rotation -

  The objective of sub-aerial discharge and rotation is to fill the TSF by way of a series of thin layers that form gently sloping beaches that support near laminar flow, therefore enabling deposition of solids. Water liberated from the tailings through the deposition phase drains towards the Decant Pond located at the centre of the facility.

  Discharge of tailings into the TSF currently occurs from discharge points located at the northern and southern ends of the facility. Discharge occurs from only one point at a time, but regular rotation of the active discharge point is conducted to maximise the development of thin layers and the development of target OID.

- Decant Pond Control -

  The objective of Decant Pond control is to concentrate bleed and surface water runoff in a location area where it can be easily recovered.

  It is essential that the decant pond is maintained in a central location adjacent to the RWS and the TSF Embankment (Water management and general operation of the RWS are discussed in **Section 9**). This is to be managed by strategic use of each discharge point in a rotational manner as appropriate.

8.2 Tailings Beach Slope and Rheology

The beach slope depends upon the tailings discharge solids concentration, rheology, and the total flow in the tailings stream. Another significant factor is whether the tailings are being discharged sub-aerially (i.e. on a drying beach), or sub-aqueously (i.e. into the decant pond).

A three-stage tailings beach slope model has been adopted, based on the beach slopes observed in the TSF from aerial and bathymetric surveys to date.

The January 2025 survey shows sub-aerial (above water level) beach slopes ranging from 0.1% to 0.5%. These slopes are likely to be limited by the short sub-aerial beach lengths.

Sub-aqueous (below water level) beach slopes of between 1.0% and 5.5% have been measured from the July 2025 survey. The sub-aqueous beach has been characterised by two slopes, an upper slope and a lower slope.

The adopted beach slope profile for tailings deposition modelling is as follows:

- Sub-aerial: Northern 0.3%, Southern 0.5%
- Sub-aqueous (upper slope): Northern 5.5%, Southern 2.2%
- Sub-aqueous (lower slope): Northern 1.3%, Southern 4.5%

The design beach slopes will be reviewed as part of routine surveillance and monitoring procedures.

8.3 Tailings Deposition Modelling

Tailings deposition modelling was undertaken to estimate the tailings storage capacity of the facility following the 9.25 m Stage 3 embankment raise. The modelling was undertaken using Muk 3D software. The design assumptions for the 3d modelling are detailed in **Section 4** and **Section 6**.

Based on recent process data provided by MMG, 7.03 Mt of tailings (5.14 Mm^3) were deposited into the TSF up to the 21st of January 2025. This therefore requires an additional 15.3 Mt of tailings to be stored within the DRM TSF to accommodate the tailings production forecast to 2043 (**Section 4.3**). This converts to 11.3 Mm^3 based on the adopted tailings OID of 1.35 t/m^3.

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Based on an assumed operational decant pond volume of 200 ML (informed by probabilistic water balance modelling described in **Section 9.1**), the Stage 3 TSF will provide an additional 14.2 Mm^3 of capacity (from January 2025). This converts to 19.2 Mt based on the adopted design density of 1.35 t/m^3.

Based on the above, the Stage 3 raise will provide a total tailings capacity of **26.2 Mt** (i.e. 3.9 Mt above the total forecasted production). However, it is noted that this estimated tailings capacity is subject to change based on the size of the decant pond and achieved tailings beach slopes.

9 WATER MANAGEMENT

9.1 Water Balance Modelling

9.1.1 Introduction

To inform the water management criteria, ATCW conducted probabilistic water balance modelling for the Stage 3 raise to understand the potential variations in the decant pond over the life of the facility.

The operating pond volume influences the geometry of the tailings beach, as beach slopes increase below the pond water level (refer to **Section 8.2**).

The outcomes of the water balance modelling is documented in **Appendix C**. The following sections present a summary of the outcomes for “Scenario 3” of the water balance modelling, which considers the influences of climate change and the TSF evaporators currently in operation. This is considered to be the most representative scenario for the purposes of the detailed design.

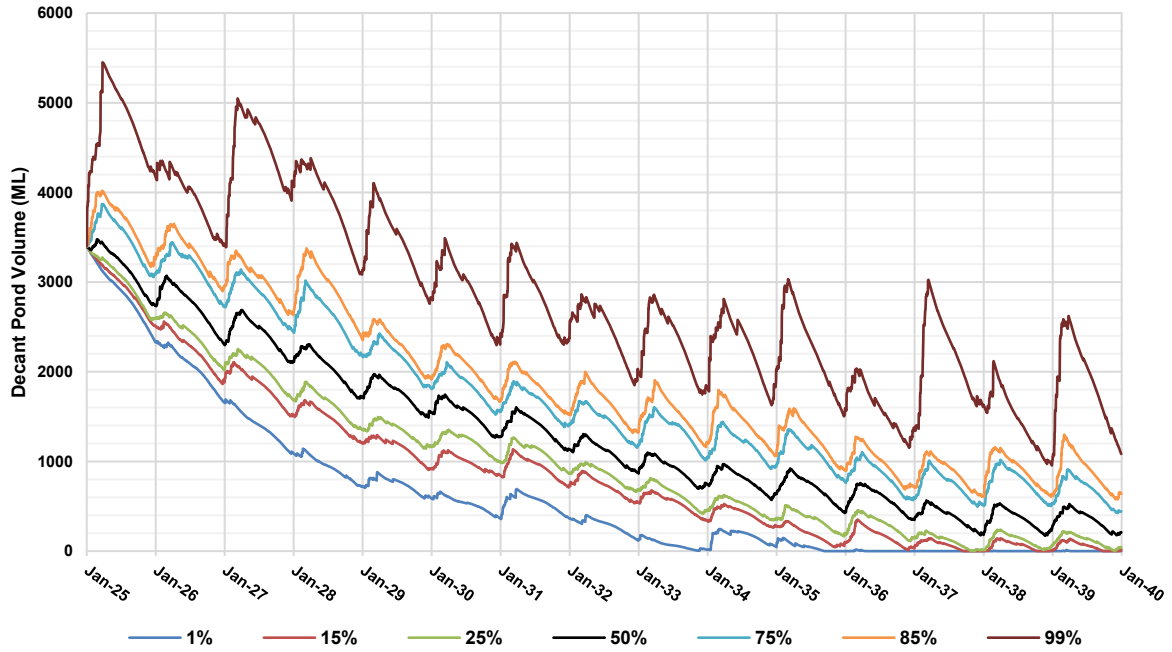
9.1.2 Operating Pond

The outcomes from the water balance study are shown in **Graph 9.1** and **Graph 9.2**.

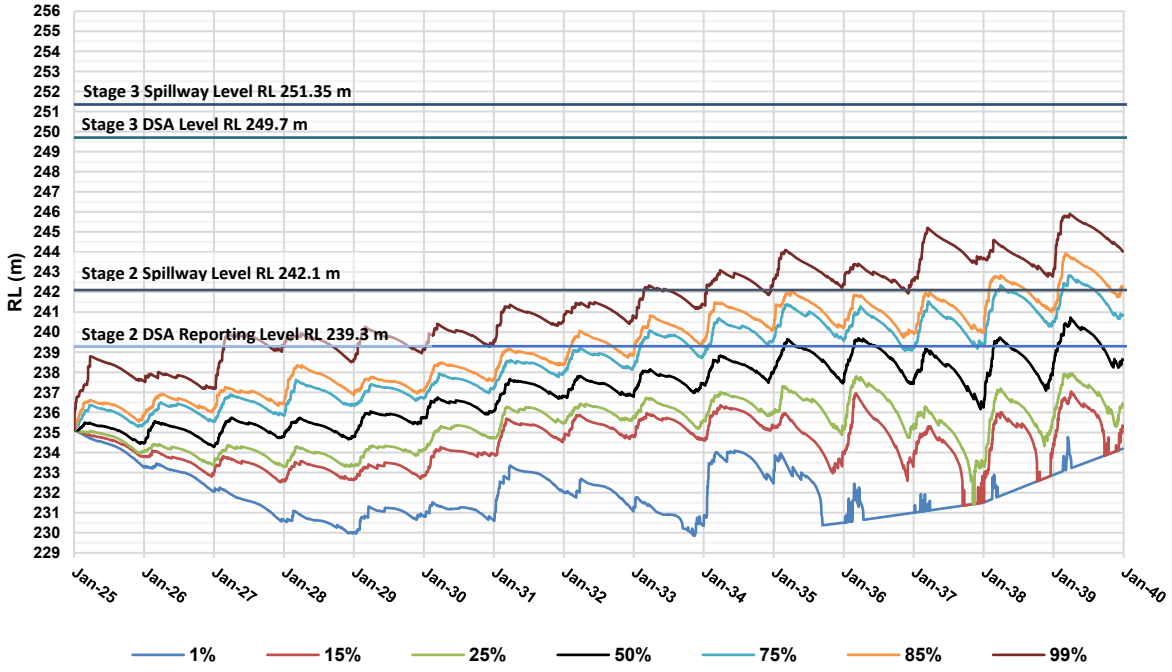
The results of the water balance modelling indicate the following:

- The TSF decant pond generally reduces over time as a result of climatic effects (i.e., evaporation rates exceeding precipitation) and the influence of the TSF evaporators. In particular, the modelling indicates that the role of the evaporators in drawing down the decant pond volumes is significant;
- There is a 15% probability of the Stage 2 DSA Reporting Level being exceeded by February 2031; and
- The Stage 3 DSA Reporting Level is not exceeded for any of the water balance realisations (maximum probability plots not shown for clarity). It is thus unlikely that the Stage 3 DSA Reporting Level will be exceeded during the operational life of the facility.

GRAPH 9.1 – MODELLED DECANT POND VOLUME



GRAPH 9.2 – MODELLED DECANT POND LEVEL



9.1.3 Design Storage Allowance

The DSA for the Stage 3 TSF was calculated using the Method of Operational Simulation, as follows:

- The maximum increase in stored water inventory for the TSF over the last year of operations wet season was sampled from 100 simulated wet seasons from the water balance model. Each wet season represents a single realisation of the synthetic climate data for the period 1 November to 31 May;

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- Pearson Type III distributions were fitted to the sampled data and trend lines were derived;
- The fitted trend lines were interpolated to determine the 1:20 Annual Exceedance Probability (AEP) relevant to Significant consequence categories (as per the Manual **[5]** and **Table 9.1**), to calculate the required wet season DSA volume; and
- The DSA volume was calculated as the addition of the wet season storage volume and the Design Simulation Margin (DSM).

The assessment of the DSA is documented within **Appendix C**. The required DSA under the '**Significant**' consequence classification was determined to be **1,500 ML**. This corresponds to a DSA Reporting level of RL 249.8 m.

9.2 Flood Storage Capacity

9.2.1 Overview

The water management criteria that influence the flood storage capacity comprise:

- Operating pond volume;
- 1st November storage volume;
- Design Storage Allowance (DSA) volume;
- Extreme Storm Storage (ESS) volume; and
- Design flood freeboard and wave run-up.

The maximum water elevation within the TSF, just prior to the 1st of November each year shall provide for the DSA.

During the 12 months following the 1st of November, the pond water level may exceed the DSA, however it is a mandatory operating requirement that DETSI shall be informed at any time during the operation of the facility if the water level exceeds the Mandatory Reporting Level (MRL), which is the water level within the TSF above which the ESS plus the wave allowance at that AEP can be contained.

The water management criteria that apply to the Stage 3 TSF are summarised in **Table 9.1** on the basis of the assigned Consequence Categories listed in **Section 7.3.4**. It is noted that the design requirements specified by DETSI govern, owing to the differences in consequence category assessment methodologies as described in **Section 7.3.4**.

TABLE 9.1 – GOVERNING FLOOD STORAGE CRITERIA

Item	Criteria	Governing Requirement
Design Storage Allowance (DSA)	**1:20 AEP wet season runoff (DETSI)** 1:5 AEP wet season runoff (ANCOLD)	DETSI
Extreme Storm Storage (ESS)	**1:10 AEP, 72-hr (DETSI)** Determine by risk assessment (ANCOLD)	DETSI
Contingency Freeboard	**Wave run-up from 1:10 AEP wind (DETSI)** Nil wave run-up and nil additional freeboard (ANCOLD)	DETSI

9.2.2 Operating Pond Volume

The operating pond volume at the end of filling was adopted to be the median pond volume at the end of operations based on the water balance modelling. For the purposes of this assessment, this was taken to be equivalent to the 1st November Volume.

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9.2.3 1st November Volume

In order to estimate the available flood storage capacity, the DSA is added to the representative storage volume assumed to be in the storage system on the 1st November.

The median modelled 1st November volume at the end of operations was estimated to be **198 ML** from the water balance modelling.

9.2.4 Design Storage Allowance Volume

A DSA volume of **1,500 ML** has been adopted for the detailed design, in line with the outcomes of the water balance modelling (**Section 9.1.3**).

9.2.5 Extreme Storm Storage Volume

The ESS volume is calculated by estimating the runoff from the contributing catchment from the 1:10 AEP, 72 hour storm event, assuming 100% runoff.

An ESS volume of **953 ML** has been estimated, based on a total catchment area of 338 ha and a climate change adjusted design rainfall depth of 282 mm for the 1:10 AEP, 72 hour storm (**Section 5.7**).

9.2.6 Wave Run-Up

The wave run-up calculations for the Stage 3 TSF Embankment are based on the current best-practice methods detailed by the U.S. Department of the Interior Bureau of Reclamation **[30]**. The calculations have been completed based on the following assumptions:

- Water level within the TSF is at the spillway invert level;
- The TSF Embankment will have a “smooth” upstream face consisting of a bituminous geomembrane liner (i.e., wave run-up will be more pronounced than for a rockfill-faced embankment); and
- No infiltration or evaporation losses have been taken into account.

Estimates of the 1:10 AEP wind speed were determined by applying lognormal probabilistic distributions to wind data obtained from the BoM, as described in **Section 5.8**.

Fetch distances were calculated for a range of wind orientations across the TSF decant pond. Due to the orientation of the TSF storage, winds blowing from the SE-S direction were found to be critical to the TSF Embankment in terms of wave run-up.

Results from the assessment are presented in **Table 9.2**. It is evident that the maximum wave run-up and set-up for the 1:10 AEP wind is 0.8 m, from a wind originating from the SE-S direction.

TABLE 9.2 – WAVE RUN-UP ASSESSMENT

Direction	Fetch (km)	1:10 AEP Wind Speed (km/h)	Wave Run-up (m)	Wave Set-Up (m)	Wave run-up + set-up (m)
NE-N	0.39	59	0.46	0.003	0.463
E	0.63	71	0.78	0.006	0.786
SE-S	0.69	75	0.79	0.008	0.798

Note: Winds blowing from the SW, W and NW directions were not considered in the assessment as it was determined that these would not induce any wave actions due to the orientation of the embankment.

9.2.7 Flood Storage Capacity Summary

Typically, the design embankment crest level is determined from a bottom-up approach, by adding the flood storage and freeboard criteria to a given tailings and operating pond level. However, in the context of the DRM Stage 3 TSF, the Stage 3 crest level has been predetermined by MMG.

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The procedure to establish the 1st November level and the MRL has therefore been defined as follows:

- 1st November Level = Spillway Invert RL – Design Storage Allowance
- Mandatory Reporting Level = Spillway Invert RL – Wave Run-up – Extreme Storm Storage

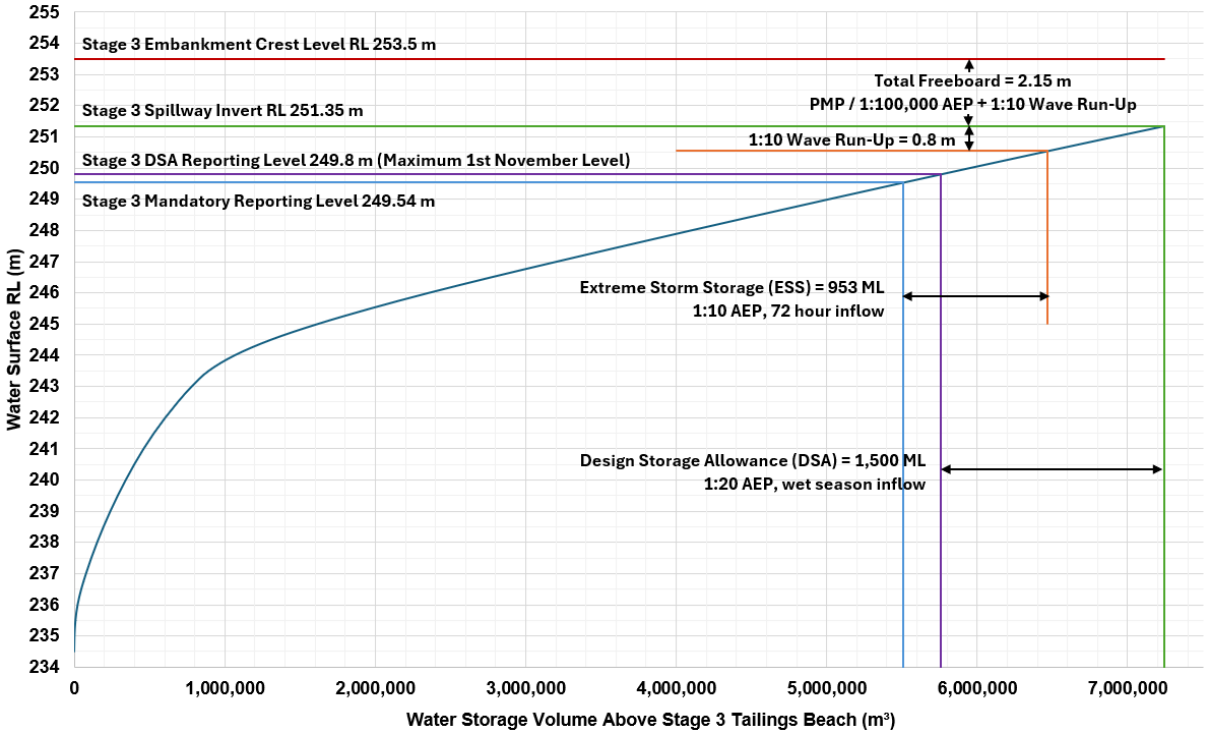
A spillway invert level of RL 251.35 m has been set for the Stage 3 TSF as discussed in **Section 9.3**.

A summary of the flood storage containment criteria for the Stage 3 TSF is summarised in **Table 9.3**, and is presented graphically in **Graph 9.3** alongside the pond volume-elevation curve above the forecasted Stage 3 tailings beach (at end of filling).

TABLE 9.3 – STAGE 3 FLOOD STORAGE CRITERIA

Description	Design Storage Allowance (DSA)	Extreme Storm Storage (ESS)
Design Criteria	1:20 AEP wet season runoff	1:10 AEP, 72-hr runoff plus 1:10 AEP wind-induced wave run-up
Required Capacity	1,500 ML	953 ML
Decant Pond Level	RL 249.8 m (max. level at 1st November)	RL 249.54 m (MRL – all reasonable efforts shall be made to avoid exceedance)

GRAPH 9.3 – STAGE 3 POND VOLUME-ELEVATION CURVE AND FLOOD STORAGE CRITERIA



9.3 Spillway Design

9.3.1 General

The spillway design criteria that apply to the Stage 3 TSF are summarised in **Table 9.4** on the basis of the assigned Consequence Categories listed in **Section 7.3.4**.

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TABLE 9.4 – GOVERNING SPILLWAY DESIGN CRITERIA

Item	Criteria	Governing Requirement
Spillway Capacity	1:1,000 AEP to 1:100,000 AEP plus wave run-up for 1:10 AEP wind (DETSI) **1:100,000 AEP plus wave run-up for 1:10 AEP wind; and PMF (ANCOLD)**	ANCOLD

The required freeboard between the spillway invert and the embankment crest (i.e. the depth of the spillway), is calculated as the combination of the peak flood height over the spillway and the maximum wind-induced wave run-up on the embankment face.

The general configuration of the Stage 3 emergency spillway is summarised in **Table 9.5**.

TABLE 9.5 – STAGE 3 EMERGENCY SPILLWAY GEOMETRY

Parameter	Stage 3 Spillway
Invert Level	RL 251.35 m
Base Width	50 m
Depth	2.15 m
Longitudinal Grade	1%
Side Slopes	1H:1V
Location	Approximately 250 m north of main embankment

9.3.2 Methodology

The spillway sizing was undertaken by carrying out rain-on-grid modelling in hydraulic modelling software TUFLOW. In order to perform satisfactorily, the spillway configuration must be able to pass the critical duration design flood without overtopping the embankment crest.

Multiple durations for both the 1:100,000 AEP and the PMP were simulated to identify the critical durations for the spillway (i.e., the storm duration which results in the greatest spillway outflow / largest flow depth).

For the purposes of the assessment, the initial pond level within the DRM TSF was conservatively assumed to be at the Stage 3 spillway invert level (RL 251.35 m).

9.3.3 Hydrology

The climate adjusted rainfall depths for the 1:100,000 AEP and the PMP (projected to 2040) were considered in this assessment (**Section 5.7**).

The PMP method areal temporal patterns were used for both the 1:100,000 AEP and the PMP in line with Australian Rainfall and Runoff (ARR) recommendations **[15]**.

The rainfall was applied as direct precipitation to the hydraulic model.

9.3.4 Hydraulics

9.3.4.1 Model Overview

Hydraulic analysis of the TSF catchment area was undertaken using TUFLOW. TUFLOW is a two dimensional (2D) finite difference program which is the industry accepted software package highly suited to the investigation of flood behaviour in complex flow scenarios. This software can simulate

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unsteady hydrodynamic flow in two dimensions on a rectilinear grid, as well as the one-dimensional unsteady hydrodynamic flow through waterway structures such as spillways. The software is based on a robust finite difference solution scheme that is able to compute both sub-critical and supercritical flow regimes.

The 2D TUFLOW model was set up to route the design floods through the storage. The model domain has been limited to the TSF catchment area extents.

9.3.4.2 Topography

The TUFLOW model development was based on a 1 m x 1 m gridded elevation raster model, resampled from site LiDAR survey provided by MMG to form the base topography. Design models have also been incorporated into the topography to represent the conditions at the end of Stage 3 filing.

The following sources were incorporated into the model topography:

- Design model for the Stage 3 emergency spillway;
- Design models for the Stage 3 tailings beach; access roads; and embankment;
- Site LiDAR dated 15 October 2024; and
- Extended site LiDAR dated 12 July 2024.

9.3.4.3 Surface Roughness

The Manning's 'n' surface roughness coefficient is used to describe the surface conditions within the model domain. Selection of the coefficient was made considering the apparent roughness of surfaces, based upon inspection of available aerial imagery, and with reference to the Innovyze database **[31]**. Innovyze are the developers of a range of hydraulic and hydrology software with a comprehensive online resource library.

A summary of the adopted Manning's 'n-values' is provided in **Table 9.6**.

TABLE 9.6 – ADOPTED MANNING'S ROUGHNESS COEFFICIENTS

Land Use	Manning's n-value
Default Roughness	0.130
TSF Surface	0.035
Drainage Lines	0.035
TSF Spillway Channel	0.025
Dense Vegetation	0.240
Rocky Areas	0.175

9.3.4.4 Spillway Routing Results

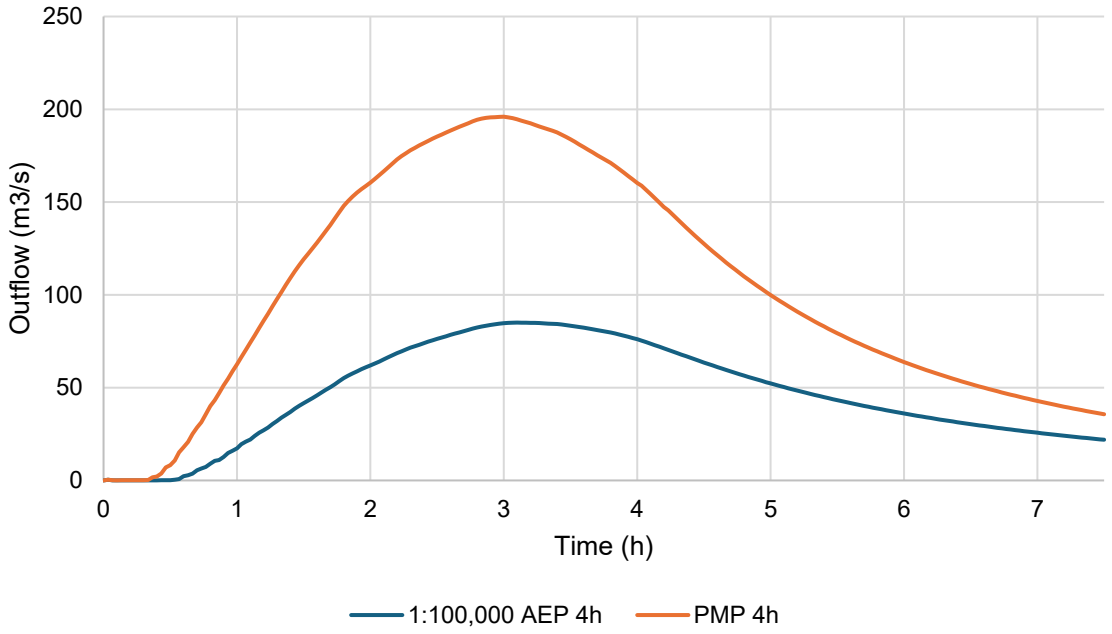
The TUFLOW model was run for both the 1:100,000 AEP and PMP design rainfall estimates, for the 0.25 hr to 6 hr durations. The results of the spillway routing assessment are summarised in **Table 9.7** and represent the critical duration event as determined from the hydraulic modelling.

The critical duration outflow hydrograph for the 1:100,000 AEP and PMP flood events are presented in **Graph 9.4**.

TABLE 9.7 – STAGE 3 SPILLWAY FLOOD ROUTING RESULTS

Parameter	1:100,000 AEP	PMP
Critical Duration	4 hrs	4 hrs
Peak Outflow	85.1 m^3/s	196.0 m^3/s
Peak Flood Depth	0.78 m	1.54 m
Spillway Depth	2.15 m	2.15 m
Freeboard to Embankment Crest	1.37 m	0.61 m
Maximum Water Surface Elevation	RL 252.13 m	RL 252.89 m

GRAPH 9.4 – STAGE 3 SPILLWAY CRITICAL OUTFLOW HYDROGRAPHS



9.3.5 Spillway Capacity Summary

A summary of the spillway design outcomes and conformance to the design criteria is provided in **Table 9.8**.

TABLE 9.8 – SPILLWAY DESIGN SUMMARY

Design Criteria	Spillway Invert	Peak Flood Depth	Wave Runup + Setup	Remaining Freeboard	Assessment
1:100,000 AEP plus wave run-up for 1:10 AEP wind	RL 251.35 m	0.78 m	0.80 m	0.57 m	Pass
PMP	RL 251.35 m	1.54 m	N/A	0.61 m	Pass

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9.4 Return Water System

The existing Return Water System (RWS) is located on the eastern side of the impoundment. The RWS platform was recently raised in line with the raised decant pond level. The RWS platform will require further raising as deposition continues. ATCW understand that MMG will monitor the decant pond level relative to the existing RWS platform and be responsible for the platform raise (and relocation of pump infrastructure).

10 TSF MAIN EMBANKMENT

10.1 Overview

The existing TSF embankment will be downstream raised and continue the existing Stage 2 zoning configuration of:

- Bituminous Geomembrane (BGM) Liner on the upstream face;
- Zone 2B Liner Support;
- Zone 2C Granular Filter; and
- Zone 3A and 3B Rockfill.

Further details on the material zones are provided in **Section 12**.

The rockfill seepage collection drain at the base of the existing embankment will be continued through the base of the embankment raise (refer **Section 10.5**).

A layout plan is presented in **Figure 2** and typical sections of the embankment are presented in **Figures 3** and **4**.

10.2 Foundations

Embankment foundation preparation requirements will be relatively straight-forward, with a nominal 0.5 m surface stripping required for the new embankment contact areas. Following the stripping of the foundation, the foundation material is generally expected to be weathered rock. Rock foundations will need to be generally clean, thus requiring the removal of loose soils and all soft or weak material.

10.3 Upstream Toe Plinth

A reinforced concrete toe plinth will be constructed within a trench at the upstream toe of the embankment, upon which the BGM liner will later be anchored.

Similarly to the existing TSF construction, the plinth trench is proposed to be terminated on moderately to slightly weathered rock.

The reinforced concrete plinth will be cast in the base of the trench and held in place with anchor dowels.

The plinth will also act as the surface through which contact and foundation grouting works will be conducted.

10.4 Foundation Grouting

In order to intersect any potential deeper sources of foundation seepage beneath the TSF embankment, a program of foundation grouting is proposed prior to the embankment raise construction, comprising shallow depth contact grouting; and deeper foundation grouting.

The foundation grouting will be conducted at regular intervals along the length of the plinth to a minimum depth of 6 m, in order to intersect and grout any potential deeper sources of foundation seepage beneath the TSF Embankment.

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Shallow depth contact grouting beneath the plinth will also be conducted to minimise the extent of seepage beneath the plinth/foundation rock interface.

10.5 Seepage Collection System

Prior to construction of the Stage 3 embankment raise, the existing seepage collection pond will be decommissioned and removed.

The new seepage collection system will consist of the construction of a rockfill seepage collection drain within the lowest point of the embankment foundations, connecting with a seepage interception trench at the downstream toe. HDPE drain pipes will be placed within the seepage collection drain to facilitate drainage.

The downstream seepage interception trench will have a circular concrete seepage monitoring chamber (precast concrete soakwell) installed and will have Concrete Canvas liners placed on the base and downstream wall of the excavation. After installation of the soakwell and Concrete Canvas liner, the trenches will be backfilled with Zone 3C rockfill and will be wrapped in geotextile.

The location and alignment of the seepage interception trench have been determined based upon test pitting investigations to identify the excavation depth to bedrock for the trench. The outcomes from the investigations are summarised in **Appendix D**.

The seepage collection works will be constructed during the early stages of construction, to ensure continued operation of the TSF seepage collection system throughout the duration of construction.

10.6 BGM Liner

The upstream face of the existing TSF embankment is lined with a BGM liner. A new section of BGM liner will be placed on the upstream face of the Stage 3 TSF embankment raise.

The new liner will be anchored at the crest within an anchor beam comprised of mass concrete. The BGM liner will be anchored along the embankment toe via a reinforced concrete toe plinth at the abutments, and will connect to the existing Stage 2 mass concrete anchor beam elsewhere to form a continuous lining system. A 3 m wide bench has been allowed for on the Stage 2 crest for construction access and for safety.

The BGM liner at the TSF Embankment abutments will be fitted with a Concrete Canvas fire protection layer.

11 CIVIL WORKS

11.1 Spillway

The Stage 3 TSF Embankment Spillway will be constructed entirely in cut along the natural hillside approximately 250 m north of the TSF Embankment, and will be excavated to competent rock on the base.

The spillway area will be cleared and stripped of topsoil, followed by bulk excavation of the spillway. Excavation is proposed to be performed through ripping, however, a drill and blast operation may be required if harder rock is encountered. The spillway location has been selected to minimise disturbances to the TSF Embankment, if drill and blast is required.

The materials won from the spillway excavation will be used as construction materials for the Stage 3 embankment raise.

The Stage 3 spillway is expected to be excavated to competent rock along the base, sides, and outlet chute and is hence assessed to be inherently resistant to erosion and hydraulic forces. No armouring, channel protection, nor structural reinforcement are therefore proposed.

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11.2 Northern Discharge Bund

A discharge bund will be constructed on the northern side of the facility, to contain tailings within the lease boundary. The purpose of this bund is to provide a platform for tailings deposition and to provide access to the main embankment crest.

The discharge bund will be constructed predominantly from Zone 3A rockfill to RL 253.5 m to match the Stage 3 embankment crest level. This results in a maximum height of approximately 9.5 m.

The maximum tailings level adjacent to the northern discharge bund is estimated to be approximately RL 245.5 m at the end of Stage 3 filling (**Section 8.3**), and minimal water is expected to pond against the bund throughout the life of the facility on the basis of the water balance modelling (**Appendix C**).

Nevertheless, a zone of low permeability 2B materials will be constructed on the upstream side of the bund to mitigate the chance of seepage. A layer of rockfill rip rap will also be constructed along the upstream face to prevent surface erosion of the 2B materials.

11.3 Construction Haul Road / Permanent Access Roads

A haul road will be constructed from the toe of the existing TSF to the proposed Stage 3 spillway location; and along the north-west perimeter of the impoundment linking the Northern Discharge Bund with the TSF Embankment; and the main access road to the Dugald River Mine Village perimeter road.

The road will be constructed entirely in cut, except for a small section of fill required to grade the road to the existing access road at the toe of the TSF.

The materials won from the road excavation will be used as construction materials for the Stage 3 embankment raise.

The road will initially be used during construction for hauling and carting and access for heavy vehicles. Following construction, only light vehicle access will be required, at which point gravel surfacing will be placed and V-drains will be constructed along the road shoulders.

11.4 Tailings Discharge Access Roads

The existing discharge point access roads are proposed to be extended as part of the Stage 3 works to facilitate the operation of the discharge points detailed in **Section 8.1**.

The construction of the access roads will require both cut and fill and will comprise gravel surfacing along the entire length. Materials won from the cutting will be used as construction materials for the Stage 3 embankment raise and for the fill required for the access roads.

Safety bunds will be placed along the road shoulders and containment berms will be constructed to border the tailings pipeline. V-drains will be constructed along the road shoulders to facilitate longitudinal drainage.

12 CONSTRUCTION MATERIALS

12.1 Overview

Construction of the Stage 3 TSF Embankment involves the placement of five zones of rockfill, granular filter and drainage fill materials, which can be broadly categorised into the following groups:

1. Lower permeability granular and BGM support layer material – Zone 2B
2. Granular filter material – Zone 2C
3. Rockfill embankment and drainage materials - Zones 3A, 3B & 3C

Details of the material zones are provided in the following sections.

In addition, the following materials will be supplied and installed within the TSF Embankment and associated civil works:

1. Geosynthetics – Bituminous Geomembrane (BGM) Liner, non-woven geotextile, Concrete Canvas.
2. Concrete – Reinforced concrete toe plinth; mass concrete anchor beam; concrete soakwell.

12.2 Bituminous Geomembrane Liner

For the TSF Embankment, reinforced elastomeric BGM has been adopted as the water proofing element for the upstream face, primarily for the following reasons:

- It is cheaper than PVC whilst having similar deformation characteristics; and
- It requires a simpler anchorage system compared to PVC, with no intermediate face anchors due to the frictional resistance and higher unit weight.

Reinforced elastomeric BGMs are bonded by heat, employing a relatively simple procedure requiring a lesser input of skilled labours. They are robust and have excellent UV stability and weathering properties necessary to survive for up to 40 years uncovered. These materials have a density greater than 1 t/m^3, hence will not float in water and are less susceptible to wind uplift than traditional polyethylene or PVC geomembranes.

The BGM product will comprise one of the following:

- Coletanche ES range bituminous geomembrane - manufactured by Axter Limited; or
- Teranap range bituminous geomembrane – manufactured by Siplast International.

Further assessment of the product particulars will be undertaken prior to tendering.

12.3 Geotextile

Geotextile is required as a protective layer between the capping layer and the Zone 3C rockfill drain, as well as along the drain base and side walls.

The geotextile will be a staple fibre non-woven geotextile with characteristics summarised on the Drawings. A conforming geotextile material is the non-woven Texcel R range 1200R, which is supplied by Geofabrics Australasia Pty Ltd.

12.4 Concrete canvas

The BGM liner at the TSF Embankment abutments will be fitted with Concrete Canvas as a fire protection layer. The seepage interception trench will also have a Concrete Canvas liner fitted to the base and downstream face of the trench excavation as the water-proofing component of the trenches.

Concrete Canvas is a Geosynthetic Cementitious Composite Mat (GCCM). Concrete Canvas is a flexible, concrete impregnated fabric that hardens when hydrated to form a thin, durable, water proof and erosion resistant concrete layer.

The specified Concrete Canvas liner is a proprietary product with a single Australian-based agent. All works associated with the CC liner will be conducted by a specialist lining installation subcontractor.

12.5 Zone 2B

Zone 2B material is proposed to form the granular supporting layer for the BGM liner. Zone 2B material is expected to generally consist of Clayey Gravels (with sand) and Silty, Clayey Gravels (with sand). Materials estimated to be suitable for Zone 2B consist of colluvial clayey gravel deposits in the foothills of the Knapdale Range.

A test pitting investigation was conducted by ATCW in May 2024 (**Appendix E**) to identify a suitable borrow location for Zone 2B (and Zone 2C) materials. An area on the downstream side of the TSF (to

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the north-west) was judged to contain a sufficient quantity of suitable material, and has been proposed as a borrow area.

It is expected that production of Zone 2B will require screening to exclude particles greater than 30 mm in diameter. Oversized materials are expected to be able to be blended into the rockfill zones.

12.6 Zone 2C

Zone 2C Granular Filter material forms the intermediate filter within the TSF Embankment, separating and filtering Zone 2B from the Zone 3A rockfill. Zone 2C material is expected to consist predominantly of Gravel in a matrix of Clay, Silt and Sand, with Cobbles up to a maximum particle size of 150 mm.

Zone 2C is proposed to be sourced from the same borrow area as Zone 2B. However, Zone 2C is not expected to require screening.

12.7 Zone 3A and Zone 3B

Zone 3A & 3B Rockfill forms the bulk of the embankment.

Quartzite rock forms the Knapdale Range and produces a high quality rockfill for embankment construction.

Rockfill obtained from the spillway and haul road excavations is proposed to be used as Zone 3A or 3B where appropriate.

12.8 Zone 3C

Zone 3C materials will be used within the rockfill drain and seepage interception trench.

Zone 3C will consist of clean, sound, hard and durable rockfill. Soft, friable, or excessively weathered particles will be removed prior to placement.

Rockfill obtained from the spillway and haul road excavations is proposed to be used as Zone 3C where appropriate.

13 STABILITY ANALYSES

13.1 Overview

Stability analyses were performed for the Stage 3 TSF embankment using SLOPE/W software from the Geostudio package. The analyses employed a General Limit Equilibrium (GLE) approach, which divides a defined area into a fixed number of slices satisfying both force and moment equilibrium between them.

The GLE formulation is based on two factors of safety equations and allows for a range of interslice shear-normal force conditions. One equation gives the factor of safety with respect to moment equilibrium (Fm) while the other equation gives the factor of safety with respect to horizontal force equilibrium (Ff). The Morgenstern-Price method is a commonly used approach for determining the factors of safety. This method involves calculating the factors of safety separately (forces and momentums) and then finding the point at which they intersect.

13.2 Analysed Scenarios & Assessment Criteria

The stability scenarios analysed for the TSF embankment are presented in **Table 13.1**. Minimum stability criteria are also presented for each loading condition; assigned based on the ANCOLD Tailings Guidelines **[6]**.

A single cross-section was analysed for the main embankment, representing the maximum height and critical embankment section for stability. An additional cross-section was also analysed representing the northern discharge bund for the long-term scenario.

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It is noted that the End of Construction loading case was analysed with effective stress parameters, as undrained conditions are not expected to occur within either the embankment materials or rock foundation. The embankment materials are expected to be predominantly coarse grained and free draining, and are judged to be adequately characterised with effective stress drained parameters.

It is also noted that seismic loading is not expected to result in a strength loss of neither the embankment nor foundation (i.e. materials not judged to be susceptible to strain weakening); and that the rockfill embankment and rock foundation are judged to not be susceptible to liquefaction. Notwithstanding, a post-seismic assessment (adopting conservative reduced strength parameters) was carried out in line with best practice and to demonstrate the robustness of the design post-earthquake in lieu of a strain weakening model.

TABLE 13.1 – STABILITY SCENARIOS & CRITERIA

Structure	Scenario	Shear Strength Model	Minimum FoS
TSF Embankment	Long-Term	Effective Strength	1.5
	Liner Leak	Effective Strength	1.5
	Dam Crest Flood	Effective Strength	1.3
	End of Construction	Effective Strength	1.3
	Post-Seismic	Post-Seismic Strength	1.0
Northern Discharge Bund	Long-Term	Effective Strength	1.5
	Dam Crest Flood	Effective Strength	1.3
	Post-Seismic	Post-Seismic Strength	1.0

13.3 Material Parameters

13.3.1 Overview

The material properties used in the stability analyses are summarised in **Table 13.2**. The basis for adoption of the strength parameters is provided in the proceeding sections.

TABLE 13.2 – MATERIAL STRENGTH PARAMETERS

Material	Strength Envelope		Unit Weight (kN/m^3)
	Effective Strength	Post-Seismic Strength	
Zone 2B	c' = 0 kPa, ϕ' = 35°	c' = 0 kPa, ϕ' = 29°	20
Zone 2C	Leps Lower-Average (Capped at 40°) Refer **Graph 13.1**	Leps Lower Bound (Capped at 36°) Refer **Graph 13.1**	22.5
Zone 3A	Leps Average (Capped at 40°) Refer **Graph 13.1**	Leps Lower Bound (Capped at 36°) Refer **Graph 13.1**	22.5
Zone 3B			
Foundation – Quartzite Rock	Bedrock (Impenetrable)		22.5
Tailings	No strength		20

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13.3.2 Zone 2B BGM Support Layer

Significant differences between drained and undrained strength response are not expected for granular materials, hence drained strength parameters have been used for the Zone 2B material in all stability analyses.

The saturated density and drained friction angle of 35° for the Zone 2B has been adopted based on typical values for dense sandy gravel materials **[32]**. For the post-seismic assessment, a 20% strength reduction has been applied. Laboratory testing of the Zone 2B materials was not deemed necessary due to the relatively small contribution of the zone to the embankment stability (5 m width zone).

13.3.3 Zone 2C Granular Filter & Zone 3A / 3B Rockfill

Due to the particle sizes and essentially well graded nature of the Zones 2C, 3A and 3B materials, significant differences between drained and undrained strength response are not expected.

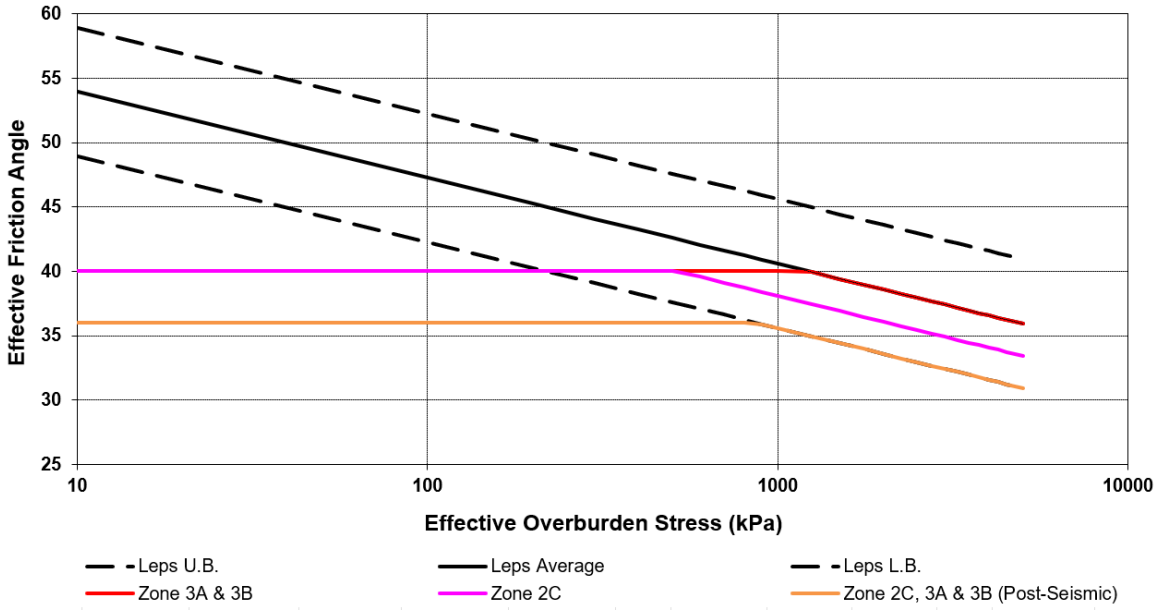
In order to represent the strength of the rockfill material, Leps **[33]** functions have been adopted. Leps is a database method which adopts upper, average and lower bound strength functions based on varying materials of different grading, density and strength. The database is based on a large amount of data obtained from large-scale triaxial tests on gravels and rocks.

A 'lower-average bound' has been applied to the Zone 2C granular filter. The 'average' has been applied to the Zone 3A & 3B rockfill. Both strength envelopes have been capped at 40° as shown in **Graph 13.1**.

For the post-seismic assessment, the 'lower bound' has been applied for the Zone 2C, 3A & 3B materials, and have conservatively been capped at 36° as shown in **Graph 13.1**.

The density values for the compacted rockfill have been adopted based on past experience with compacted, well-graded metamorphic rockfill.

GRAPH 13.1 – ZONE 2C, 3A & 3B STRENGTH ENVELOPES (LEPS)



13.3.4 Foundations

Within the upper 5 m depth, the TSF embankment foundation area generally consists of moderate strength, highly fractured, highly weathered to moderately weathered quartzite.

Foundation preparation for the Stage 1 and 2 embankment construction consisted of the removal of all loose, or water softened soil and rock by machine excavation. The foundation preparation generally revealed weathered rock foundations **[2]**.

The same foundation preparation is proposed for the Stage 3 embankment construction.

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Based on the above, a ‘Bedrock (Impenetrable)’ strength model has been applied to the foundation.

13.3.5 Tailings

As the embankment is downstream raised, there is no reliance on the tailings to provide strength against instability. A ‘no strength’ model has been applied to the tailings.

13.4 Tailings & Decant Pond Levels

Based on current tailings beach modelling, the tailings are predicted to reach an approximate level of RL 236 m at the end of Stage 3. This low level of tailings relative to the embankment (at RL 253.5 m) is due to the steep sub-aqueous beach slope which has been historically observed. If the size of the operating pond is reduced in future, the tailings level may be higher at the embankment.

A tailings level of RL 236 m has therefore been adopted in the stability model representing the end of filling of Stage 3. An operating pond level at RL 248 m has conservatively been adopted, based on the maximum estimated decant pond from the water balance modelling (**Appendix C**).

For the end of construction case, a tailings level of RL 222 m and operating pond level of RL 236 m has been adopted, considering the current levels and historical rate of rise.

Due to the presence of the BGM liner and free-draining embankment materials, a phreatic surface is not expected to develop within the embankment. Nevertheless, a conservative case modelling a ‘liner leak case’ has been modelled, which assumed a significant liner leak remains undetected, and a steady state phreatic surface is allowed to develop within the embankment.

13.5 Results

The results of the stability analyses for the Stage 3 configuration are summarised in **Table 13.3**. Outputs from the stability analyses are presented in **Appendix F**.

TABLE 13.3 – STABILITY ANALYSES RESULTS

Structure	Scenario	Description	Failure Direction	FoS Required	FoS Modelled	Figure No.
TSF Embankment	Long-Term	Tailings at RL 236 m Pond at RL 248 m	Downstream	1.5	1.60	F1
			Upstream		2.30	F2
	Liner Leak	Tailings at RL 236 m Pond at RL 248 m	Downstream	1.5	1.59	F3
	Dam Crest Flood	Tailings at RL 236 m Pond at RL 253.5	Downstream	1.3	1.60	F4
	End of Construction	Tailings at RL 222 m Pond at RL 236 m	Upstream	1.3	1.56	F5
	Post-Seismic	Tailings at RL 236 m Pond at RL 248 m	Downstream	1.0	1.38	F6
Northern Discharge Bund	Long-Term	Tailings at RL 236 m Pond at RL 248 m	Downstream	1.5	1.92	F7
	Dam Crest Flood	Tailings at RL 236 m Pond at RL 253.5	Downstream	1.3	1.92	F8
	Post-Seismic	Tailings at RL 236 m Pond at RL 248 m	Downstream	1.0	1.66	F9

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14 DEFORMATION ANALYSES

14.1 Overview

The Stage 3 embankment raise has been assessed for seismic-induced deformation using empirical methods based on data collected from dams that have experienced earthquakes in the past, in accordance with the ANCOLD Guidelines **[7]**.

The embankment and foundations have been assessed as being not susceptible to liquefaction, based on the expected plasticity, density and dilative nature of the materials. Hence the following simplified empirical database methods have been utilised for this assessment:

- Swaisgood (1998, 2003) **[34] [35]**
- Pells and Fell (2002, 2003) **[36] [37]**

The methods outlined above are considered sufficient, provided that the dams are well constructed and there is a large margin between estimated settlement and available freeboard.

14.2 Swaisgood (1998, 2003)

The Swaisgood (1988) method **[34]** utilises a database on embankment dams which have been subject to earthquake, and relates the amount of deformation and cracking to the earthquake loading experienced by the dam. It requires the following inputs:

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

Crest settlement (as a percentage of the embankment height) is estimated by:

$$CS = SEF \times RF$$

$$RF = 0.01D^{-0.61}$$

$$SEF = e^{(0.72M+6.28PGA-9.1)}$$

Where:

CS = Vertical Crest Settlement (as % of Dam Height)

RF = Resonance Factor for Rockfill

SEF = Seismic Energy Factor

D = Distance between seismic energy source and dam (km)

M = Magnitude of the earthquake

The Swaisgood (2003) method **[35]** utilises an expanded database on embankment dams and simplifies the Swaisgood (1998) formula as follows:

$$\% \text{ Settlement} = e^{(6.07PGA+0.57M-8.00)}$$

The earthquake data used in the calculations was based on the PSHA **[20]**. Inputs and results of the assessment are summarised in **Table 14.1**.

The results of Swaisgood **[34] [35]** estimates crest settlements in the range of 0 to 6 mm, which indicates a relative degree of damage of “None” as shown in **Graph 14.1.**

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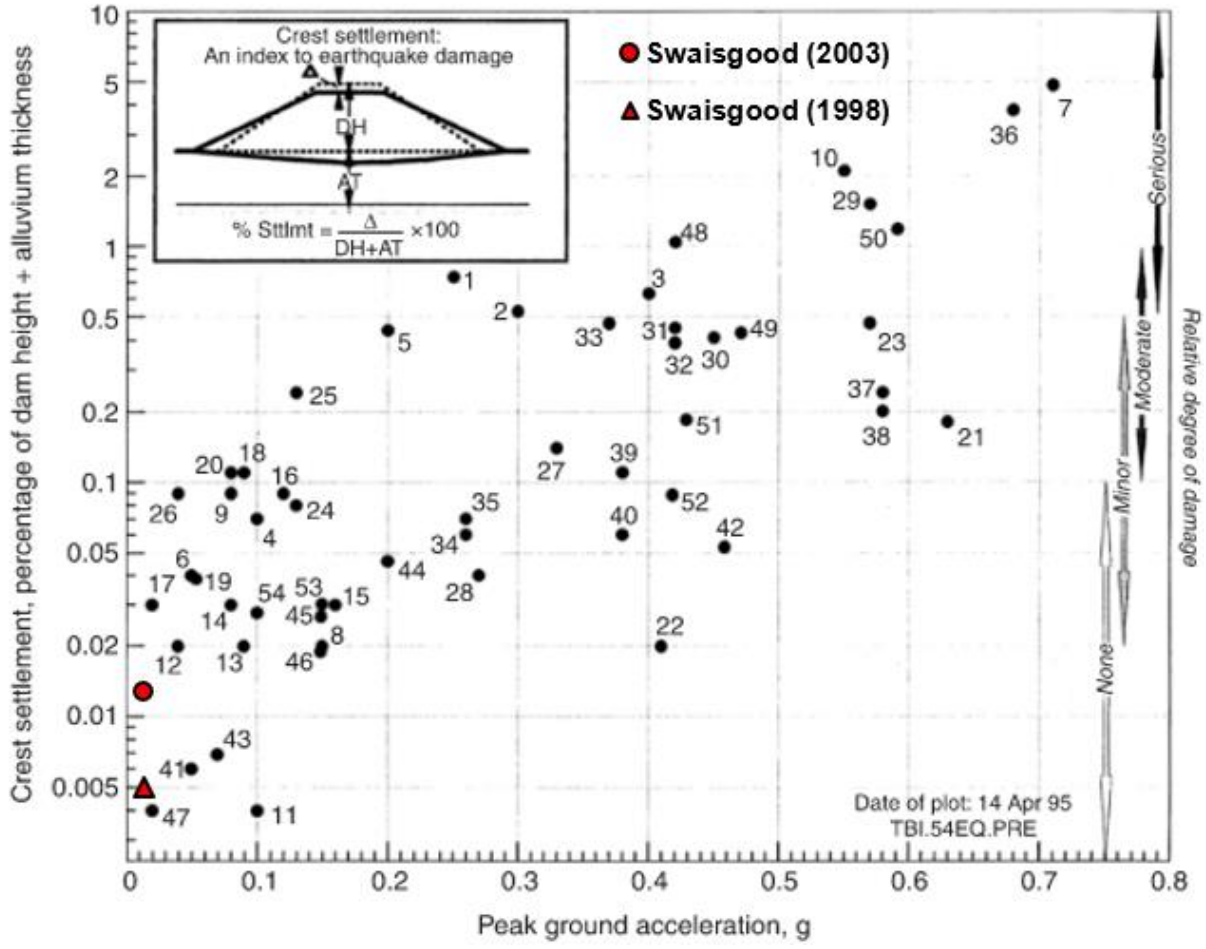
TABLE 14.1 – SWAISGOOD (1998, 2003) METHOD FOR ESTIMATING SEISMIC EMBANKMENT DEFORMATIONS

Parameter	Swaisgood (1998)	Swaisgood (2003)
D (km)	63.78	
M	6.15	
PGA (g)	0.0146	
RF	0.010	N/A
SEF	0.010	N/A
Embankment Height (m)	47.5	
Alluvial Depth (m)	0.0	
CS (%)	0.000	0.012
Estimated Settlement (mm)	0.05	5.80

GRAPH 14.1 – RELATIVE CREST SETTLEMENT VERSUS PEAK GROUND ACCELERATION (SWAISGOOD, 1998,2003)



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14.3 Pells and Fell (2002, 2003)

The method developed by Pells and Fell **[36] [37]** gathered data from 305 dams, which represents a larger database than Swaisgood estimations.

The method utilises two correlations, one for earthfill dams and the other for earth and rockfill dams. Since the DRM Stage 3 TSF comprises predominantly rockfill, the second correlation has been adopted.

Graph 14.2 shows damage contours versus earthquake magnitude and peak ground acceleration for earth and rockfill dams.

As shown, the embankment falls within the damage class contours "0" which is associated with the "No or slight" damage category. Based on this and the classification system presented in **Table 14.2**, the expected maximum relative crest settlement is less than 0.03% (<15 mm).

GRAPH 14.2 – EARTH AND ROCKFILL DAMS – CONTOURS OF DAMAGE CLASS VERSUS EARTHQUAKE MAGNITUDE AND PGA (PELLS AND FELL, 2003)

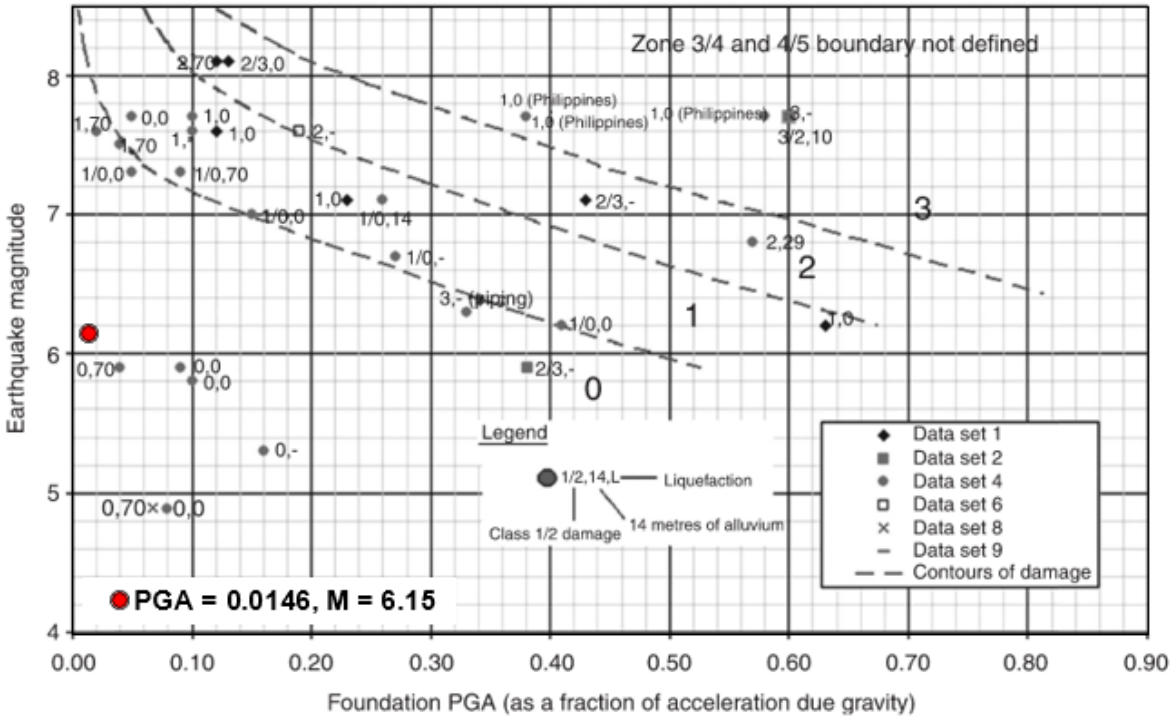

TABLE 14.2 – DAMAGE CLASSIFICATION SYSTEM (PELLS AND FELL 2003)

Number	Description	Maximum longitudinal crack width (mm) (1)	Maximum relative crest settlement (%) (2)
0	No or slight	< 10	< 0.03
1	Minor	10 – 30	0.03 – 0.20
2	Moderate	30 – 80	0.20 – 0.50
3	Major	80 – 150	0.50 – 1.50
4	Severe	150 – 500	1.50 – 5.00
5	Collapse	> 500	> 5.00

Note 1: Maximum crack width is taken as the maximum width, in millimetres, of any longitudinal cracking that occurs.
Note 2: Maximum relative crest settlement is expressed as a percentage of the maximum dam height (from general foundation to the dam crest.

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14.4 Discussion

Fell et al. **[38]** provide the following points regarding embankment dam performance during earthquakes, based on reviews of past performance conducted by others (Sherard, Seed, Seed et al.):

- Even at short distances from the epicentres, there have been no complete failures of embankments built of clay soils, but several dams have come close to failure.
- Well-constructed dams of clay soils on clay or rock foundation, not susceptible to strain weakening, can withstand extremely strong shaking resulting from earthquakes of up to Magnitude 8.25 with peak ground accelerations ranging from 0.35 g to 0.8 g (they suffer cracking but few, if any, have failed catastrophically).
- Dams which have suffered complete failure as a result of earthquake shaking have been constructed primarily with saturated sandy materials or on saturated sand foundations. Liquefaction is a major contributory factor in these failures.
- The dams most susceptible to failure under earthquake loading are hydraulic fill dams and tailings dams constructed using upstream methods, because they are susceptible to liquefaction if the fill or tailings are granular and saturated.
- There are very few cases of dam failures during the earthquake shaking. Most of the failures occur from a few minutes up to twenty-four hours after the earthquake. However, cracking and displacements do occur during the earthquake.

With respect to the above points: the DRM Stage 3 TSF embankment will be founded on competent and fractured rock (any alluvial or loose materials will be removed as part of foundation preparation) and is expected to be well-constructed with good quality control. Further, the DRM Stage 3 TSF embankment will be raised in a downstream direction (as opposed to upstream methods).

Based on the empirical deformation analyses detailed in the preceding sections, the expected maximum crest settlements resulting from the design earthquake would be less than 15 mm. The available freeboard (either tailings or pond freeboard) is expected to significantly exceed this.

15 QUANTITATIVE RISK ASSESSMENT

15.1 Overview

A Quantitative Risk Assessment (QRA) has been carried out for the Stage 3 TSF. MMG has elected to undertake this assessment to maintain consistency across its global portfolio and to enhance the rigour and defensibility of the design process. The use of a QRA allows for a more accurate and structured evaluation of the TSF risk profile, supports the identification of critical failure modes, and informs risk mitigation strategies. The QRA Report is attached in **Appendix G**, and the outcomes are summarised in the following sections.

15.2 Methodology

The risk assessment process includes a sequence of predefined steps, as illustrated in **Diagram 15.1**.

The risk assessment methodology is based on the ANCOLD Guidelines on Risk Assessment **[28]**. The workflow also includes the presentation workshops and the deliverables as part of the process.

Due to the relative simplicity of the DRM Stage 3 TSF, the Workshop 2 and the ALARP Workshop were combined into a single workshop.

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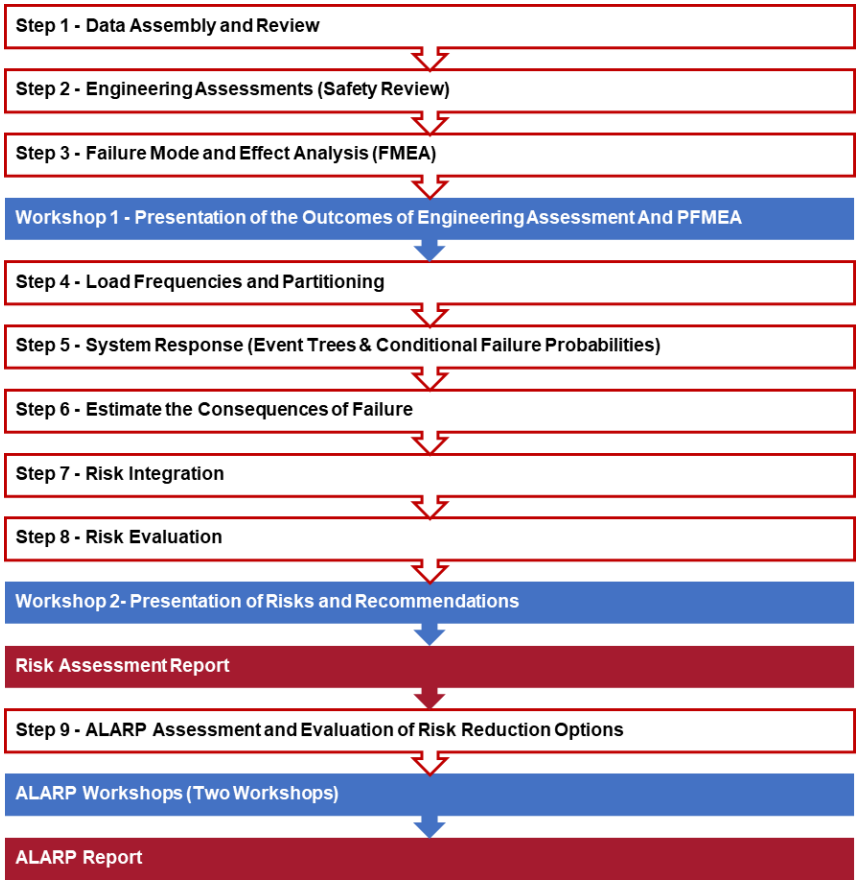
DIAGRAM 15.1 – RISK ASSESSMENT METHODOLOGY



15.3 Failure Modes

A Failure Mode and Effects Analysis (FMEA) workshop was conducted on 20th May 2025 as part of the QRA process which included representatives from ATCW, MMG, and the DRM Independent Tailings Review Board. The outcomes of the workshop are documented in the Stage 3 Quantitative Risk Assessment Report **Appendix G** and are summarised in **Table 15.1**.

TABLE 15.1 – STAGE 3 TSF CREDIBLE FAILURE MODE ASSESSMENT

No.	FM ID	Failure Mode	Initiating Event	Credibility
1	DR TSF-Emb-OT-1	Overtopping erosion due to insufficient installed flood capacity	Flood	Not Credible
2	DR TSF-Emb-OT-2	Overtopping erosion due to insufficient available flood capacity caused by the spillway blockage	Flood	Not Credible
3	DR TSF-Emb-OT-3	Overtopping erosion due to insufficient available flood capacity caused by wind-induced wave effects	Flood, Wind	Not Credible
4	DR TSF-Spill-OT-4	Partial breach due to progressive headcut erosion at the spillway	Flood	Not Credible

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No.	FM ID	Failure Mode	Initiating Event	Credibility
5	DR TSF-Emb-OT-5	Overtopping erosion due to failure of the Return Water system	Normal, Flood	Not Credible
6	DR TSF-Emb-OT-11	Overtopping erosion due to long-term deformation of the embankment and loss of freeboard	Normal, Flood	Not Credible
7	DR TSF-Emb-OT-12	Overtopping erosion due to deformation of the embankment and loss of freeboard post-seismic events	Earthquake	Not Credible
8	DR TSF-Emb-OT-22	BGM Liner Failure resulting in excessive seepage and displacement of the embankment materials	Normal, Flood, Earthquake	Not Credible
9	DR TSF-Emb-OT-23	Sloughing of the embankment upstream face due to wind-induced wave effects, resulting in loss of freeboard and overtopping erosion	Wind	Not Credible
10	DR TSF-Emb-SS-6	Overtopping due to instability of the downstream slope, causing slumping and loss of freeboard	Normal, Flood, Earthquake	Credible
11	DR TSF-Drg S-SS-7	Overtopping due to instability of the downstream slope resulting from failure of the seepage collection system	Normal, Flood, Earthquake	Not Credible
12	DR TSF-Emb-SS-8	Overtopping due to the instability of the upstream slope, causing slumping and loss of freeboard	Normal, Flood, Earthquake	Excluded due to negligible consequences, as a global failure of the embankment is not anticipated
13	DR TSF-Emb-BGM-9	BGM Liner Failure Leading to Seepage and Instability of the Upstream Slope	Normal, Flood, Earthquake	Excluded due to negligible consequences, as a global failure of the embankment is not anticipated
14	DR TSF-Emb-SS-18	Overtopping due to instability of the downstream slope resulting from failure of the Return Water System component	Flood, Normal	Not Credible
15	DR TSF-Emb-IE-15	Internal erosion of the embankment	Normal, Flood, Earthquake	Not Credible
16	DR TSF-Emb-IE-16	Internal erosion of the embankment into the foundation or at the embankment foundation contact	Normal, Flood	Not Credible

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No.	FM ID	Failure Mode	Initiating Event	Credibility
17	DR TSF-Emb-IE-17	Internal erosion through the soil/rock foundation	Normal, Flood	Not Credible
18	DR TSF-Emb-SS-25	Internal erosion along a buried conduit	Normal, Flood	Not Credible
19	DR TSF-Emb-LIQ-13	Embankment Breach due to flow liquefaction or foundation liquefaction	Earthquake	Not Credible
20	DR TSF-Emb-OT-14	Embankment Breach due to overtopping by liquefied tailings	Earthquake, Normal	Not Credible
21	DR TSF-Emb-BGM-10	BGM Liner Failure Leading to Excessive Seepage and Loss of Water Containment	Normal, Flood, Earthquake	Excluded due to negligible consequences, as a global failure of the embankment is not anticipated
22	DR TSF-Emb-IE-19	Fire damage to BGM Liner	Normal	Not Credible
23	DR TSF-Emb-SE-20	Overtopping due to slope instability caused by the formation of erosion gullies from surface water runoff	Flood	Not Credible
24	DR TSF-TD S-OP-21	Failure of Tailing Delivery System	Flood, Normal	Excluded due to negligible life safety consequences
25	DR TSF-Drg S-OP-24	Failure of the Seepage Collection System Pump	Flood, Normal	Excluded due to negligible life safety consequences

15.4 Annual Probabilities of Failure

The failure mode advanced for detailed risk assessment is "Overtopping due to instability of the downstream slope causing slumping and loss of freeboard". The annual failure probability due to slope failure has been derived from “Probability and Risk of Slope Failure” (Silva et. al.) **[39]**.

The overall Total Annual Probability of Failure for the Stage 3 TSF embankment is **5.5E-08**. This meets the USBR Risk Guidelines (2019) **[40]** criteria of not greater than 1E-04. This value of 1E-04 is commonly used as a threshold as it is approximately the lowest probability of death per year for an individual throughout their lives.

USBR Guidelines indicate that when the annualised failure probability is above the USBR threshold level (1E-04), there is generally increasing justification to reduce or better understand the risks. Below this threshold level, justification is generally decreasing to reduce or better understand the risk. It should be noted that GISTM and ANCOLD do not have any criteria for evaluating the Total Annual Probability of Failure. This assessment has been undertaken in the context of best practice.

15.5 Societal Risk

The Societal Risk Rating has been determined based on the ANCOLD Guidelines on Risk Assessment (2022) **[28]** and based on the consequences of failure determined from the dam break assessments (**Section 7**).

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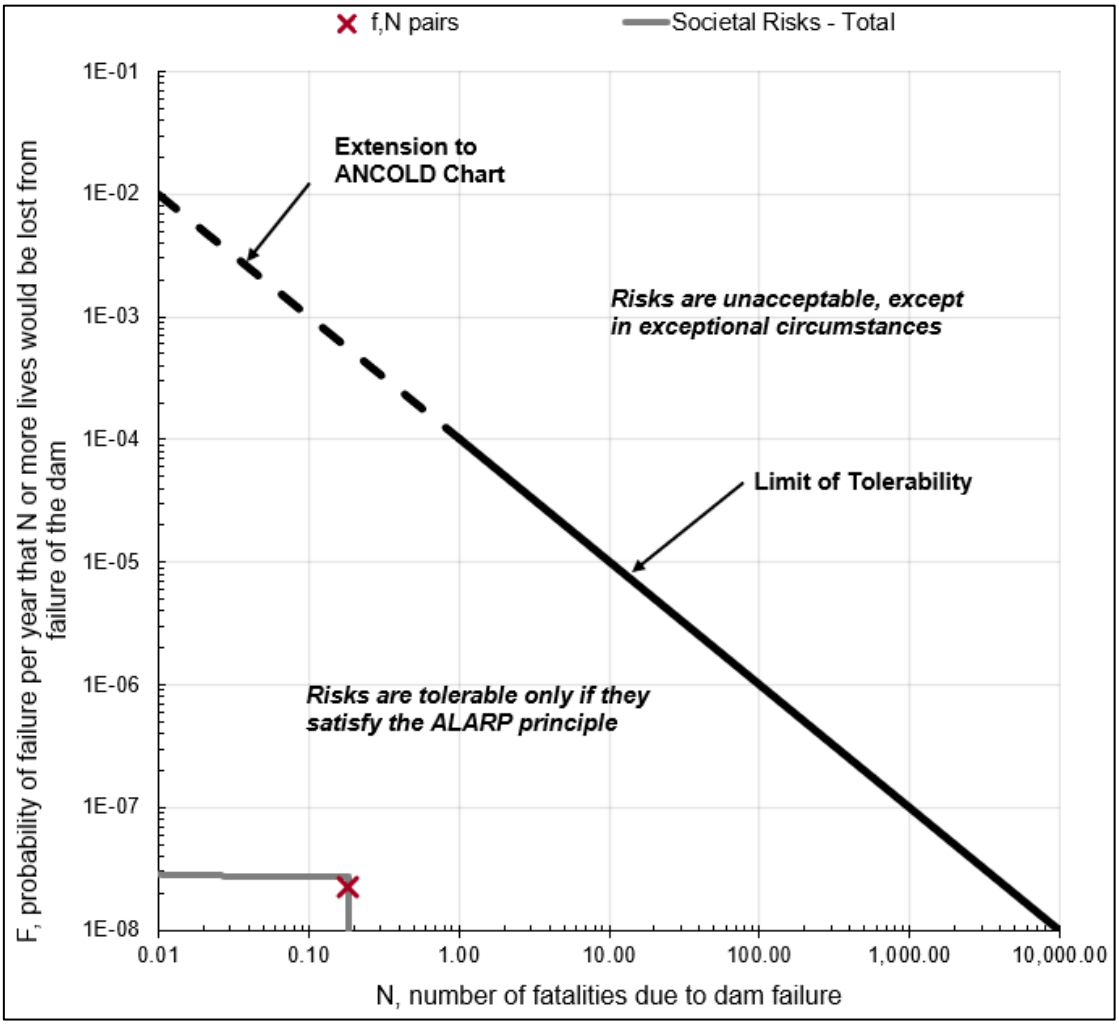
The total societal risk due to failure of the Stage 3 TSF is assessed to be **5.2E-09**. This satisfies the ANCOLD societal risk criteria for new dams or major augmentations of not greater than 1E-04.

15.6 Societal Risk Plot

The best estimate of the societal risk of the Dugald River Stage 3 TSF, based on the assumptions outlined in **Appendix G**, is presented in **Graph 15.1**.

The F-N curve plots more than 4 orders of magnitude below the ANCOLD Limit of Tolerability, on the basis of the assumed structural and operational conditions.

GRAPH 15.1 – STAGE 3 TSF SOCIETAL RISK PLOT



15.7 Individual Risk

The individual risk rating has been estimated by adopting the methodology outlined by Maslin et al. **[41]**. The proposed methodology was later modified by Lang and Foster **[42]**.

The adopted methodology is consistent with the ANCOLD Guidelines on Risk Assessment **[28]**.

Two estimates have been carried out to determine the individual or group most at risk:

i. MMG personnel in the vicinity of the Stage 3 TSF; and

ii. Harmony personnel within the Little Eva Pit extents

The Individual Risk is assessed to be 1.0E-09 for the MMG personnel, and 1.3E-10 for the Harmony personnel.

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Consequently, the MMG personnel represent the group most at risk, with a total Individual Risk imposed by the Stage 3 TSF of **1.0E-09**. The Individual Risk estimate satisfies the ANCOLD criteria for new dams or major augmentations (not greater than 1E-05).

15.8 As Low as Reasonably Practicable Demonstration

To demonstrate that the risks are "as low as reasonably practicable" (ALARP), the methodology described in Commentary C11-7 of the ANCOLD Guidelines on Risk Assessment **[28]** has been adopted.

As part of the ALARP assessment, it was concluded that overall, reliable and effective risk control measures and multiple lines of defence are already in place (or will be in place following construction) to control the hazard. The level of existing control measures is consistent with good industry practice.

Two potential additional control measures (Risk Mitigation Options) have been identified to mitigate the risks associated with the critical hazard:

1. Risk Mitigation Option 1: The placement of surplus excavation material along the downstream face to provide additional buttressing; and
2. Risk Mitigation Option 2: Increasing the height of the proposed Little Eva Pit flood protection levee.

A reasonably practicable assessment has been carried out for each of the risk mitigation options. The outcomes of the reasonable practicability test are summarised in **Table 15.2**.

TABLE 15.2 - REASONABLY PRACTICABLE TEST FOR STAGE 3 TSF ADDITIONAL CONTROL MEASURES

Risk Mitigation Option	Overall Assessment	Justification
Place Surplus Material at Downstream Toe	Not Reasonably Practicable	There is a strong degree of confidence that the dam's risk position plots below the applicable safety threshold. Therefore, the implementation of the additional control measure is deemed "Not Reasonably Practicable" based on the following key considerations: • The overall opportunities to improve controls for the critical hazard are determined to be **Weak** • The mitigation option is anticipated to have a **negligible impact** on the annual failure probability (AFP) and the overall societal risk • The overall justification rating for the gross disproportion assessment is assessed to be **Poor**
Raise the Little Eva Pit Flood Protection Levee	Not Reasonably Practicable	There is a strong degree of confidence that the dam's risk position plots below the applicable safety threshold. Therefore, the implementation of the additional control measure is deemed "Not Reasonably Practicable" based on the following key considerations: • The overall opportunities to improve controls for the critical hazard is determined to be **Weak** • The annual failure probability (AFP) is **not anticipated to improve** following the implementation of the risk mitigation option. • The overall improvements to the societal risk following the implementation of the risk mitigation option are estimated to be **less than one order of magnitude** • The overall justification rating for the gross disproportion assessment is assessed to be **Poor**

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15.9 Conclusions and Recommendations

The risk assessment and ALARP assessment outcomes indicate that the Stage 3 TSF societal risk profile is lower than the ANCOLD limit of tolerability for major augmentations **[28]** to an extent determined to be “ALARP”.

Neither of the risk reduction mitigation measures is considered reasonable or practicable and recommended for implementation.

Notwithstanding, the following recommendations are made to effectively monitor and manage the risks and enhance the dam safety management system:

- Regularly update the dam safety plans, including the Operation and Maintenance Plan and the Dam Safety Emergency Plan.
- Regularly review and update the surveillance program based on the recommendations made in the ANCOLD Guidelines on Dam Safety Management System **[43]**. This ensures early detection of any potential issues or anomalies.
- Reassess the credibility of the identified potential failure modes if any modifications are made to the design or proposed operational status. Similarly, any identification of poor construction practices or deviations from specifications post-construction requires an immediate review of the failure modes to ensure the continued integrity and safety of the dam structure.
- Review the risk assessment outcomes if there are material changes to the assumed downstream conditions, such as the structure and alignment of the Little Eva Pit Flood Protection Levee and/or the number of Harmony personnel expected to be working within the Little Eva Pit.
- Ensure that the dam operations and management staff receive appropriate training and have the necessary skills to carry out the operation and maintenance tasks or to respond effectively to various scenarios in an emergency.

16 INSTRUMENTATION

Nine (9) survey monitoring points have been installed on the crest and downstream bench of the Stage 2 TSF Embankment. It is proposed that these survey monitoring points be removed and reinstalled on the Stage 3 crest and downstream bench.

The survey stations are monitored daily by an automatic total-station located in a small cubicle located next to the main solar array. The station automatically records the position of each prism daily when atmospheric conditions are most favourable. The system is configured to send an email alert if movement thresholds are exceeded. An automated reporting function compiles and sends a management report on a weekly and monthly basis.

17 TSF OPERATIONS

An operation plan exists for the existing Stage 2 TSF. The Operation Plan **[44]** outlines the requirements and methodologies for the operation, inspection, monitoring and reporting for the TSF.

The Plan presents the procedures to be implemented so that the Dugald River TSF is operated in accordance with the design objectives and associated regulatory approvals.

The requirements for monitoring of the TSF is summarised in **Table 17.1**. The Operation Plan will be reviewed upon commissioning of the Stage 3 TSF.

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TABLE 17.1 – SUMMARY OF TSF MONITORING REQUIREMENTS

Item	Frequency	Responsible Personnel	Purpose	Records / Reports
Plant Tailings Production Records	Daily	Inspections Coordinator	Tailings filling reconciliation and density checks.	Compile monthly & forward to EOR for density assessment. Retain data for use during annual inspection report.
Estimate of Decant Water Level	Daily	Inspections Coordinator	Generation of a comprehensive inflow database and to maintain pond within regulatory operating levels.	Routine Checklist & TARP. Retain data for use during annual inspection report, and potential water balance calibrations.
Return Water Decant Pond Clarity	Daily	Inspections Coordinator	Check that tailings are not flowing through the RWS Pump intake.	Routine Checklist & TARP. Retain data for use during annual inspection report.
Tailings Beach Aerial & Bathymetric Survey	Quarterly	Inspections Coordinator Senior Surveyor	Decant pond volume, tailings beach slope correlation and density checks.	Forward to EOR for assessment. Retain data for use in annual inspection report.
Survey of TSF Embankment Movement Monitoring Points	Daily	Inspections Coordinator Senior Surveyor	Monitor settlement and vector movements of the embankment crest and downstream slope.	Compile monthly & forward to EOR for assessment. Retain data for use during annual inspection report.
Seepage Collection Pond Monitoring	Dailly	Inspections Coordinator	Monitor the rate of seepage from the TSF Embankment and/or foundations.	Compile monthly & forward to EOR for density assessment. Retain data for use during annual inspection report.
Rainfall & Evaporation	Daily	SSHE Department	Development of a database of daily climate data, used to confirm / update design estimations.	Retain data for use during annual inspection report.
Fauna Mortality	Weekly / Monthly	SSHE Department	Monitor mortality rates for further assessment (refer to Items D41 & D42 of the Dugald River EA).	Report to DEHP within 48 hours of discovery of any mortalities.
Tailings Net Acid Producing Potential (NAPP) & metal concentrations	8 tests per 100,000 t of tailings	SSHE Department	Develop a database of acid generating potential of tailings (refer to Item H1 of the Dugald River EA).	Retain data for use during annual inspection report.

18 TSF CLOSURE

18.1 Closure Objectives

Decommissioning and rehabilitation requirements for the TSF are addressed by Schedule Item D28 of the Dugald River Environmental Authority (EA) **[45]**, which states that the TSF site must be rehabilitated to achieve a stable, safe and non-polluting landform.

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The following general objectives relate to the rehabilitation of the Dugald River TSF:

- Return the majority of disturbed land to a condition similar to the pre-existing condition of native habitat;
- Upon rehabilitation, make disturbed areas stable to ensure that the proposed subsequent land use is not compromised by surface instability or erosion;
- Ensure that constructed landforms are geochemically stable to the extent that they do not impact on surface water or groundwater quality. In particular for the TSF, this will mean controlling and minimising the transport mechanism either upwards or downwards for oxidation products within the tailings; and
- Revegetation initiatives to boost the re-establishment of the native ecosystem using direct seeding species mixes.

18.2 Closure Concept

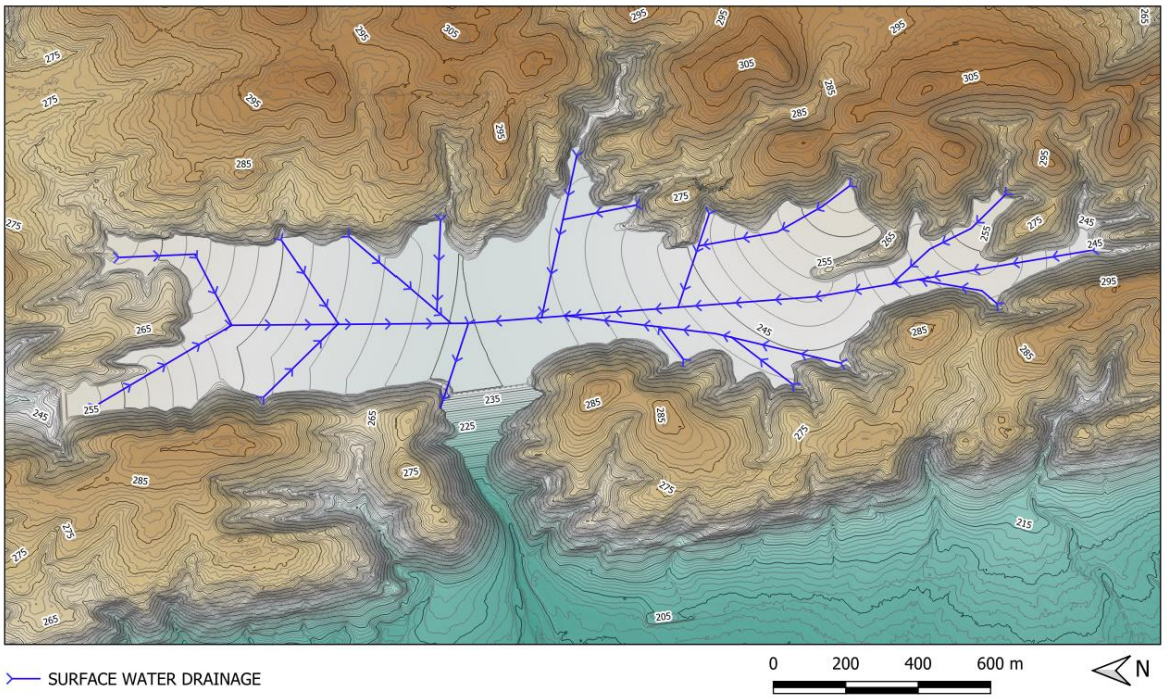
The general approach to closure will incorporate a low water flux cover system that includes a capillary break, sealing layer, waste rock layer and revegetated topsoil. Four cover options have been proposed to be modelled to assess their relative performance regarding net percolation and to determine which option(s) would meet the closure objectives. These options are presented in the Conceptual Closure Design Report **[46]**.

Rehabilitation of the embankment will comprise flattening the batter from 1.5H:1V to 6.5H:1V, undertaken by pushing excess fill material from the crest of the embankment to fill the downstream toe of the embankment. To allow for a self-shedding closure landform whilst also minimising erosion, the final tailings beach slopes are proposed as follows:

- 1.5% for first 500 m (top 1/3 of beach);
- 1% for second 500 m (middle 1/3 of beach); and
- 0.67% for remaining slopes (bottom 1/3 of beach).

The proposed conceptual general arrangement for the final drainage of the rehabilitated TSF is shown in **Diagram 18.1**. The conceptual drainage channels shown are intended to allow for the capture of runoff from upstream external catchment sources, rather than incidental rainfall on the TSF itself. Further detail is provided in the Conceptual Closure Design Report **[46]**.

DIAGRAM 18.1 – CONCEPTUAL SURFACE WATER DRAINAGE



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19 CLOSURE

Your attention is drawn to the “Conditions of Report” and “Conditions of Investigation” which appear at the end of this report.

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FIGURES

LEGEND:
- TAILINGS DEPOSITION LINE
- RETURN WATER PIPELINE
- ELECTRICAL LINE
- ID WIND FARM TURBINE LOCATIONS PROPOSED

TAILINGS (STEEL) & RETURN WATER (HDPE) PIPELINES
MINE VILLAGE
TAILINGS PIPELINE VALVE (FOR NORTHERN/SOUTHERN DISCHARGE)
TAILINGS PIPELINE SPILL CONTAINMENT DAMS (8 NO.)
NORTHERN TAILINGS PIPELINE & ACCESS ROAD
SOUTHERN TAILINGS PIPELINE & ACCESS ROAD
RETURN WATER PIPELINE (HDPE), POWERLINE & ACCESS ROAD
SD1 ACCESS ROAD
SD2 ACCESS ROAD
SOUTHERN DISCHARGE POINT 3 (SD3)
SD3 ACCESS ROAD
NORTHERN DISCHARGE POINT 1 (ND1)
RETURN WATER SYSTEM (PAD, DECANT & BOOSTER PUMPS)
RELOCATE RWS PLATFORM (BY OTHERS)
SOUTHERN DISCHARGE POINT 1 (SD1)
SOUTHERN DISCHARGE POINT 2 (SD2)
NORTHERN DISCHARGE POINT 2 ACCESS ROAD
NORTHERN DISCHARGE POINT 2 (ND2)
MAIN EMBANKMENT ACCESS RAMP
NOMINAL DECANT POND EXTENTS AT END OF FILLING
STAGE 3 TSF EMBANKMENT CREST RL 253.50 m
NOMINAL TAILINGS BEACH EXTENTS AT END OF STAGE 3 FILLING
NORTHERN DISCHARGE BUND CREST RL 253.50 m
STAGE 3 SPILLWAY
SEEPAGE COLLECTION SYSTEM
CONSTRUCTION HAUL ROAD/PERMANENT ACCESS ROAD (NORTH)
CONSTRUCTION HAUL ROAD/PERMANENT ACCESS ROAD (SOUTH)
LEASE BOUNDARY
ZONE 2B & 2C BORROW AREA
A FIG. 4
E 410000
E 409000
N 7764000
N 7763000
N 7762000
N 7765000

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MMG DUGALD RIVER
STAGE 3 TAILINGS STORAGE FACILITY - DETAILED DESIGN

CIVIL WORKS AREAS
GENERAL ARRANGEMENT PLAN

DWG. No. FIGURE 1

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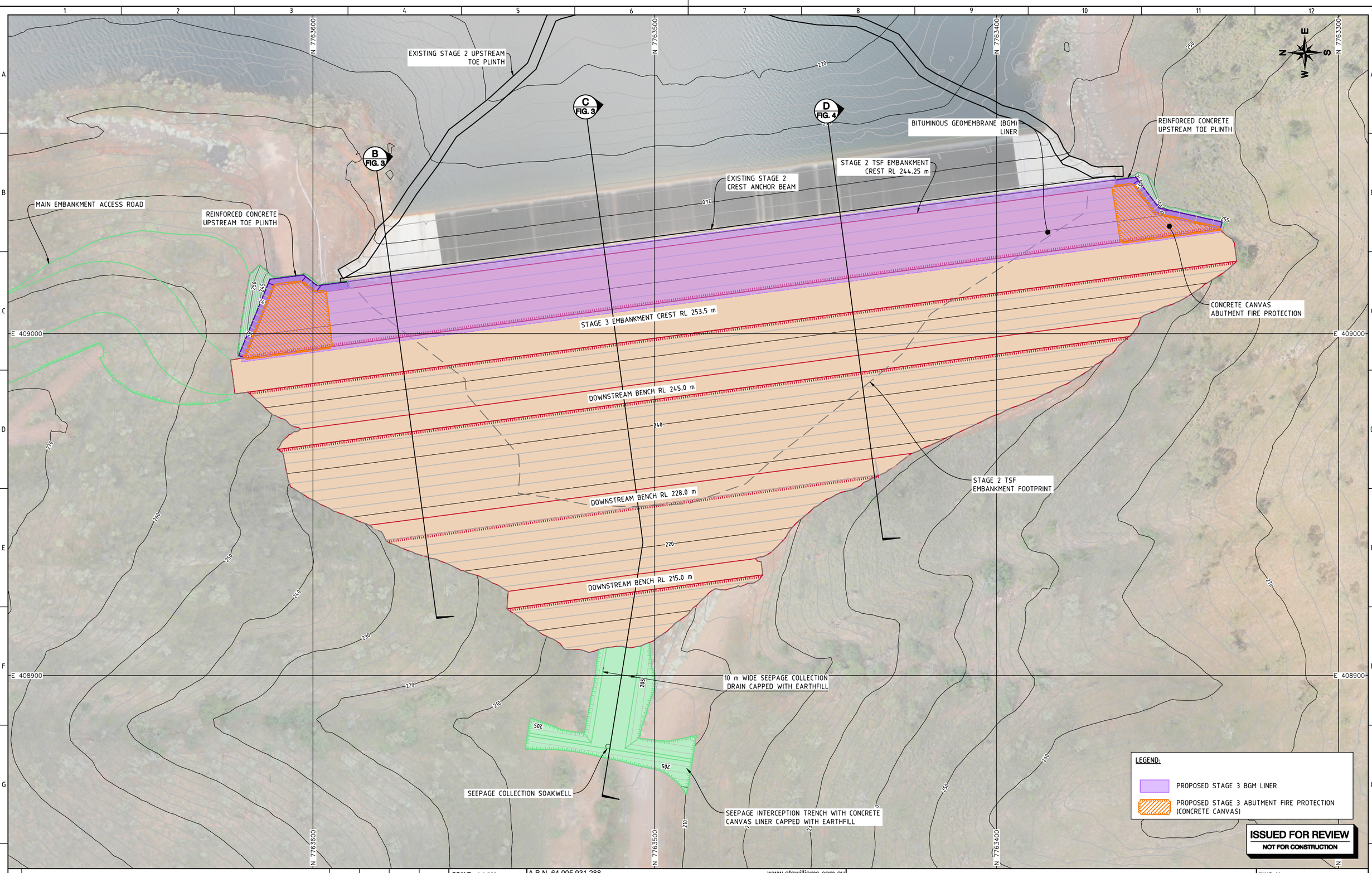

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TSF EMBANKMENT AREA GENERAL LAYOUT

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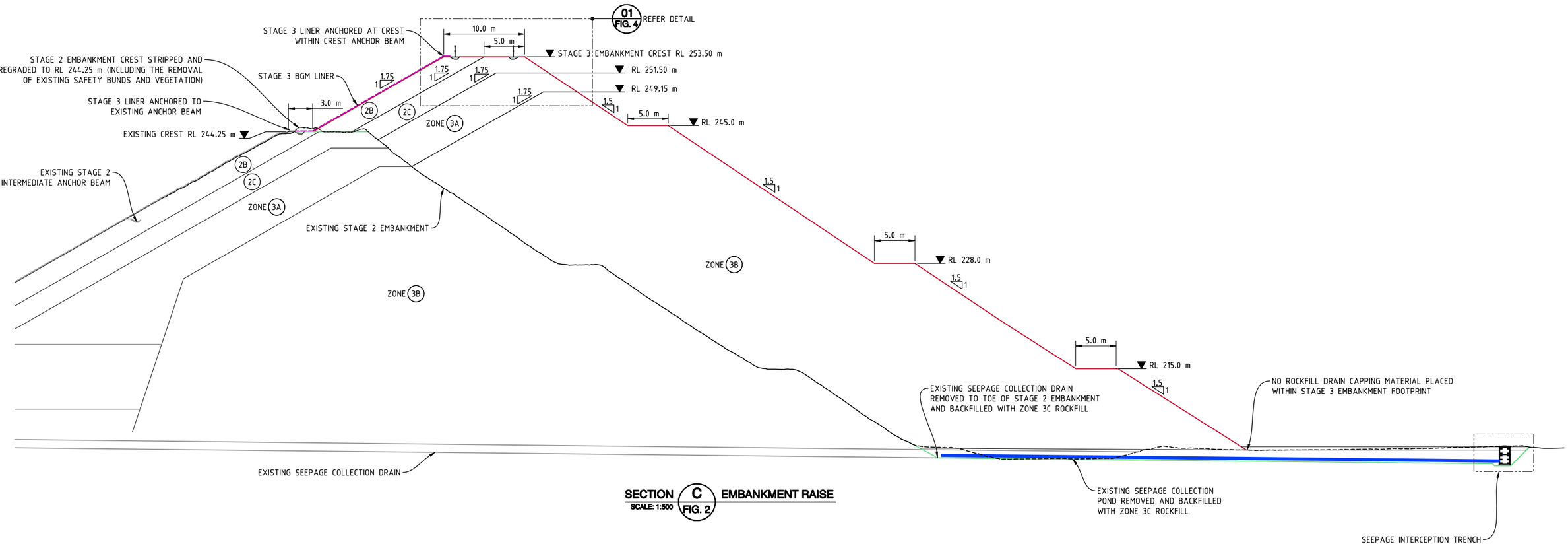
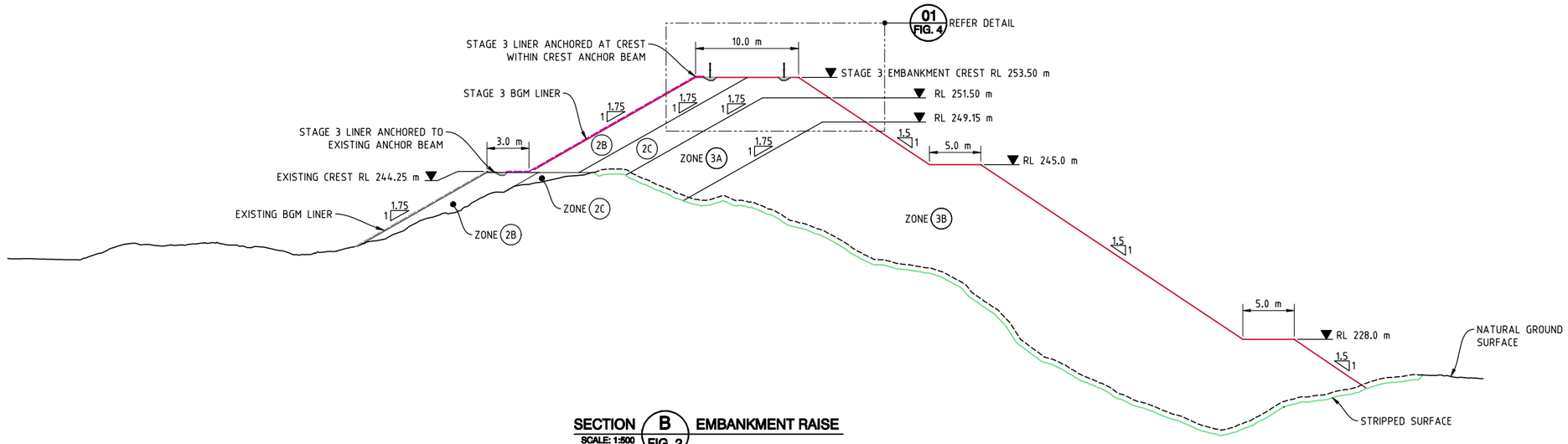


SECTION C EMBANKMENT RAISE
SCALE: 1:500 FIG. 2



SECTION B EMBANKMENT RAISE
SCALE: 1:500 FIG. 2

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TSF EMBANKMENT AREA
SECTIONS (SHEET 1 OF 2)

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FIGURE 3

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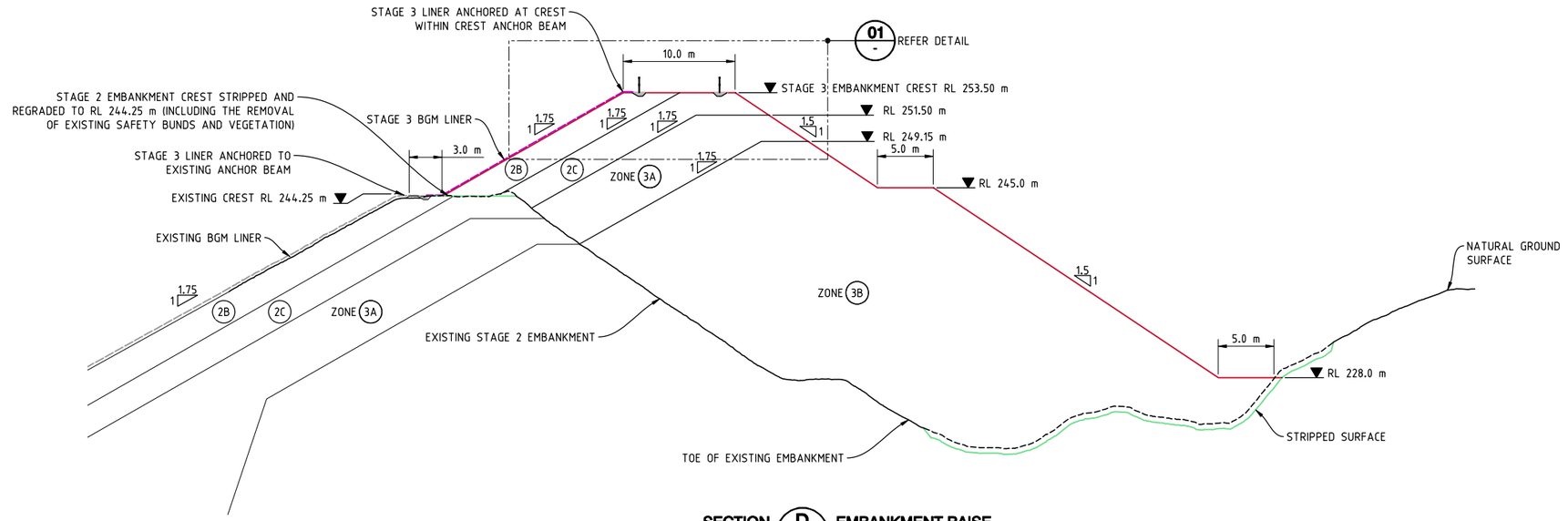
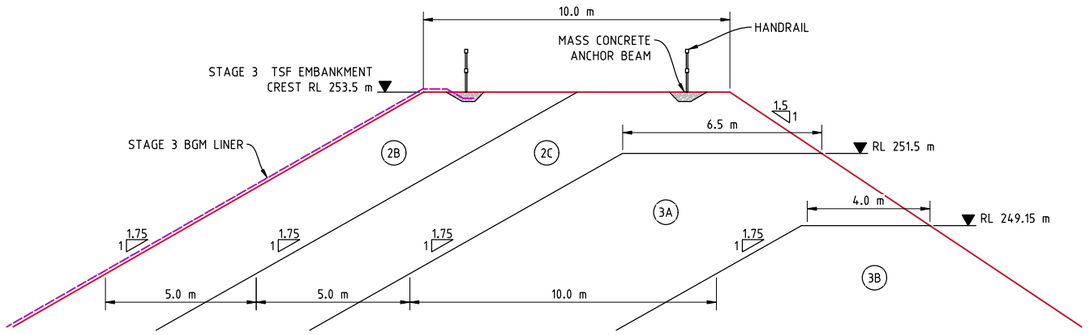
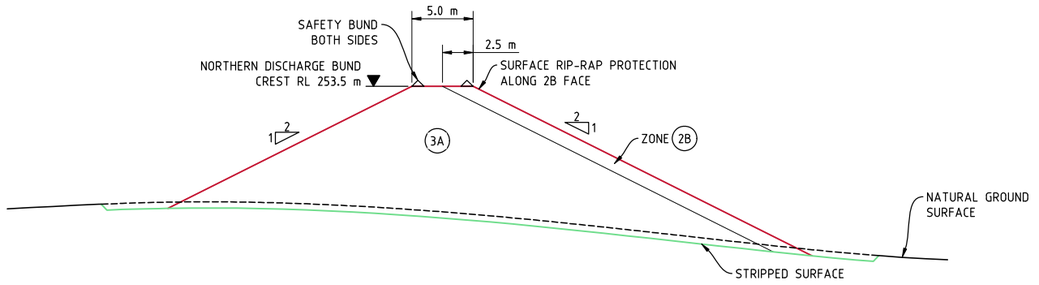


SECTION D EMBANKMENT RAISE
SCALE: 1:500 FIG. 2



DETAIL 01 - TSF EMBANKMENT CREST
SCALE: 1:200 FIG. 3



TYPICAL SECTION A NORTHERN DISCHARGE BUND
SCALE: 1:500 FIG. 1

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TSF EMBANKMENT AREA
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APPENDICES

APPENDIX A – TAILINGS LABORATORY TESTING REPORT

LAB REPORT

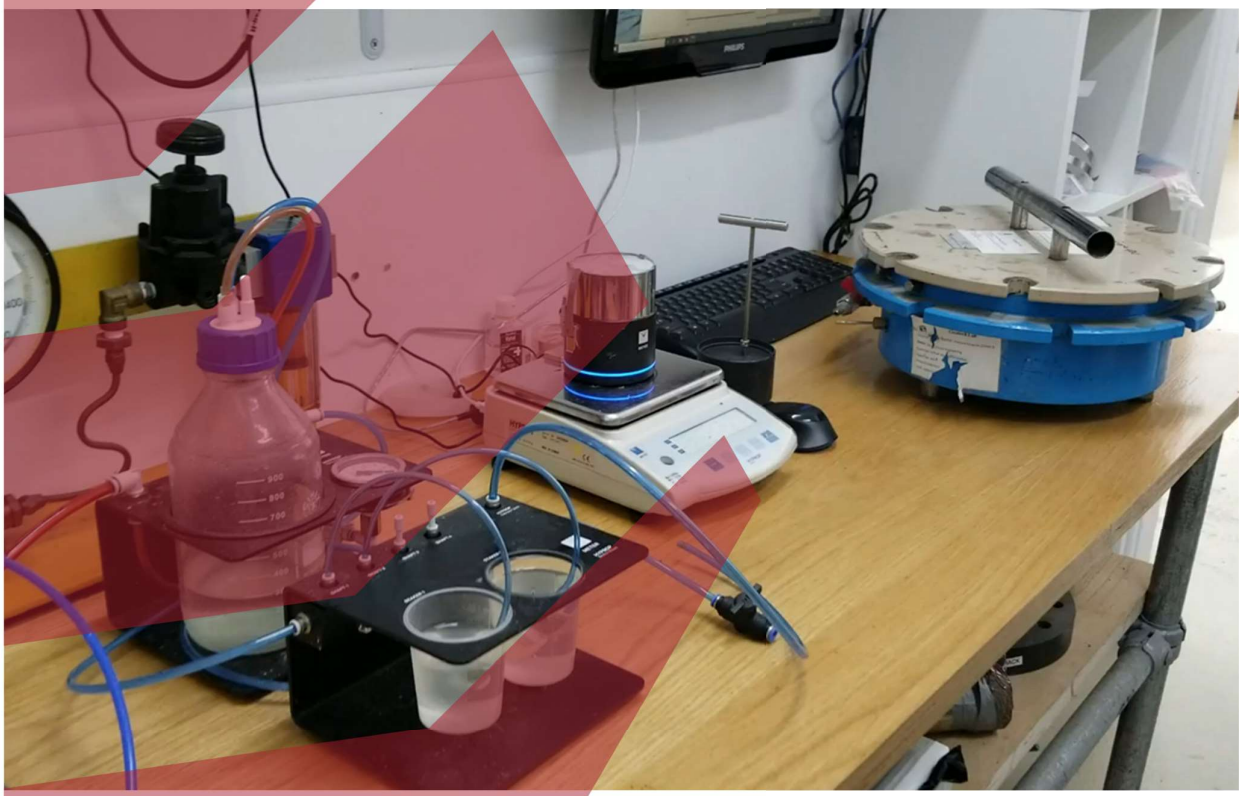
MMG Australia Limited

Dugald River TSF Stage 3 Raise Detailed Design

Laboratory Factual Report

L250542-R01-RevA

May 2025



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Project Number:	250542
Revision Status:	A

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
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APPENDICES

APPENDIX A – LABORATORY TEST CERTIFICATES

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1 INTRODUCTION

ATC William Pty Ltd (ATCW) was requested to conduct a laboratory testing program for MMG Australia Limited (MMG) pertinent to the detailed design of the Stage 3 Raise for the Tailings Storage Facility (TSF) at Dugald River Mine Site in Cloncurry QLD, Australia.

This is a factual report and does not include interpretation of results.

2 LABORATORY TESTING PROGRAM

2.1 Overview

The laboratory testing program was carried out at ATCW's NATA-accredited laboratory located in Melbourne.

All the test work undertaken at ATCW's laboratory was completed in accordance with **AS 1289** "*Methods of testing soils for engineering purposes*" or a well-established in-house method in accordance with the laboratory quality system requirements of ATCW.

ATCW cannot confirm the adherence of external laboratories to any quality system.

The full scope of the laboratory testing program is outlined in **Section 2.4**. The laboratory test certificates have been attached as **Appendix A**.

2.2 Sample Receipt

On March 03, 2025, ATCW's laboratory received the following samples from MMG:

- Tailings 8 x 20 L buckets (approximately 40 kg total).

Presented in **Table 1** is a summary of the tailings samples that underwent testing.

TABLE 1: SAMPLES SCHEDULED FOR TESTING

Name	Description	Register Number
Tailings	As Received Tailings	14325
Decant	Decant Water from Tailings	14425
Tailings	Flocculated Tailings	15325

2.3 Sample Preparation

The tailings samples originating from the MMG Dugald River Mine were assigned a register number (refer to **Table 1**). Samples first underwent classification testing then, once determined to be similar, one of the samples then progressed through the rest of the testing program (14325). The corresponding flocculated samples were registered separately. Post-flocculation, tailings samples were registered as sample number #15325.

It is understood that the tailings samples were sampled on site, and the site water (process water) would have a conductivity of 5,000 µS/cm. ATCW recreated the process water by modifying Melbourne tap water to have the above conductivity and pH as measured from the tailings bleed water (see **Section 8** and **10**). This modified Melbourne tap water was then added to the tailings to create the extra slurry required for the tailings test work.

Flocculation of the tailings samples for modelling test work was conducted using BASF338 Flocculant. The tailings were treated with a dosage rate of 23 g/ton at a solids concentration of 12-15%.

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All sample preparation was undertaken in accordance with **AS 1289.1.1** "*Sampling and preparation of soils – Preparation of disturbed soil samples for testing*" and ATCW's in-house slurry preparation procedure IHM 1.1.

2.4 Scope of Work

Presented in **Table 2** is the laboratory testing program that was completed under this scope.

TABLE 2: LABORATORY TESTING PROGRAM

Item	Description	Reference
1	Solids Concentration / Moisture Content (Slurry)	**Section 3**
2	Atterberg Limits - Liquid Limit (Standard) 4 Point	**Section 4**
3	Soil Particle Density (Specific Gravity)	**Section 5**
4	Particle Size Distribution - Sieve & Hydrometer	**Section 6**
5	Minimum and Maximum Density	**Section 7**
6	Electrical Conductivity	**Section 8**
7	Total Dissolved Solids and Fluid Density	**Section 9**
8	pH Value	**Section 10**
9	Segregation Threshold (Static)	**Section 11**
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13	Soil Moisture Characteristic Curve	**Section 15**
14	Rotary Rheology	**Section 16**
15	Consolidation - Rowe Cell	**Section 17**

3 AS RECEIVED MOISTURE CONTENT

3.1 Procedure

For determination of the solids moisture content, the procedure outlined in **AS 1289.2.1.1** "*Soil moisture content tests – Determination of the moisture content of a soil – Oven drying method (standard method)*", was adopted.

3.2 Definition

In a soil mixture or slurry, the solids concentration (C_w) is the ratio, typically expressed as a percentage, of the mass of solids (W_s) to the total mass (W_t). Specifically, the solids concentration can be defined as follows:

$$C_w = \frac{W_s}{W_t}\, x\, 100 = \frac{W_s}{W_s + W_w} x\, 100$$

where: C_w is the solids concentration as a percentage;

W_s is the mass of solids;

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W_t is the total mass; and

W_w is the mass of water.

Additionally, the moisture content (geotechnical term) is (w) is the ratio, typically expressed as a percentage, of the mass of water (W_w) to the mass of solids (W_s). Specifically, the moisture content can be defined as follows:

$$w = \frac{W_w}{W_s}\ x\ 100$$

where: w is the moisture content (net) as a percentage;

W_s is the mass of solids; and

W_w is the mass of water.

As the samples tested had high salinity (refer to **Section 9**), salt corrections have been applied when determining the solids concentration and moisture content.

3.3 Results

Presented in **Table 3** is the as received moisture contents for the tailings samples.

The NATA accredited laboratory test certificate pertinent to the results is provided in **Appendix A**.

TABLE 3: AS RECEIVED SOLIDS CONCENTRATION

ATCW Register Number	Sample Description	Condition	Solids Content, cw (%)
14325	Tailings	As Received	57.1

4 ATTERBERG LIMITS

4.1 Procedure

For determination of the liquid limit, plastic limit, and plasticity index (i.e. Atterberg limits), the procedures outlined in **AS 1289.3.9.2** "*Soil classification tests – Determination of the cone liquid limit of soil – One-point method*", **AS 1289.3.2.1** "*Soil classification tests – Determination of the plastic limit of a soil – Standard method*" and **AS 1289.3.3.2** "*Soil classification tests – Calculation of the cone plasticity index of a soil*" were adopted, respectively.

4.2 Definition

The physical and mechanical behaviour of fine-grained soils, including tailings, can be described in a framework with four distinct states that are delineated by the Atterberg limits. Presented in **Diagram 1**, the states are liquid, plastic, semisolid and solid.

From point A to point B, a material is considered in a liquid state. When a material reduces beyond the moisture content corresponding to point B, which is referred to as the Liquid Limit (LL), it will reach a plastic state whereby it can be moulded into any shape without rupture.

The range of moisture contents over which the soil exhibits plastic behaviour is known as the Plasticity Index (PI) and can be expressed as:

$$PI = LL - PL$$

where: PI is the plasticity index;

LL is the liquid limit; and

PL is the plastic limit.

When a material reduces beyond the moisture content corresponding to point C, which is referred to as the Plasticity Index (PI), it will reach a semisolid state whereby visible cracks will appear when remoulding.

Reducing the moisture content of a material beyond point D, which is referred to as the Shrinkage Limit (SL), it will reach a solid state whereby no further volume change will occur.

A measure of the soil strength using the Atterberg limits is known as the Liquidity Index (LI) and is expressed as:

$$LI = \frac{w - PL}{PI}$$

where: LI is the liquidity index;

w is the moisture content;

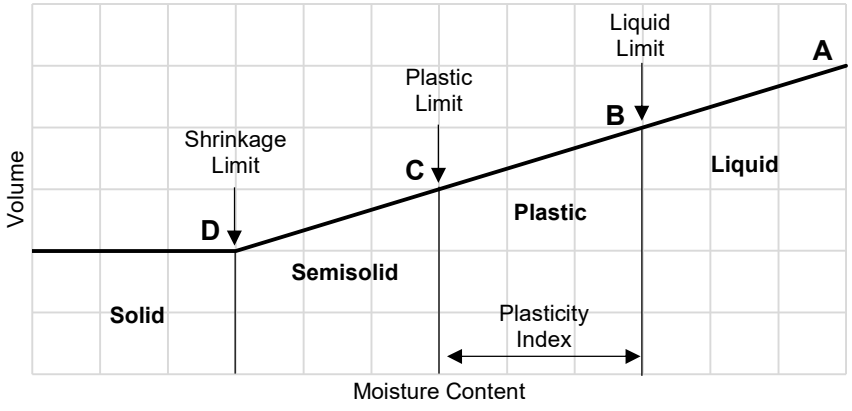
PL is the plastic limit; and

PI is the plasticity index.

If the LI is less than 0 it can be said that the material is in a solid/semisolid state, if the LI is greater than 1 it can be said that the material is in a liquid state, and if the LI is between 0 and 1 it can be said that the material is in a plastic state.

Simply applied, Atterberg limits can be used to assist in classifying materials. Used more broadly, Atterberg limits can be used in correlations to estimate other geotechnical parameters or characteristics such as strength, anisotropy, or liquefaction potential.

DIAGRAM 1: SOIL STATES – ATTERBERG LIMITS



4.3 Results

Presented in **Table 4** is a tabulated summary of the Atterberg limits determined for the tailings samples.

The NATA accredited laboratory test certificate pertinent to the results is provided in **Appendix A**.

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TABLE 4: ATTERBERG LIMITS

ATCW Register Number	Sample Description	Liquid Limit, LL (%)	Plastic Limit, PL (%)	Plasticity Index, PI (%)	Linear Shrinkage (%)	Group Classification Symbol
14325	Tailings	28	16	12	3.2	CL

5 SOIL PARTICLE DENSITY

5.1 Procedure

For determination of the soil particle density, the procedure outlined in **AS 1289.3.5.1** "*Soil classification tests – Determination of the soil particle density of a soil – Standard method*", was adopted.

5.2 Definition

For engineering purposes, the particle density of a soil (ρ_{st}) is the ratio, typically expressed as mass per unit volume, of the mass of the soil solids (W_s) to the volume of solids (V_s). Specifically, the particle density can be defined as follows:

$$\rho_{st} = \frac{W_s}{V_s}$$

where: ρ_{st} is the particle density expressed as mass per unit volume;

W_s is the mass of solids; and

V_s is the volume of solids.

For typical soils, it is appropriate to assume that the particle density is between 2.60 t/m^3 and 2.75 t/m^3, but due to the nature of tailings, in this case it was appropriate to determine the particle density as part of the testing program.

5.3 Results

Presented in **Table 5** is a tabulated summary of the particle densities of the tailings samples.

The NATA accredited laboratory test certificate pertinent to the results is provided in **Appendix A**.

TABLE 5: SOIL PARTICLE DENSITY

ATCW Register Number	Sample Description	Test Temperature (°C)	Sample > 2.36 mm (%)	Particle Density, ρ_{st} (t/m^3)
14325	Tailings	23.1	None	2.96 *

** Apparent average soil particle density – particle size less than 2.36 mm*

6 PARTICLE SIZE DISTRIBUTIONS

6.1 Procedure

For determination of the particle size distributions, the procedure outlined in **AS 1289.3.6.1** "*Soil classification tests – Determination of the particle distribution of a soil – Standard method of analysis by sieving*", **AS 1289.3.6.3** "*Soil classification tests – Determination of the particle distribution of a soil – Standard method of fine analysis using a hydrometer*" and **AS 1289.2.1.1** "Soil moisture content tests – Determination of the moisture content of a soil – Oven drying method (standard method)" were adopted.

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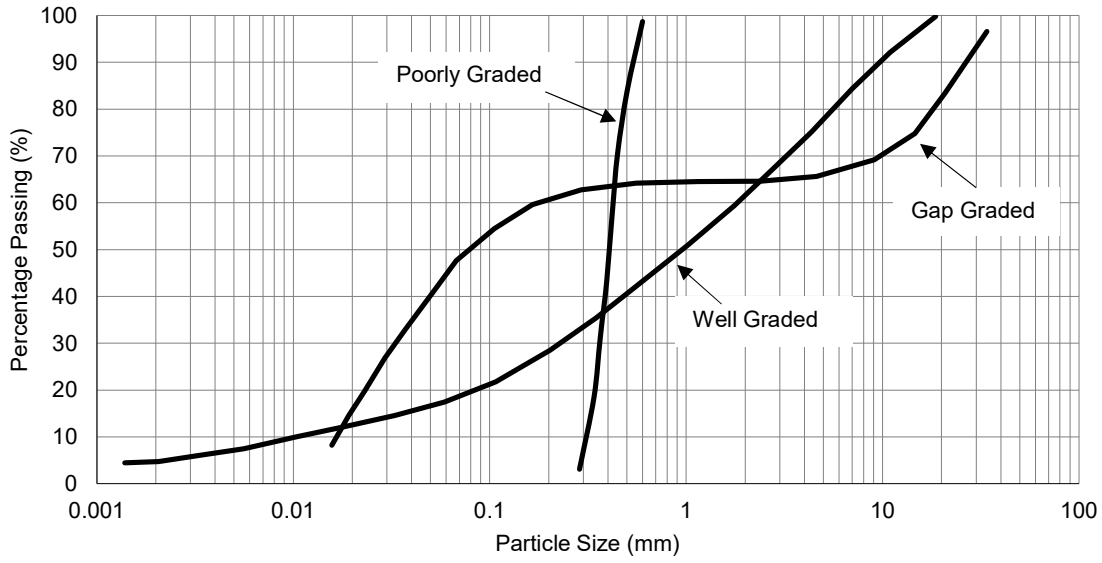
6.2 Definition

A Particle Size Distribution (PSD) of a granular material, such as for soil or tailings, is a list or function that defines the relative amount of particles present, within a representative mass of material, according to the respective particle size.

The results are typically plotted on a graph of the percent of particles finer than a given particle size against the particle size itself (on a logarithmic scale). Presented in **Diagram 2** are particle size distribution curves of three materials with different gradations (i.e., well, poorly and gap graded).

Similar to the Atterberg limits, a PSD can be used to assist in classifying a material as well as in correlations to estimate additional geotechnical parameters and liquefaction potential.

DIAGRAM 2: PARTICLE SIZE DISTRIBUTION CURVES (EXAMPLES)



6.3 Results

Presented in **Figure 1** is the particle size distribution of the tailings sample.

The NATA accredited laboratory test certificates pertinent to the results are provided in **Appendix A**.

7 MINIMUM AND MAXIMUM DRY DENSITY

7.1 Procedure

For determination of the minimum dry density, the procedure outlined in **AS 1289.5.5.1** "*Soil compaction and density tests – Determination of the minimum and maximum dry density of a cohesionless material – Standard method*" was adopted.

For determination of the maximum dry density, the procedure outlined in **AS 1289.5.1.1** "*Soil compaction and density tests – Determination of the dry density/moisture content relation of a soil using standard compaction effort*" was adopted.

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7.2 Definition

A sub-sample of tailings was oven dried and gently ground using a rubber pestle to break up the sample to individual particles. The sample was then poured through a funnel into a 1 litre mould until the sample was slightly higher than the collar of the mould. A straight edge was then used to gently remove the excess material. The test was repeated, and the lower value of the two tests was reported as the minimum dry density.

The maximum density test in **AS 1289.5.5.1** is performed on a saturated sample using a vibrating table and is designed for coarse cohesionless materials. The method, in this case, was deemed not applicable as the fine particle size of the tailings would result in slow dissipation of pore water pressure generated during vibration, thus, resulting in lower densities. Therefore, an estimation of maximum density was performed using a standard compaction hammer (**AS1289 5.1.1**) on a sample moistened to what was estimated to be the optimum moisture content.

7.3 Results

Presented in **Table 6** is a tabulated summary of the minimum and maximum densities of the tailings.

The laboratory test certificate pertinent to the results is provided in **Appendix A**.

TABLE 6: MINIMUM AND MAXIMUM DRY DENSITY

ATCW Register Number	Sample Description	Sample Type	Minimum Dry Density (t/m^3)	Maximum Dry Density (t/m^3)
14325	Tailings	Tailings Slurry	1.05	1.88

8 ELECTRICAL CONDUCTIVITY

8.1 Procedure

For determination of the electrical conductivity of the tailings slurry and decant water, an in-house procedure (i.e., IHM 11.0) was adopted in accordance with the laboratory quality system requirements of ATCW.

8.2 Description

The decant specimen was prepared by removing the decant from the tailings slurry sample after it was left to settle.

8.3 Results

Presented in **Table 7** is a tabulated summary of the electrical conductivity of the tailings slurry and decant bleed water.

The laboratory test certificates pertinent to the results is provided in **Appendix A**.

TABLE 7: ELECTRICAL CONDUCTIVITY

ATCW Register Number	Sample Description	Soil – Suspension / Groundwater	Electrical Conductivity (µS/cm)
14425	Tailings Decant	Bleed Liquor - Decant	5,860

9 TOTAL DISSOLVED SOLIDS AND FLUID DENSITY

9.1 Procedure

For determination of the Total Dissolved Solids (TDS) and fluid density, an in-house procedure (i.e., IHM 4.0) was adopted in accordance with the laboratory quality system requirements of ATCW.

9.2 Description

The test sample was prepared from the decant water recovered from the settled tailings slurry described in **Section 8.1**.

9.3 Results

Presented in **Table 8** is a tabulated summary of the TDS and fluid density of the tailings slurry decant.

The laboratory test certificate pertinent to the results is provided in **Appendix A**.

TABLE 8: TDS AND FLUID DENSITY

ATCW Register Number	Sample Description	Sample Type	Salt Content (g/g Water)	Density of Liquor (g/mL)	TDS (mg/L)
14425	Tailings Slurry Decant	Decant Water	0.005306	0.99872	5,272

10 PH VALUE

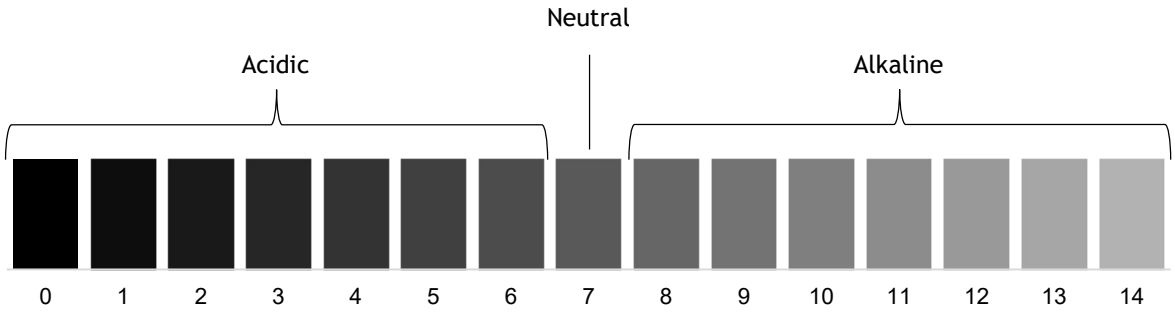
10.1 Procedure

For determination of the acidity (pH), the procedure outlined in **AS 1289.4.3.1** "*Methods of testing soils for engineering purposes Soil chemical tests - Determination of the pH value of a soil - Electrometric method*", was adopted.

10.2 Definition

As presented graphically in **Diagram 3**, pH is a scale used to specify how acidic or basic (i.e. alkaline) a water-based solution or slurry is. Acidic mixes have a lower pH, while basic mixes have a higher pH. At room temperature, pure water is neither acidic nor basic and has a pH of 7 (i.e. neutral).

DIAGRAM 3: PH SCALE



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Electrical conductivity of an electrolyte solution, such as water, is a measure of its ability to conduct electricity. High quality deionized water at 25 °C has a conductivity of about 5.5 µS/m, typical drinking water is in the range of approximately 5–50 mS/m, while sea water is about 5 S/m (i.e. 5,000,000 µS/m).

The pH and conductivity measurements can be used to determine how corrosive a solution or slurry is compared to other electrolyte solutions, for example beach, which is alkaline, or hydrochloric acid, which is acidic.

Furthermore, if the required volume of site water is unobtainable, by testing a small amount and determining the aforementioned parameters, site water, with representative properties, can be manufactured to complete the proposed testing program as is the case for this program.

10.3 Results

Presented in **Table 9** is a tabulated summary of the TDS and fluid density of the tailings slurry and decant.

The laboratory test certificate pertinent to the results is provided in **Appendix A**.

TABLE 9: PH VALUE

ATCW Register Number	Sample Description	Soil – Suspension / Groundwater	pH
14425	Decant	Bleed Liquor	6.8

11 SEGREGATION THRESHOLD

11.1 Procedure

For determination of the segregation threshold, an in-house procedure (i.e., IHM 5.0) was adopted in accordance with the laboratory quality system requirements of ATCW.

11.2 Description

Segregation threshold tests were carried out on the tailings sample. The purpose of the segregation threshold test is to estimate the solids content at which separation of the coarser grading fraction (i.e., segregation) first occurs during static or dynamic settling.

The test procedure requires a sample of slurry to be mixed in a glass cylinder and allowed to settle either under static or dynamic conditions. The solids content is varied by adding site water as required and the test is repeated until signs of segregation is observed.

Two sub-samples of equal volume are then taken using a small pipette, one from the bottom of the cylinder and the other from just below the surface. These samples are put into separate test tubes and are both diluted, agitated, and decanted to separate out the coarser particles.

The volume of the coarser particles remaining are compared and the whole test is repeated, after adjustment of the solids concentration, until the volume of coarse particles are considered to be significantly different. The solids concentration of the slurry in the cylinder is then determined and this value is deemed the segregation threshold.

11.3 Results

Presented in **Table 10** is the solids concentrations at which the segregation threshold has been estimated for the tailings.

The laboratory test certificate pertinent to the results is provided in **Appendix A**.

TABLE 10: SEGREGATION THRESHOLD

ATCW Register Number	Sample Description	Sample Type	Condition	Segregation Threshold Solids Concentration, C_w (%)
15325	Flocculated Tailings	Tailings Slurry	Static	40.0

12 INITIAL SETTLED DENSITY (UNDRAINED)

12.1 Procedure

For determination of the initial settled densities (drained and undrained), an in-house procedure (i.e., IHM 7.0) was adopted in accordance with the laboratory quality system requirements of ATCW.

12.2 Description

The initial settled density test is performed to understand the initial settled characteristics of a slurry deposited at a specific depth and solids concentration.

The test was performed by taking the sample at a solids concentration representative of the high-rate thickener underflow (understood to be 57% w/w) and pouring it as a slurry into a large diameter drained or undrained acrylic cell to the target depth of 50 mm. A large diameter cell is required to limit the effect of friction between the settling sample and the side walls.

The settlement of the surface of the tailings over time is recorded until it is evident that settlement has ceased or is negligible.

12.3 Results

Presented in **Table 11** is a tabulated summary of the results from the initial settled density tests. The initial settled density results are also presented graphically in **Figure 2** to **Figure 4.**

TABLE 11: INITIAL SETTLED DENSITY – UNDRAINED

Parameter		15325
Sample Type		Flocculated Tailings
Suction (kPa)		Undrained
Solids Concentration, C_w (%)	Initial	57.0
	Final	65.4
Initial Height (mm)		51.0
Final Height (%)		40.5
Settled Dry Density, ρ_d (t/m^3)		1.15
Bleed Water	Percentage of Initial Water (%)	29.8
	Volume of Water per Dry Solids (m^3/t)	0.225

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13 SHRINKAGE LIMIT DENSITY

13.1 Procedure

For determination of the shrinkage limit density, an in-house procedure (i.e., IHM 6.0) was adopted in accordance with the laboratory quality system requirements of ATCW.

13.2 Description

The shrinkage limit density test is carried out to determine the maximum dry density that could result from the evaporative drying (i.e., desiccation) of the tailings.

The test was performed by pouring the tailings, at a self levelling solids concentration, into a large diameter tray to a target depth (i.e., approximately 60 mm). A large diameter cell is required to limit the effect of friction between the sample and the side walls.

The sample was left to dry and desiccate until no further volume change could be measured. The sample is then oven dried to determine the shrinkage limit density and crack volume.

13.3 Results

Presented in **Table 12** is a tabulated summary of the results from the shrinkage limit density test. A summary of the results is also presented graphically in **Figure 5**.

TABLE 12: SHRINKAGE LIMIT DENSITY

Parameter	36623
Sample Description	Tailings
Shrinkage Limit Density, ρ_d (t/m^3)	1.80
Crack Volume (%)[#]	5.8

[#] *Crack volume is based on total volume at the end of the test.*

14 EVAPORATIVE STRENGTH GAIN

14.1 Procedure

For determination of evaporative strength gain, an in-house procedure (i.e. IHM 8.0) was adopted in accordance with the laboratory quality system requirements of ATCW.

14.2 Description

For the evaporative strength gain test, the tailings sample was prepared by pouring the slurry into a large diameter tray and allowing it to settle. Once settlement ceased, excess decant was removed using a syringe and the sample was allowed to slowly air dry.

Test determinations for moisture content and yield stress were then made at regular intervals during the drying process.

The shear strength of the tailings sample was measured using a Thermo Haake VT550 (< 10 Pa) with the shear vane rotation set at 0.1 rpm. Additional measurements (i.e., above 10 Pa) were made with a Geonor H-60 Handheld shear vane.

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14.3 Results

The results from the evaporative strength gain tests are graphically presented in **Figure 6** and **Figure 7.**

It is noted that due to the rapid strength gain exhibited by the tailings sample, limited strength determinations were able to be made.

15 SOIL MOSTURE CHARACTERISTIC CURVE

15.1 Procedure

For the determination of the soil moisture characteristic curve (drying) the procedure outlined in UMS GmbH's HYPROP Operation Manual (2015) was adopted. Associated activities were undertaken in accordance with the laboratory quality system requirements of ATCW.

15.2 Description

The suction characteristics of soils are typically presented as 'soil moisture characteristic curves', also termed 'water retention curves'. Soil moisture characteristic curves depict the suction characteristics of partially saturated soils in terms of matric suction and volumetric water content and can be used to model the behaviour of materials in a desaturating or unsaturated state (i.e. vadose zone). The hydraulic conductivity function is one such soil property that can be estimated directly from the soil moisture characteristic curve.

The volumetric water content is used to express the soil moisture characteristic curve as it is a function of both the moisture content and density of the sample (see equation below), both of which influence the respective matric suction caused by evaporation. It is noted that matric suction within the sample is equal to the negative pore water pressure, as the pore air pressure is assumed to be atmospheric during testing (see equation below).

$$\theta = \rho_d \, x \, w$$

where: θ is the volumetric water content;

ρ_d is the dry density; and

w is the moisture content (net).

$$\Psi = u_a - u_w$$

where: Ψ is the matric suction;

u_a is the pore air pressure (typically atmospheric); and

u_w is the pore water pressure.

Due to hysteresis, a soil moisture characteristic curve for both desorption (drying) and adsorption (wetting) is exhibited by a soil. In this case, only the desorption (drying) curve has been determined. Additionally, since significant volume change during drying was not apparent, the dry density was considered to be constant throughout the test.

15.3 Apparatus

Some materials, especially ones that are fine grained, may have a large suction range. Therefore, for these materials, multiple test methods are commonly used to determine a single soil moisture characteristic curve. This is as a result of the current technology not being capable of targeting a wide range of suctions (i.e. 1 kPa to 10 MPa).

To determine the suction characteristics of the tailings, Decagon Devices' HYPROP 2 was used. This device is capable of measuring suction over a large range, therefore, eliminating the need to perform multiple test methods (in this case).

The HYPROP is a modular laboratory instrument that generates a soil moisture characteristic curve using two mini-tensiometers that measure the water potential at different levels within the sample, while the sample rests on a precision laboratory scale (2,000 gram range; 0.01 gram resolution). As the sample dries, changes in water potential are correlated to changes in moisture content using the Wind / Schindler evaporation method. The HYPROP delivers water potential readings in the 0 kPa to 800 kPa range, with interpolation being made between 250 kPa and 800 kPa (the latter being the air entry value of the ceramic used).

The primary parameter obtained from soil moisture characterisation is the air entry value, Ψ_{ae}. The air entry value is defined by Fredlund and Rahardjo (1993) as the matric suction value that must be exceeded before air recedes into the pores of the soil. The matric suction at and around the air entry value is the range of suction typically of greatest interest. It was assumed that the air entry value of the fly would fall within the suction range the HYPROP is capable of measuring.

15.4 Fitting Curve

A numerical prediction method was used to fit a curve to the results from the HYPROP based on typical soil moisture curve parameters. These parameters are sometimes required as inputs into constitutive modelling packages. The resulting best fitting curve, based on a typical method, is provided along with the suction and moisture content measurements.

15.5 Sample Preparation

The tailings sample was moist tamped within the HYPROP sample ring and left to saturate over a 24-hour period. Once the sample was fully saturated, tensiometers were inserted into the sample and the evaporative drying process commenced as per the procedure outlined in UMS GmbH's HYPROP Operation Manual (2015).

It is noted that Melbourne tap water was used to saturate the sample.

15.6 Results

The soil moisture characteristic curve (drying) and fitting curve parameters have been provided in **Figure 8**.

The results for the HYPROP have not been corrected for salt.

16 RHEOLOGICAL TESTING (ROTARY RHEOMETER)

Rheological parameter measurement using a rotary rheometer was carried out on the Flocculated tailings.

The rheology rotary testing was carried out using a Thermo Haake VT550 Viscometer. A MV2P Couette flow (bob in cup) sensor system was used for the measurement of flow curve rheology.

For the testing, each sample was mixed, and the cup was filled to the correct level prior to testing.

When the flow curve testing was complete, the sample in the cup was discarded, the bob and cup was cleaned and dried, the remaining sample was then remixed, and the flow curve test was repeated.

The flow curves were produced over a shear rate range of 0.1 sec^{-1} to 500 sec^{-1}, however, undeveloped flow was observed below a shear rate of 1 sec^{-1}.

Herschel–Bulkley modelling was performed on the flow curve data at shear rates above the observed undeveloped flow in order to provide a theoretical line of best fit of the experimental data and for inferred yield strength parameters only.

The parameters derived have not been compared against each other for overall material characterization modelling.

Modelling was performed using the Thermo Haake Rheowin Data Manager software.

A FL100 shear vane sensor system was used for the direct measurement of the yield stress using a vane rotation of 0.25 RPM. The rheology measurements for the tailing samples were tested at nominal solids concentrations of 64.8%, 67.1%, 69.1% and 71.1%.

The flow curves resulting from testing is presented in **Appendix B**. The shear vane test results are presented in **Appendix C**. The data derived from the flow curves is plotted on **Figure 9** and **Figure 10**

The plastic viscosity has been defined as the gradient of the tangent of the flow curve at a shear rate of 500 sec^{-1} (apart from the highest solids concentration which was modelled 250 sec^{-1}), while the intercept of this tangent is shown as the tangent intercept stress. The yield stress values have been derived from the Herschel–Bulkley models. Yield stress measurements made on the samples using the FL100 vane are also plotted in **Figure 11.**

The correlation between the shear strength and the solids concentration is represented on **Figure 12**.

17 ROWE CELL (CONSOLIDATION AND PERMEABILITY)

17.1 Procedure

For consolidation testing, an in-house procedure (i.e. IHM 14.0) was adopted in accordance with the laboratory quality system requirements of ATCW.

17.2 Description

Consolidation refers to the process by which soils change volume in response to a change in pressure. It is a time dependent process whereby water within the voids of a material is expelled due to increasing self-weight or an external surcharge causing an increase in pressures within the pores.

In deep deposits of fine-grained materials overlying a low permeability base, the drainage path is predominantly upwards to the surface.

Drainage (or dissipation of pore pressures) can take a significant amount of time to occur with the material being “under-consolidated” (i.e., exhibit excess pore water pressure) for this period.

Rowe cell test data provides information that is able to define the tailings characteristics in terms of material compressibility and permeability. These parameters are primary inputs required to undertake consolidation modelling.

The Rowe cell used is a large diameter (254 mm) consolidation cylinder capable of measuring large sample deflections over a range of applied pressures from 1 kPa to 640 kPa. The permeability of the sample can be directly measured at the completion of each loading stage without affecting the sample. This test method is well suited to the testing of tailings slurries.

The proposed laboratory testing program allowed for one Rowe cell test to be performed on the tailings sample. (15325) Manufactured water was used to dilute the sample ensuring the solids concentration was such that the sample was self-levelling when poured.

17.3 Results

The results of the consolidation test work are presented **Figure 13** to **Figure 15**

REFERENCED STANDARDS

- Australian Standard AS 1289 - Methods of testing soils for engineering purposes
- AS 1289.1.1 – Sampling and preparation of soils – Preparation of disturbed soil samples for testing. ISBN 0 7337 3944 X
- AS 1289.2.1.1 - Soil moisture content tests – Determination of the moisture content of a soil – Oven drying method (standard method). ISBN 0 7337 6645 5
- AS 1289.3.9.2 – Soil classification tests – Determination of the cone liquid limit of soil – One-point method. ISBN 0 7337 5325 6
- AS 1289.3.2.1 – Soil classification tests – Determination of the plastic limit of a soil – Standard method. ISBN 0 7337 9005 4
- AS 1289.3.3.2 – Soil classification tests – Calculation of the cone plasticity index of a soil. ISBN 0 7337 9007 0
- AS 1289.3.5.1 – Soil classification tests – Determination of the soil particle density of a soil – Standard method. ISBN 0 7337 7475 X
- AS 1289.3.6.1 – Soil classification tests – Determination of the particle distribution of a soil – Standard method of analysis by sieving. ISBN 0 7337 9138 7
- AS 1289.3.6.3 - Soil classification tests – Determination of the particle distribution of a soil – Standard method of fine analysis using a hydrometer. ISBN 0 7337 5325 6
- AS 1289.5.5.1 – Soil classification tests – Determination of the minimum and maximum dry density of a cohesionless material – Standard method. ISBN 0 7337 5325 6 1 2 3
- AS 1289.5.1.1 – Soil classification tests – Determination of the dry density/moisture content relation of a soil using standard compactive effort. ISBN 0 7337 5325 6 4 5
- AS 1289.4.3.1 – Soil classification tests – Determination of the pH value of a soil – Electrometric method. ISBN 9780733708978

CONDITIONS OF REPORT

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2. This report has been prepared by ATCW for the purposes stated herein and ATCW's experience, having regard to assumptions that can reasonably be expected to make in accordance with sound professional principles. ATCW does not accept responsibility for the consequences of extrapolation, extension or transference of the findings and recommendations of this report to different sites, cases, or conditions.
3. This document has been prepared based in part on information which was provided to ATCW by the client and/or others and which is not under our control. ATCW does not warrant or guarantee the accuracy of this information. The user of the document is cautioned that fundamental input assumptions upon which the document is based may change with time. It is the user's responsibility to ensure that these assumptions are valid.
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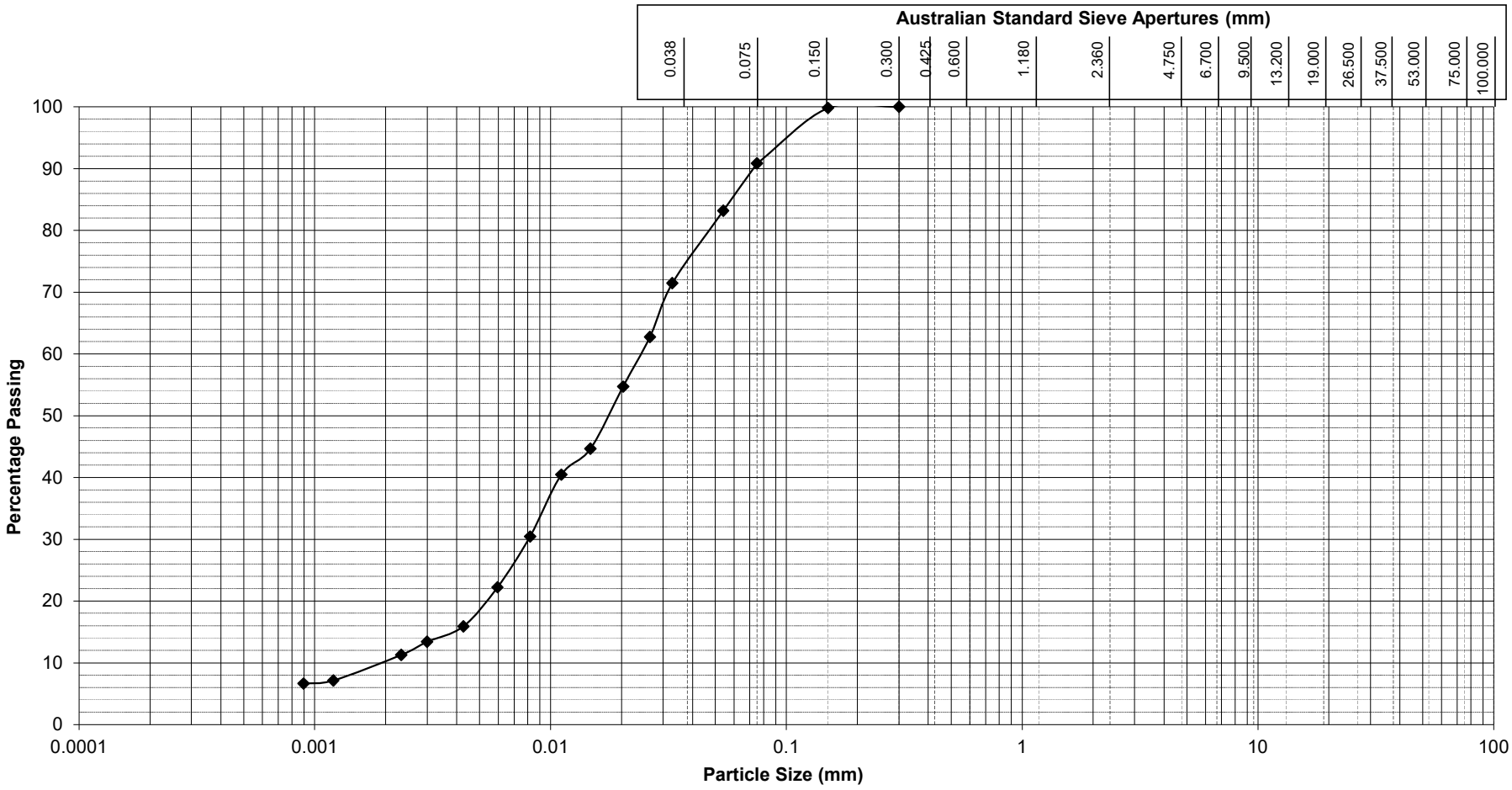
TAILINGS.WATER.WASTE.

FIGURES



ATC WILLIAMS

www.atcwilliams.com.au

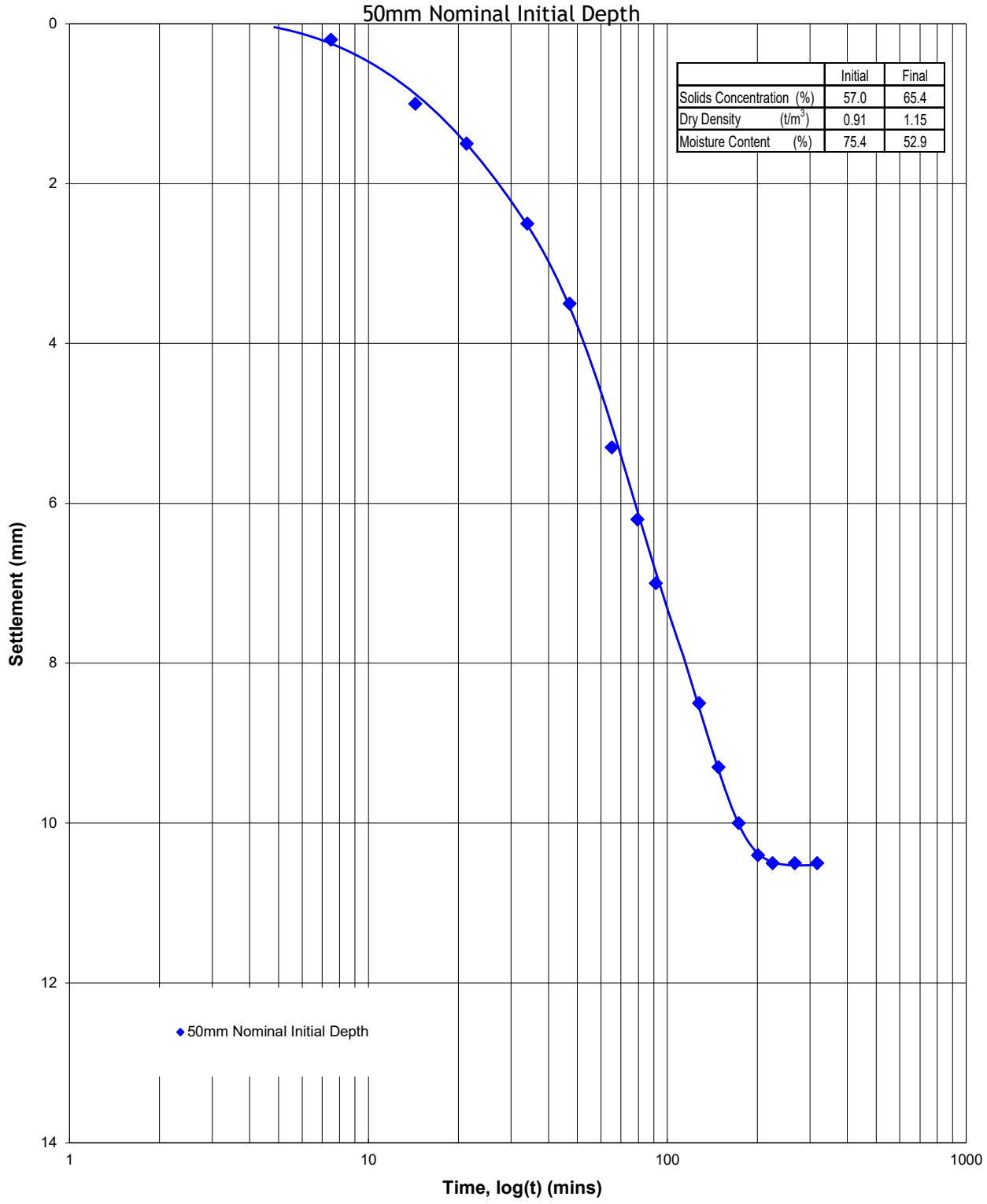
MMG Limited

Dugald River TSF Raise Design

Tailings Sample No: 14325

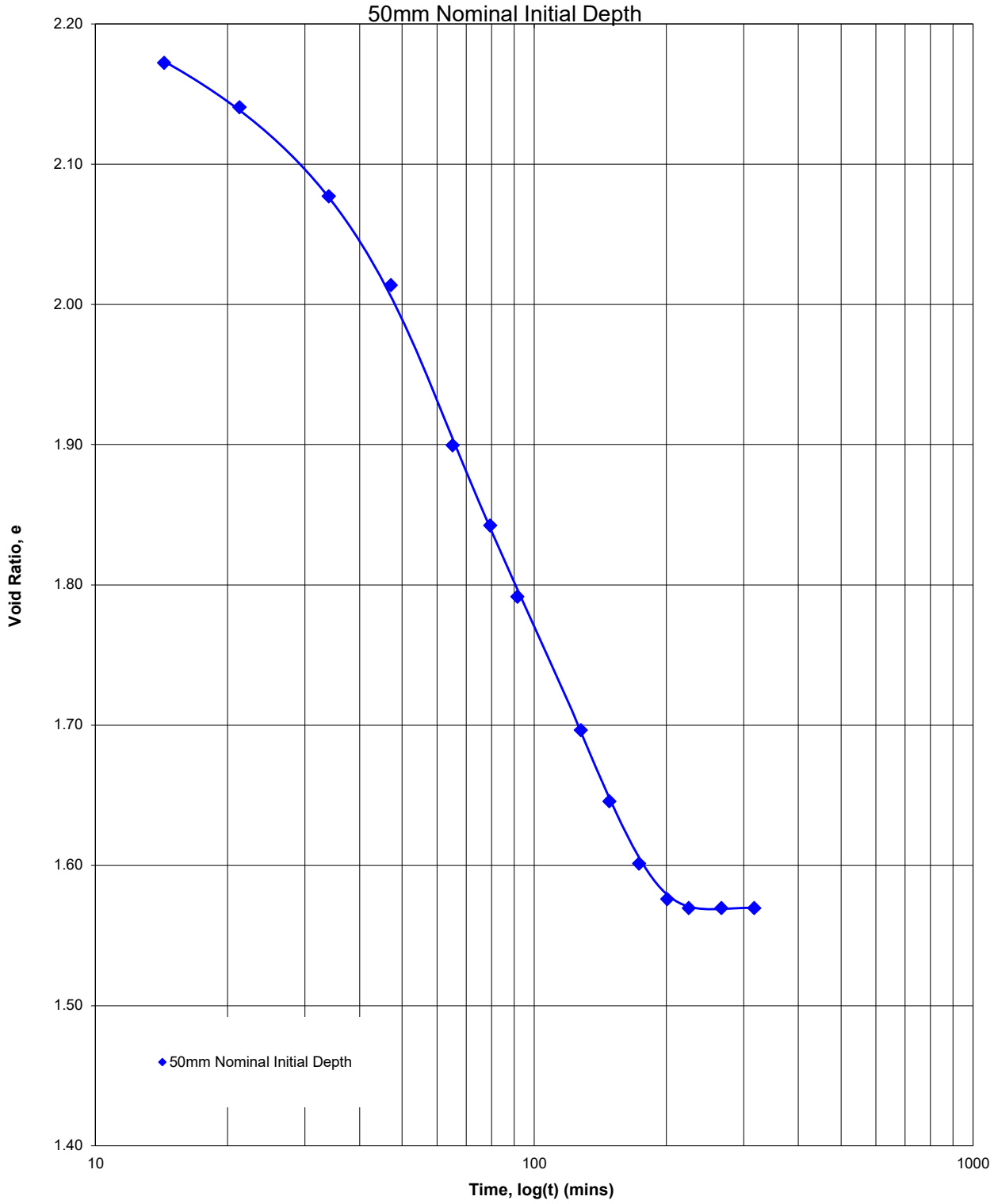
Date:	19/03/2025	**Job No:**	250542	**FIGURE 1**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/PSD Sieve and Hydrometer Figure (S+H)



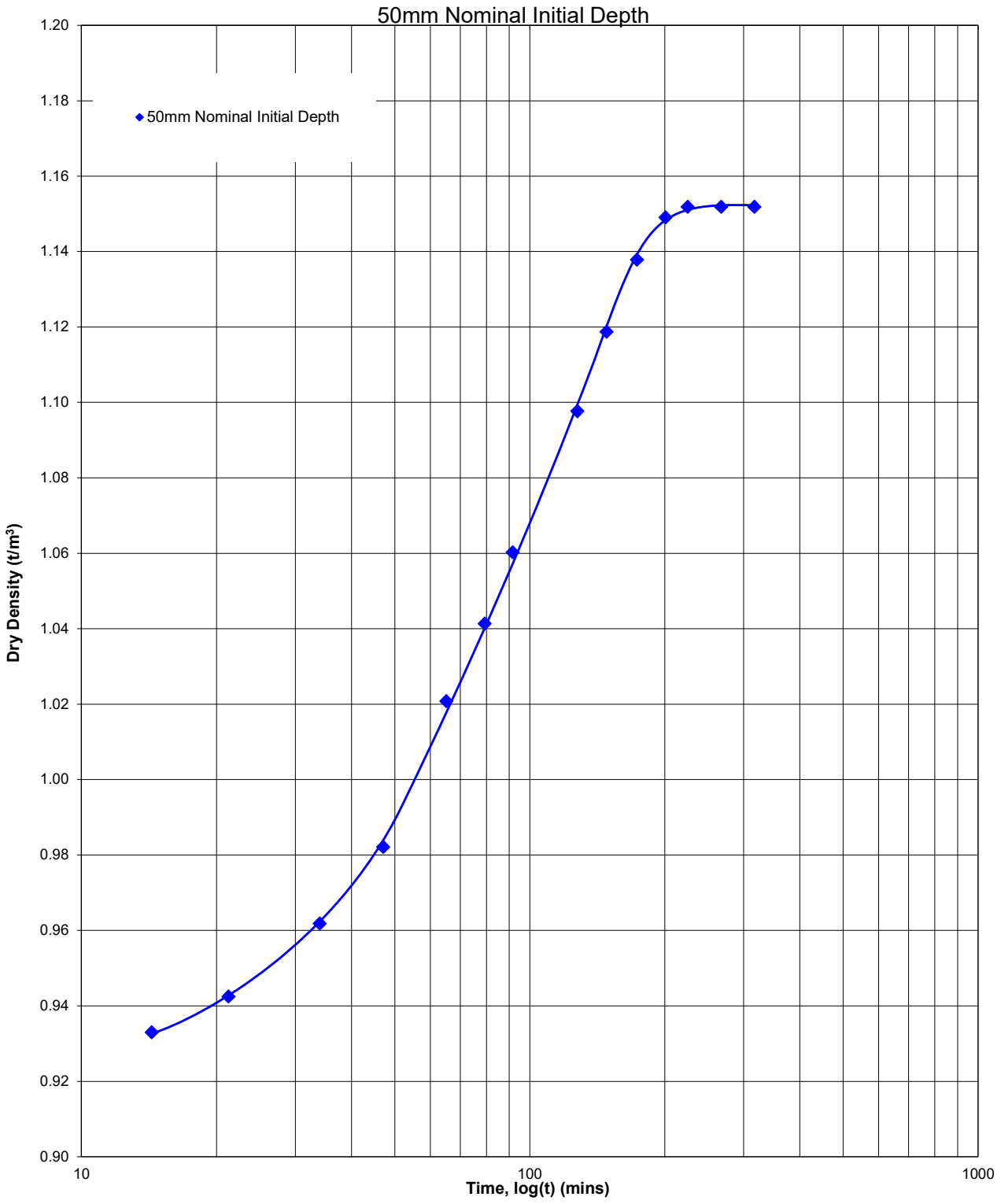
Dugald River TSF Raise Design **MMG Limited** **Flocculated Tailings (Magnaflocc 338, 23g/t)**	**Undrained Settled Density** **Settlement vs Time** **Sample No. 15325**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 31/03/2025 **FIGURE 2**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 -ISD with density and solids concentration (Including Salt Correction) ATC



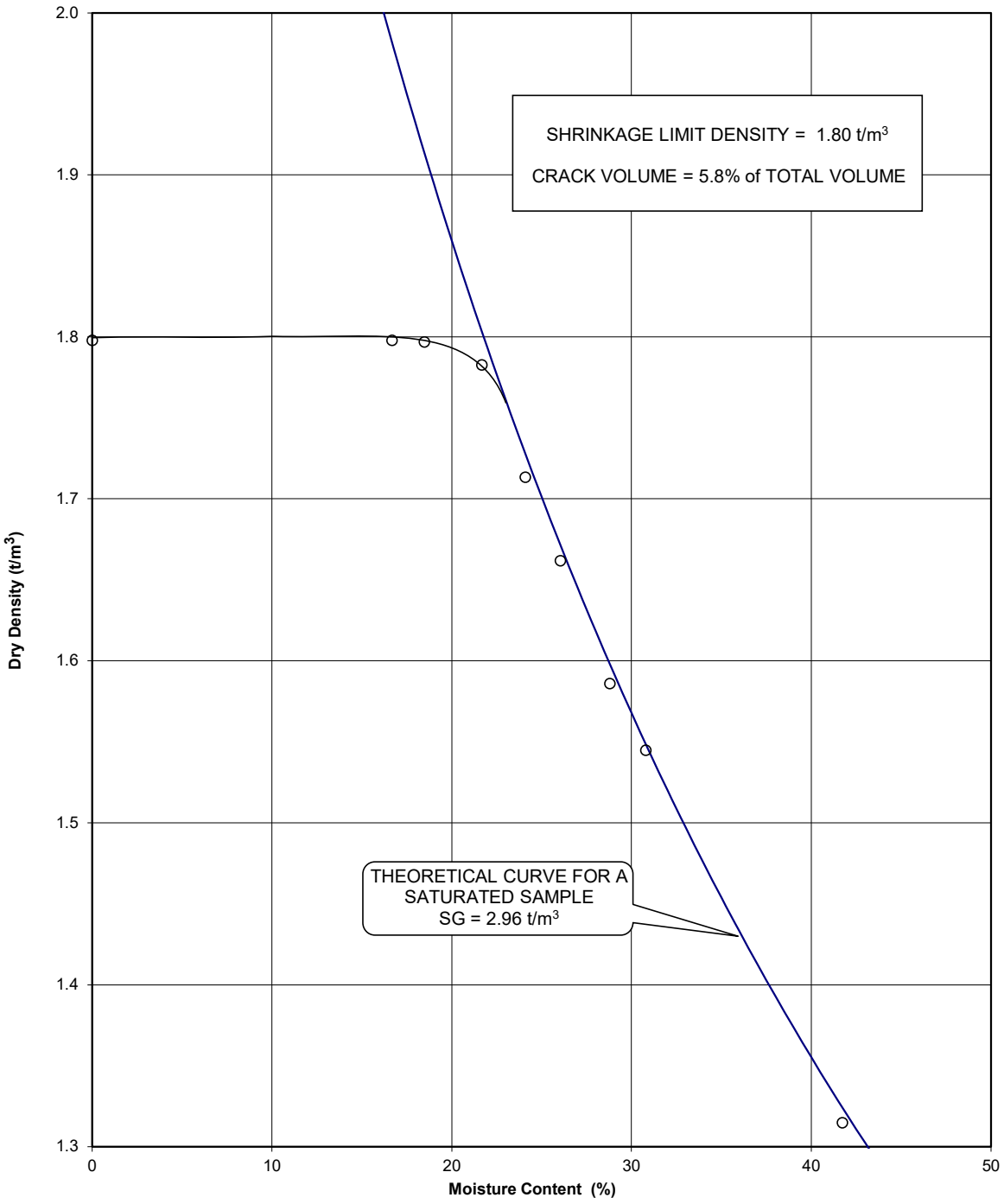
Dugald River TSF Raise Design **MMG Limited** **Flocculated Tailings (Magnaflocc 338, 23g/t)**	**Undrained Settled Density** **Void Ratio vs Time** **Sample No. 15325**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 31/03/2025 **FIGURE 3**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 -ISD with density and solids concentration (Including Salt Correction) ATC



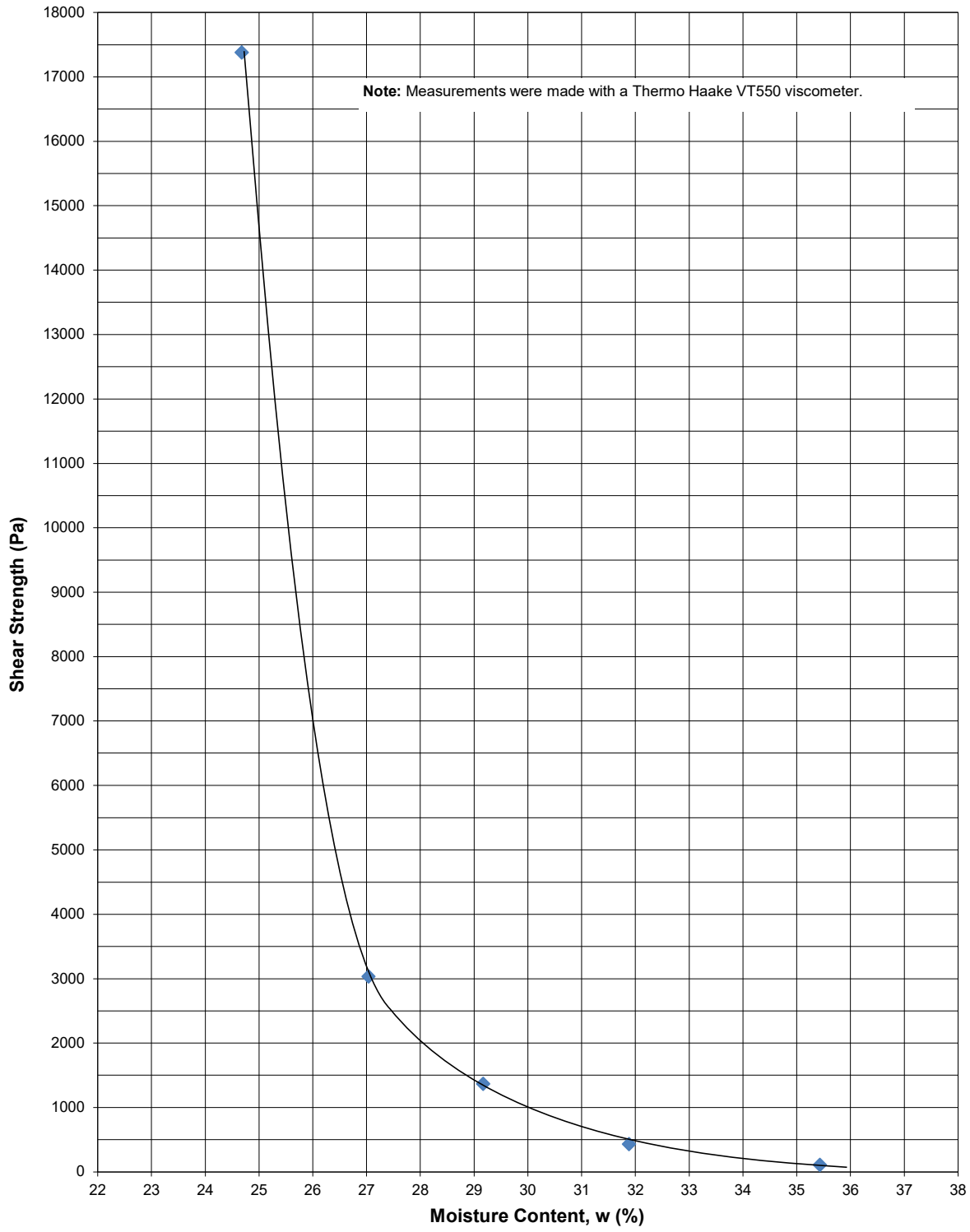
Dugald River TSF Raise Design **MMG Limited** **Flocculated Tailings (Magnaflocc 338, 23g/t)**	**Undrained Settled Density** **Dry Density vs Time** **Sample No. 15325**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 31/03/2025 **FIGURE 4**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 -ISD with density and solids concentration (Including Salt Correction) ATC



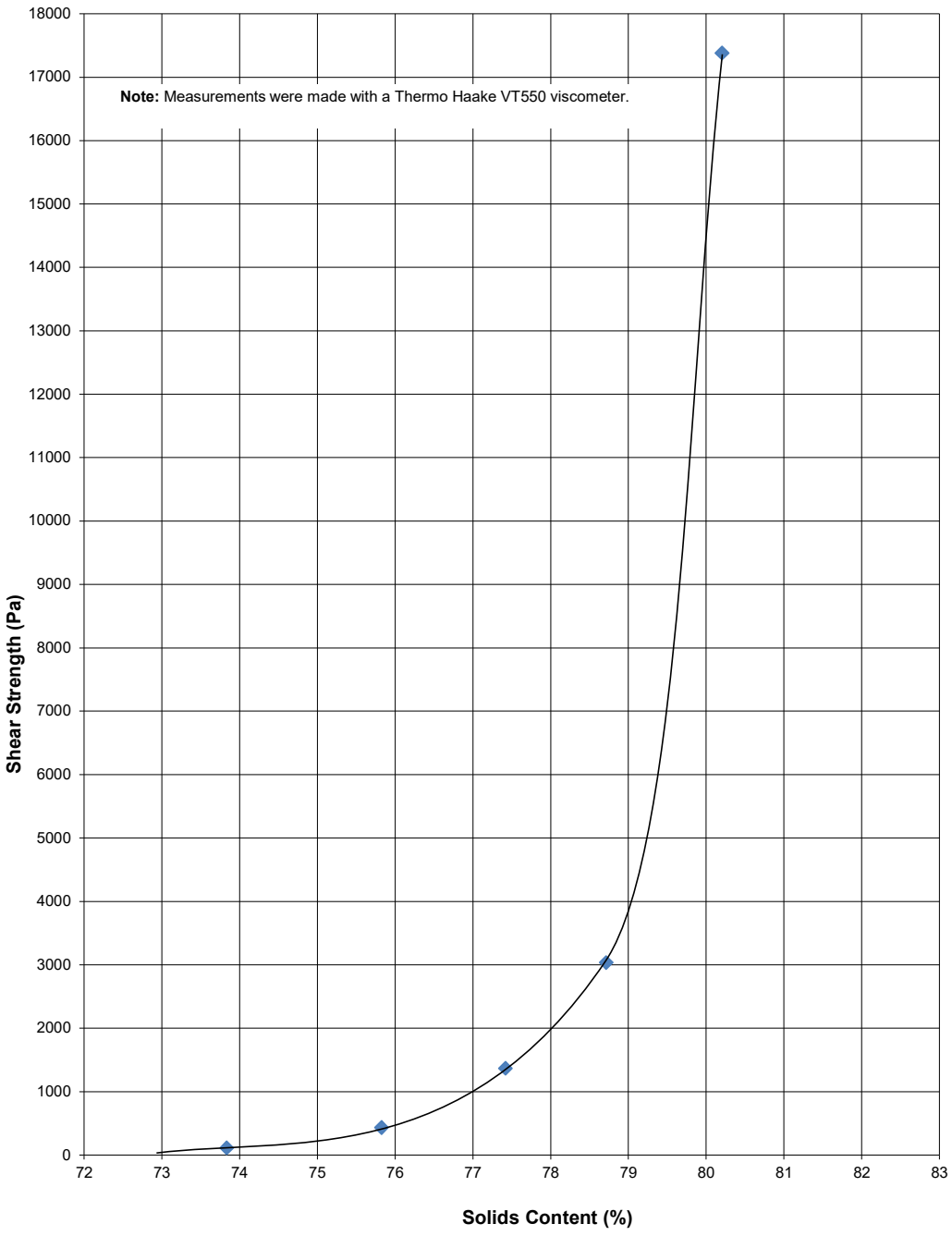
Dugald River TSF Raise Design **MMG Limited** **Unflocculated Tailings Slurry**	**Shrinkage Limit Density** **Sample No: 14325**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 27/03/2025 **FIGURE 5**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/14325 -Shrikage Limit Density



Dugald River TSF Raise Design **MMG Limited** **Unflocculated Tailings Sample**	**Evaporative Strength Gain** **Strength vs Moisture Content** **(Sample No. 14325)**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 31/03/2025 **FIGURE 6**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/14325 -Moisture Content Vs Shear Vane ATC Report Moisture



Dugald River TSF Raise Design **MMG Limited** **Unflocculated Tailings Sample**	**Evaporative Strength Gain** **Strength vs Solids Content** **(Sample No. 14325)**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 31/03/2025 **FIGURE 7**

:w1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data 14325 -Moisture Content Vs Shear Vane ATC Report Solids

SOIL MOISTURE CHARACTERISTIC CURVE - DRYING

TEST IN ACCORDANCE WITH IHM 17.0, IN DEVELOPMENT

☑ **Oven Drying Method 2.1.1**

Client:	MMG Limited	**Report No.:**	**R032725**
Address:	Dugald River Mine Cloncurry QLD 4824	**Job No.:**	250542
		Register No.:	14325
Project:	Dugald River TSF Raise Design	**Location:**	QLD

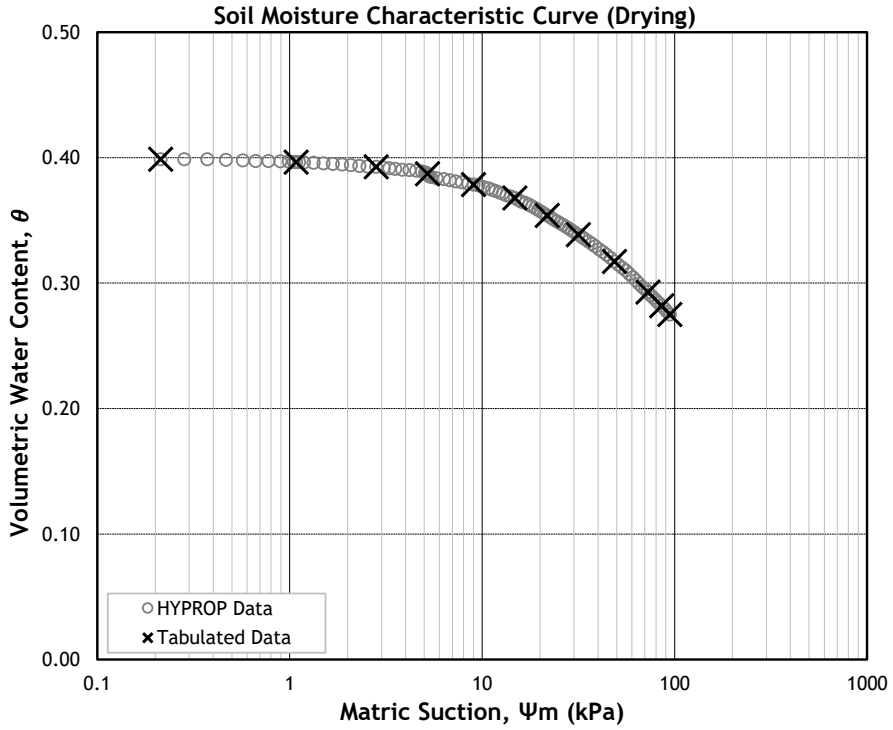
Sample Description: Tailings	Borehole No:	Test Pit Depth:

Test and Apparatus Information:

Start of Measurements:	17/04/2025 16:15
End of Measurements:	26/04/2025 15:29
HYPROP Unit Serial Number:	2043
HYPROP Balance Serial Number:	184226064
WP4C:	Not Used

Sample Properties:

Preparation Method:	Moist Tamped	
Specific Gravity, ρ_{st}:	2.96	t/m^3
Moisture Content after Saturation, w:	22.0	%
Initial Dry Density, ρ_d:	1.78	t/m^3
Initial Void Ratio, e:	0.66	
Porosity, n:	0.40	
Initial Volumetric Water Content, θ_i:	39.9	
Degree of Saturation, S:	98	%
Volume Change Correction Applied:	Not Applicable	



(kPa) Matric Suction (Ψm)	(-) Vol. Water Content (θ)
0.2	0.399
1.1	0.397
2.8	0.393
5.2	0.387
9.0	0.379
14.8	0.368
21.8	0.354
31.6	0.339
48.6	0.317
72.6	0.293
85.7	0.282
94.4	0.275

This document is issued in accordance with the laboratory quality system requirements of ATC Williams Pty Ltd.

Approved Signatory: _____ Date Tested:17/04-26/04/2025

Name of Signatory: Luke Renkin Date Reported:29/04/2025

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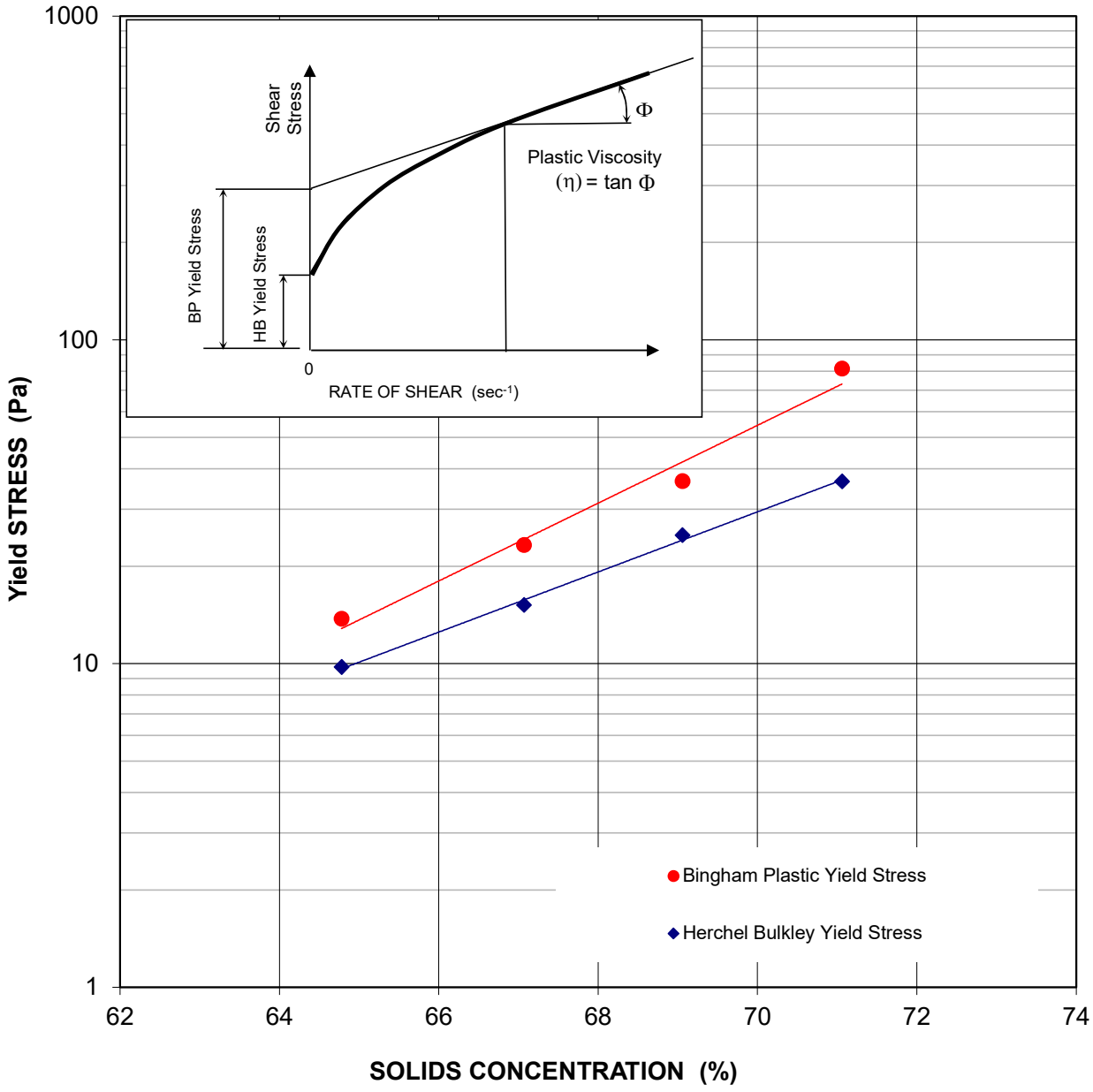
melbourne@atcwilliams.com.au www.atcwilliams.com.au ABN 64 005 931 288

FIGURE 8

Date of Issue: Nov 2024

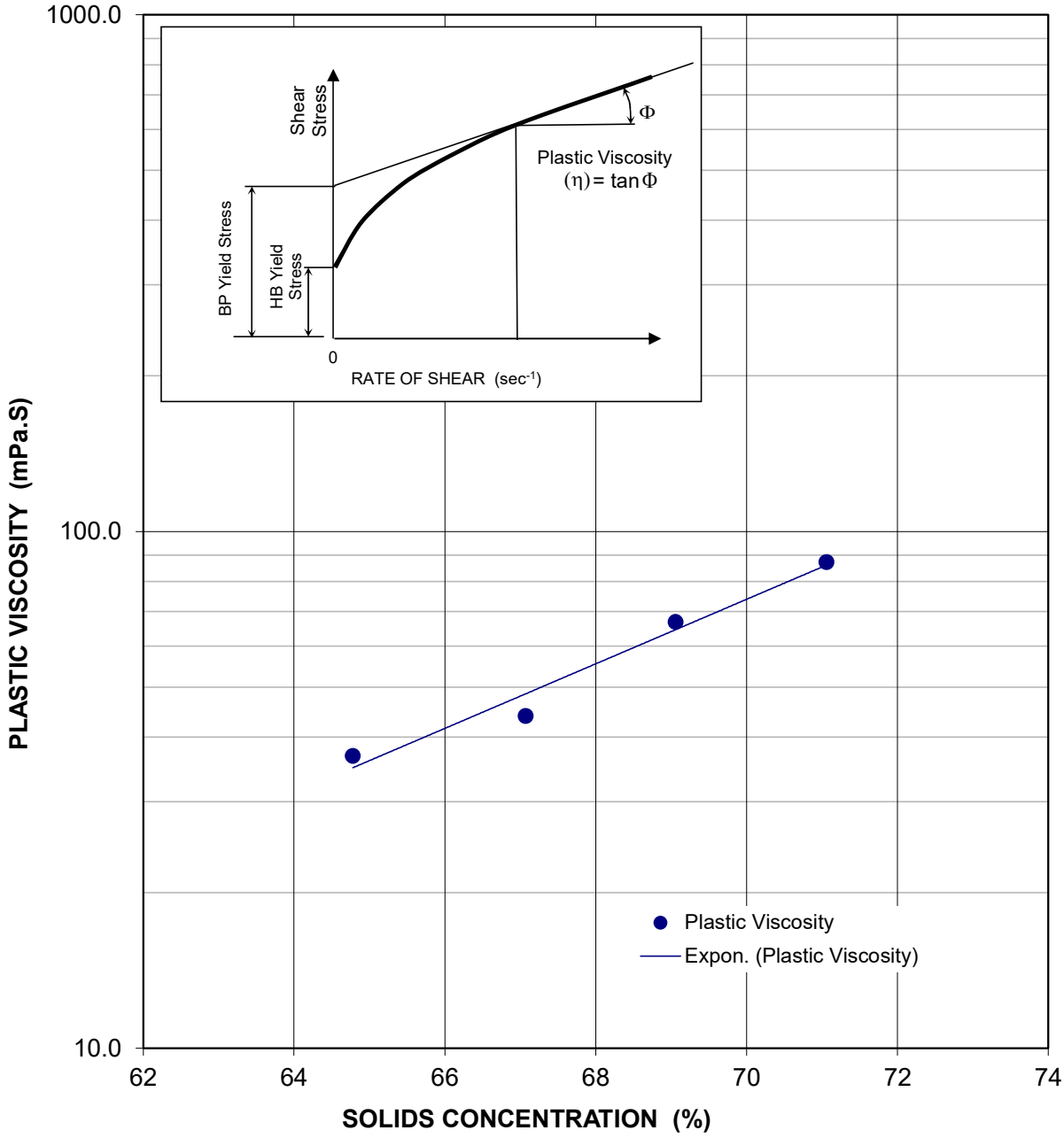
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Yield Stress Versus** **Solids Concentration**
ATC WILLIAMS ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 9**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/Rheology - 14325/14325 - Rheology Report

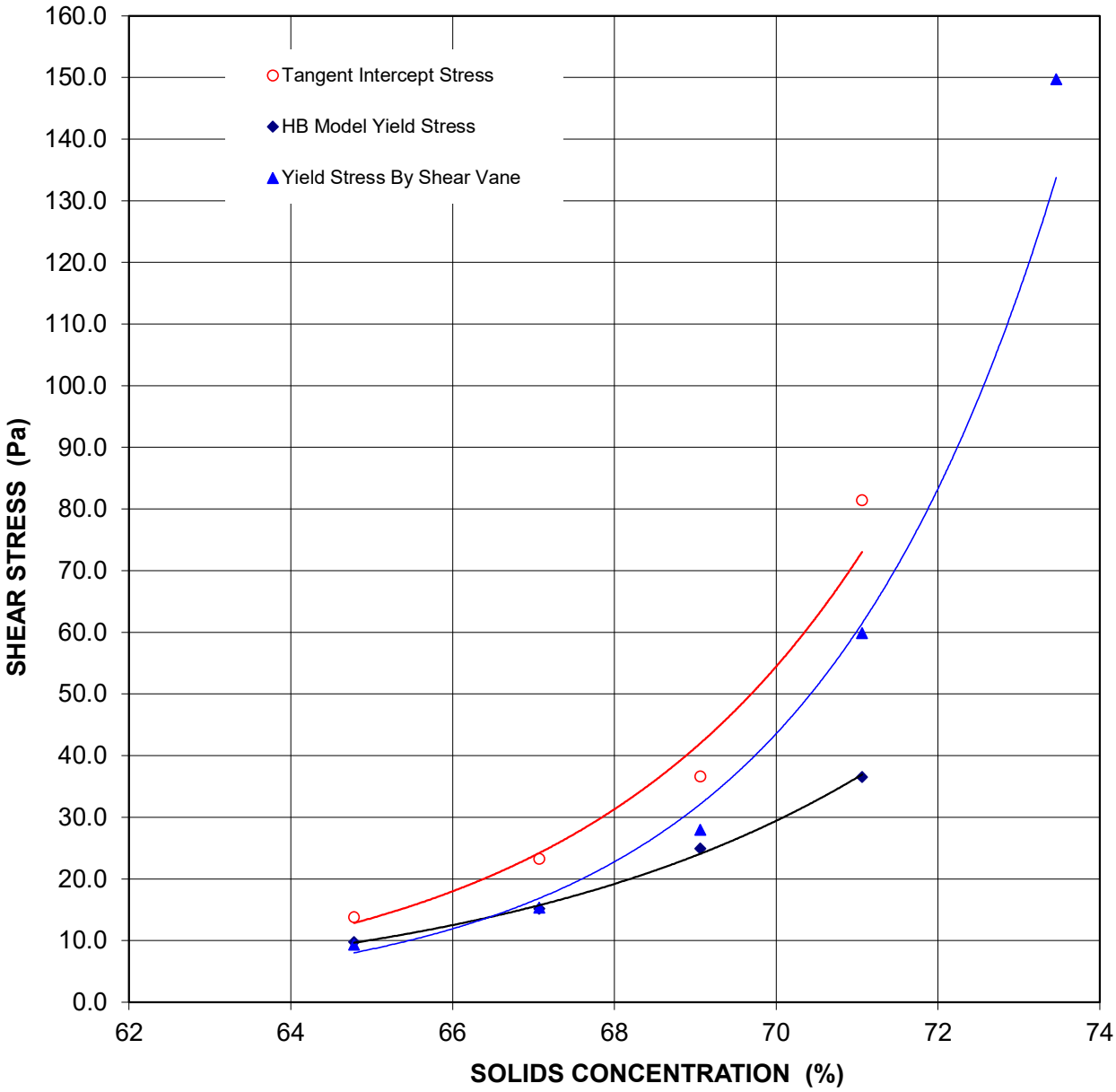
250542 - Dugald River TSF Raise Design
Sample No. 14325
PLASTIC VISCOSITY



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Plastic Viscosity Versus Solids Concentration**
ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 10**

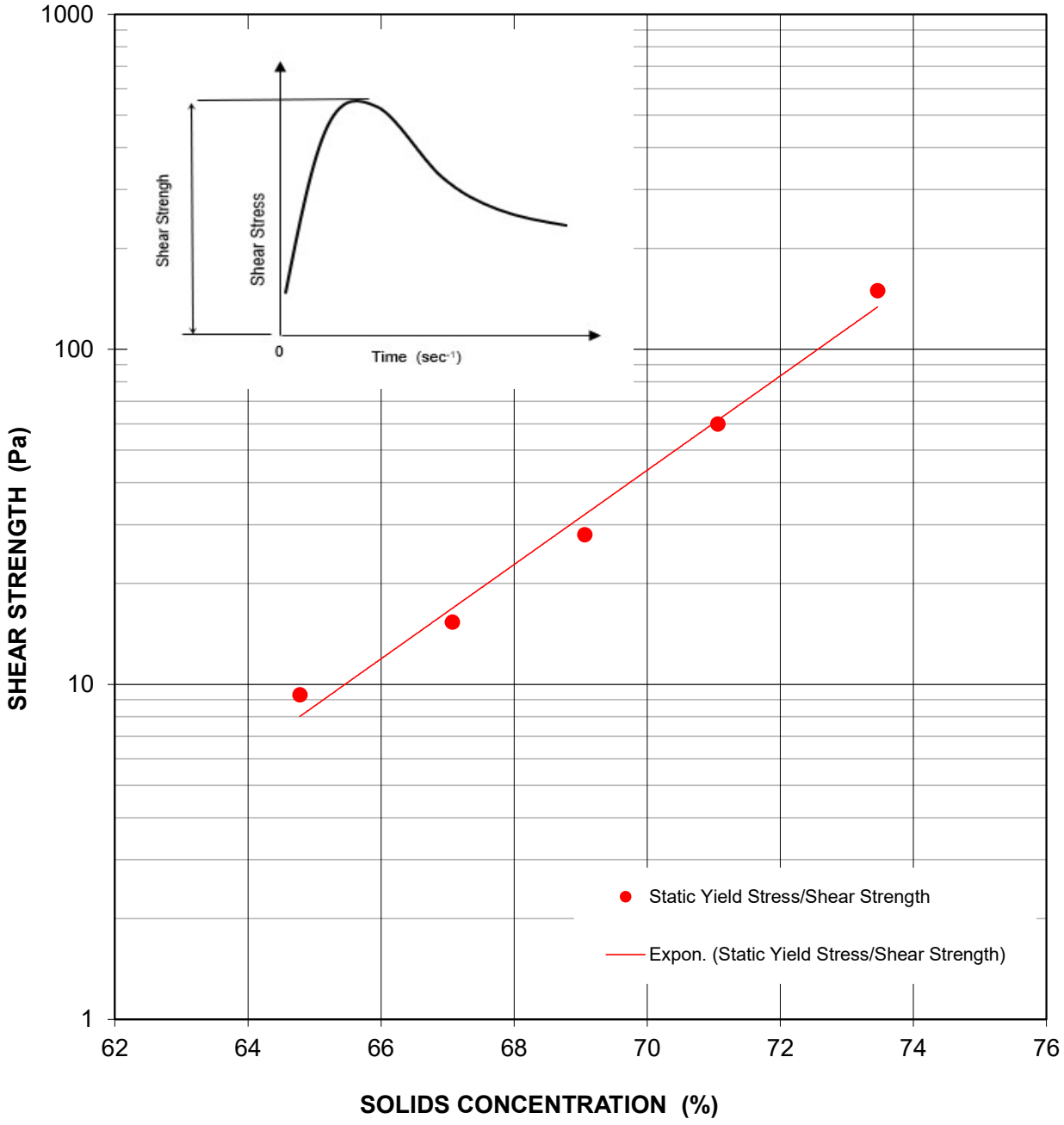
https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/Rheology - 14325/14325 - Rheology Report

250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Yield Stress Versus** **Solids Concentration**
ATC WILLIAMS ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 11**

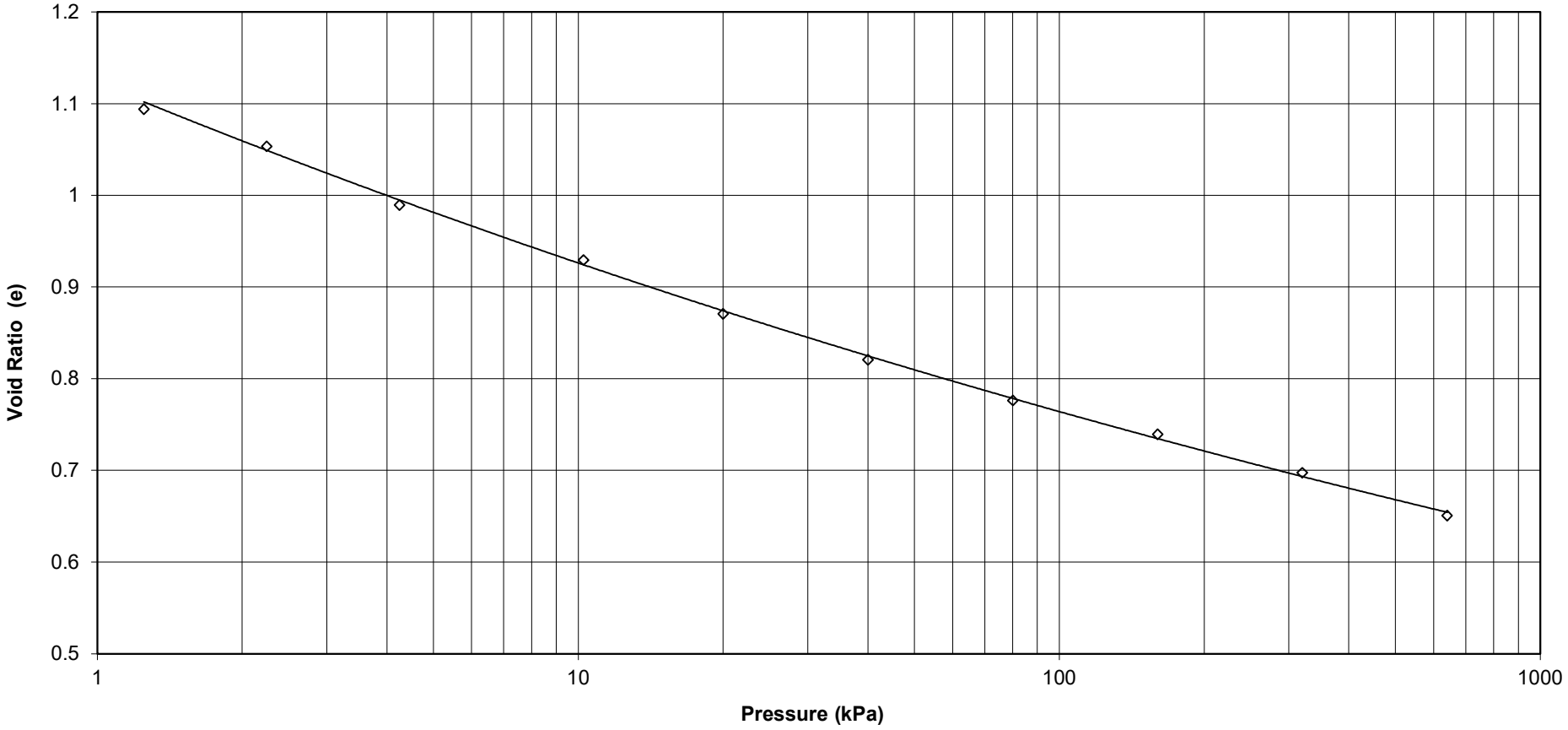
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRENGH



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Static Yield Stress Versus** **Solids Concentration**
ATC WILLIAMS ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 12**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/Rheology - 14325/14325 - Rheology Report

Void Ratio vs. Effective Pressure (e / log P)



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MMG Limited

Dugald River TSF Raise Design

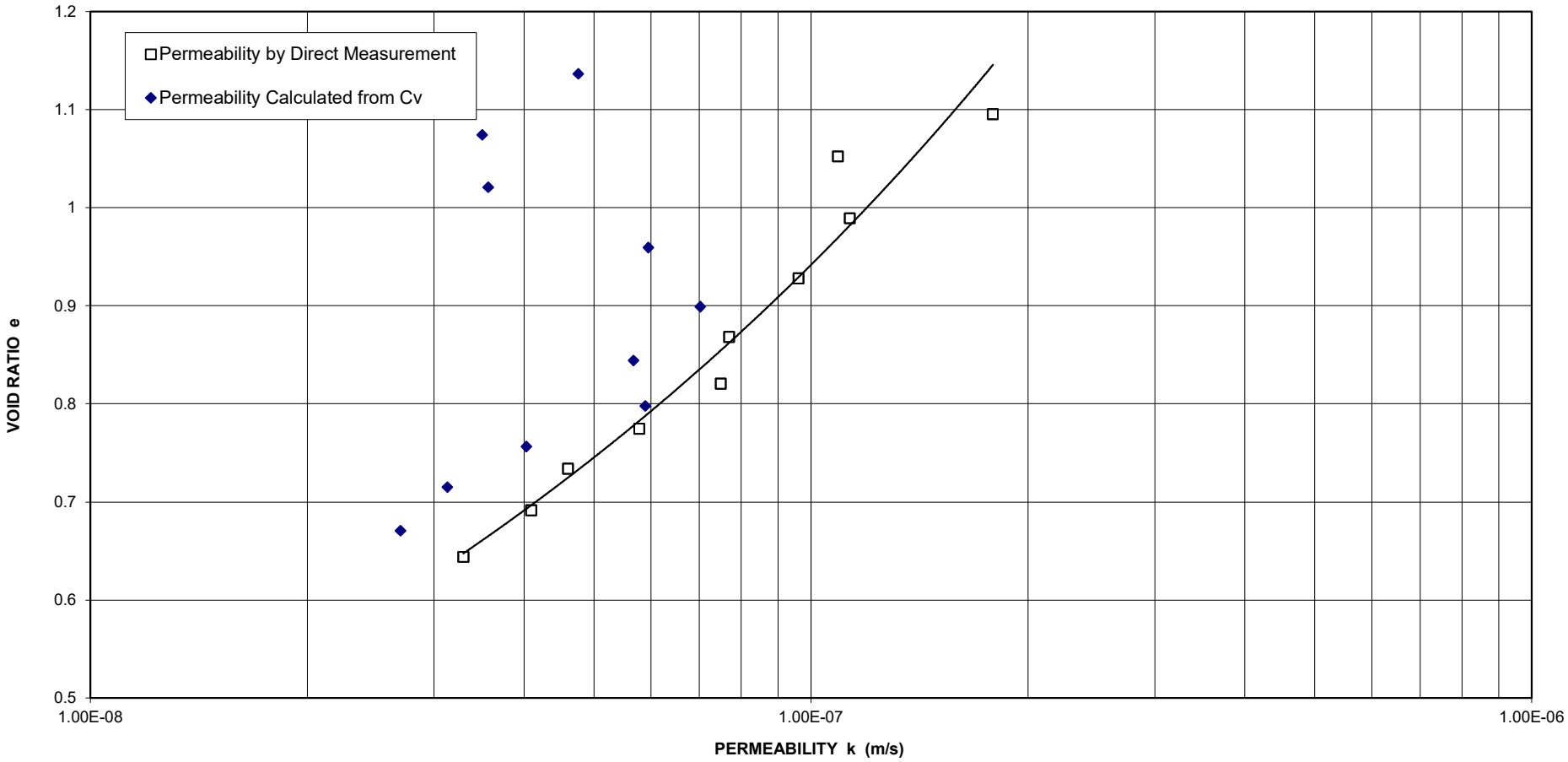
Flocculated Tailings Sample, No:15325

Rowe Cell Consolidation - Void Ratio Versus Log of Pressure

Date:	23/04/2024	**Job No:**	250542	**FIGURE 13**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 Rowe Cell/15325 Rowe Cell Report Checked e logP Report

Void Ratio vs. Permeability (e / log k)



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MMG Limited

Dugald River TSF Raise Design

Flocculated Tailings Sample, No:15325

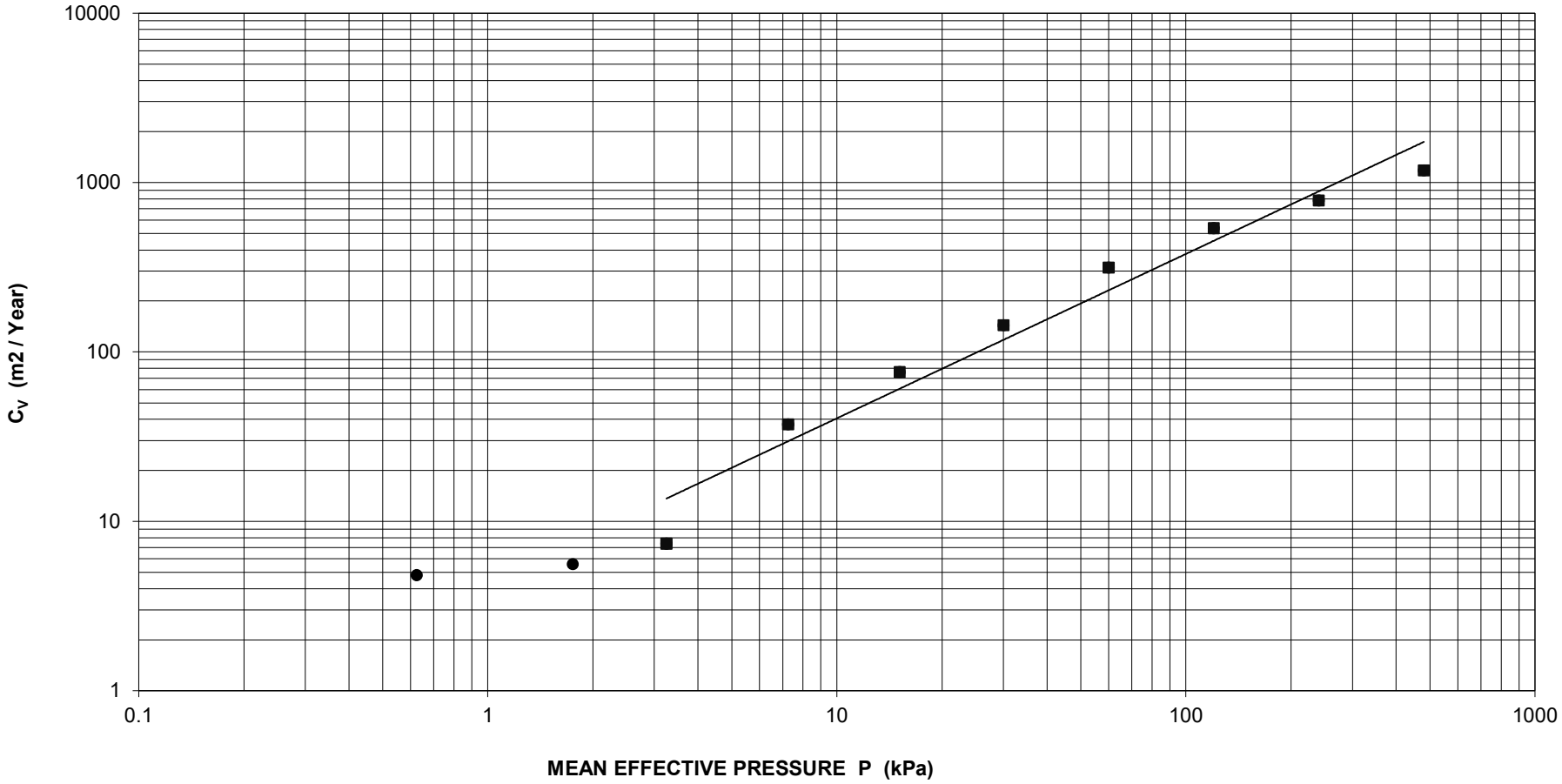
Rowe Cell Consolidation - Void Ratio Versus Log of Permeability

Date: 23/04/2024 **Job No:** 250542

FIGURE 14

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 Rowe Cell/15325 Rowe Cell Report Checked e logk Report

Coefficient of Consolidation vs. Mean Effective Pressure (log Cv / log P)



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MMG Limited

Dugald River TSF Raise Design

Flocculated Tailings Sample, No:15325

Rowe Cell Consolidation Test

Date:	45405	**Job No:**	250542	**FIGURE 15**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 Rowe Cell/15325 Rowe Cell Report Checked Log Cv logP Report

APPENDICES

APPENDIX A – LABORATORY TEST CERTIFICATES

Classification (Atterberg Limits)

TEST IN ACCORDANCE WITH AS 1289 – CONE PENETROMETER

Client: MMG Limited **Laboratory Report No.:R023925**

Address: MMG Dugald River Mine Site **Job No.:** 250542

Cloncurry QLD 4824

Project: Dugald River TSF Raise Design **Location:** QLD

Register Number	Sample Description	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Group Classification Symbol
14325	Tailings	28	16	12	3.2	-

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1, Clause

☒ Sample provided by the client

The test results relate only to the items tested.

Test Methods:

☐	Liquid Limit	AS 1289.3.9.1 (Standard - Penetrometer Method)
☒	Liquid Limit	AS 1289.3.9.2 (One Point – Penetrometer Method)
☒	Plastic Limit	AS 1289.3.2.1
☒	Plasticity Index	AS 1289.3.3.2 (Cone Plasticity Index)
☐	Linear Shrinkage	AS 1289.3.4.1
☒	Moisture Content	AS 1289.2.1.1

Sample Preparation:

☐	Natural Moisture	☒	Air Dried	☐	Oven Dried	☐	Unknown
☐	Wet Sieved	☒	Dry Sieved	☐	Unsieved		

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 13-15/03/2025

Name of Signatory: Luke Renkin Date Reported: 19/03/2025

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Form RSN 002.9 (Atterbergs-Soils)
Date of Issue: June 2024

Minimum and Maximum Dry Density of a Cohesionless Material

TEST IN ACCORDANCE WITH AS 1289.5.5.1

Client: MMG Limited ..... **NATA Report No.: R026525** .....

Address: MMG Dugald River Mine Site ..... **Job No.:** 250542 .....

Cloncurry QLD 4824 .....

Project: Dugald River TSF Raise Design ..... **Location:** QLD .....

Register Number	Sample Description	Type of Material Size of Mould	Minimum Dry Density ρd min (t/m^3)	Maximum Dry Density ρd max (t/m^3)
14325	As Received Tailings	1 Litre	1.05	1.88

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

* Modification of the standard test method: Due to the high fines content of this sample, a Standard Compaction Hammer was required to achieve maximum dry density.

The test results relate only to the items tested.

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 26 to 27/03/2025 .....

Name of Signatory Sampath De Silva …… Date Reported: 27/03/2025

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Form RSN 015.3
Date of Issue: June 2024

Determination of the Soil Particle Density of a Soil

TEST IN ACCORDANCE WITH AS 1289.3.5.1

Client: MMG Limited ..... **NATA Report No.: R024025** .....

Address: MMG Dugald River Mine Site ..... **Job No.:** 250542 .....

Cloncurry QLD 4824 .....

Project: Dugald River TSF Raise Design ..... **Location:** QLD .....

Register Number	Sample Description	Test Temperature (°C)	% of Sample >2.36 mm	Particle Density (g/cm^3)
14325	Tailings	23.1	None	2.96 #

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

* = apparent average soil particle density – particle size less than 2.36 mm

X = apparent average soil particle density – particle size greater than 2.36 mm

= soil particle density of the total sample

The test results relate only to the items tested.

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested:

Name of Signatory: Luke Renkin Date Reported: 19/03/2025

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Form RSN 003.7
Date of Issue: June 2024

Segregation Threshold of Tailings

TEST IN ACCORDANCE WITH - IN HOUSE PROCEDURE IHM 5.0

Client: MMG Limited ..... **NATA Report No.: R025425** .....

Address: MMG Dugald River Mine Site ..... **Job No.:** 250542 .....

Cloncurry QLD 4824 .....

Project: Dugald River TSF Raise Design ..... **Location:** QLD .....

Sample Register Number	Sample Description	Condition	Segregation Threshold Solids Concentration (%)
15325	Flocculated Tailings Slurry	As Received	40 (Static Condition)

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1.

☒ Sample provided by the client

The test results relate only to the items tested.

Note:
Segregation Threshold is carried out in accordance with ATC Williams In House Test Procedure IHM 5.0 and relates to the minimum solids concentration at which coarse particles do not settle out of the slurry in a static condition. However, shear induced segregation may occur in a slurry at solids concentrations above the static threshold point.

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Signatory ..... Date Tested: 20 to 24/03/2025.....

Name of Signatory Sampath De Silva Date Reported: 24/03/2025

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Determination of Conductivity
Soil chemical test

TEST IN ACCORDANCE WITH IN-HOUSE TEST METHOD IHM 11.0

Client: MMG Limited **Laboratory Report No.:R024225**

Address: MMG Dugald River Mine Site **Job No.:** 250542

Cloncurry QLD 4824

Project: Dugald River TSF Raise Design **Location:** QLD

Register Number	Sample Description	Soil – Suspension / Groundwater	Electrical Conductivity (µS/cm)
14425	Tailings Decant	Decant	5860

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

The test specimen was prepared from decant water removed from the tailings slurry sample.

The test results relate only to the items tested.

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 12/03/2025

Name of Signatory *Luke Renkin* Date Reported: 19/03/2025

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Form RSN 018.2
Date of Issue: June 2024

Determination of the pH value
Soil chemical test

TEST IN ACCORDANCE WITH AS 1289.4.3.1 ELECTROMETRIC METHOD

Client: MMG Limited **Laboratory Report No.:R024325**

Address: MMG Dugald River Mine Site **Job No.:** 250542

Cloncurry QLD 4824

Project: Dugald River TSF Raise Design **Location:** QLD

Register Number	Sample Description	Soil – Suspension / Groundwater	pH
14425	Tailings Decant	Decant	6.8

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

The test specimen was prepared from decant water removed from the tailings slurry sample.

The test results relate only to the items tested.

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 12/3/2025

Name of Signatory Luke Renkin Date Reported: 19/03/2025

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Form RSN 017.2
Date of Issue: June 2024

Particle Size Distribution Results

TEST IN ACCORDANCE WITH AS 1289

☑ Method 3.6.1 ☑ Method 3.6.3

☑ Oven Drying Method 2.1.1

ATC WILLIAMS

Client:	MMG Limited	**NATA Report No.:**	**R024125**
Address:	MMG Dugald River Mine Site Cloncurry QLD 4824	**Job No.:**	250542
		Register No.:	14325
Project:	Duglad River TSF Raise Design	**Location:**	QLD

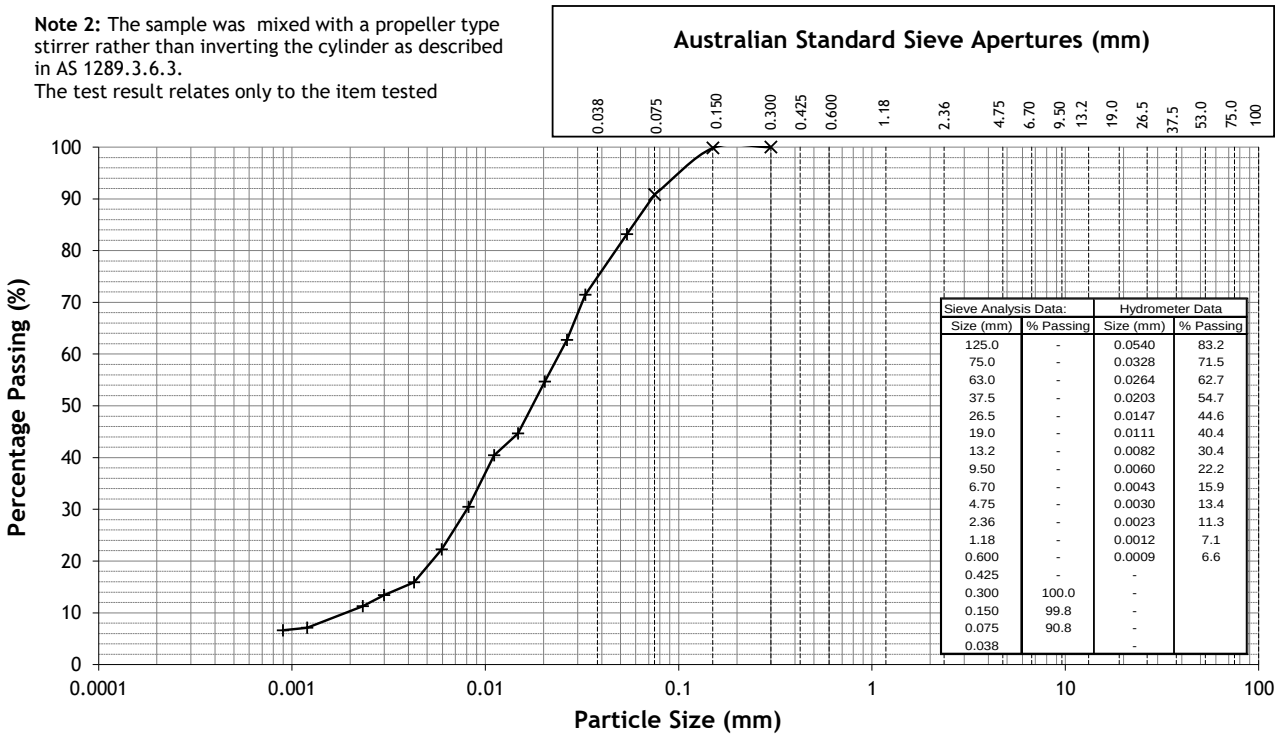
Sample Description: Tailings	Borehole No: ☐	Test Pit Depth: ☐

Dispersion Method used: Mechanical Stirrer for 1 minute **Hydrometer Type Used:** ASTM 152H

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1 Clause 6.5.4 ☑ Sample provided by the Client

Note 1: The sample was oven-dried during sample preparation and not air-dried as stated in AS 1289.3.6.3

Note 2: The sample was mixed with a propeller type stirrer rather than inverting the cylinder as described in AS 1289.3.6.3.
The test result relates only to the item tested



Sieve Analysis Data:		Hydrometer Data	
Size (mm)	% Passing	Size (mm)	% Passing
125.0	-	0.0540	83.2
75.0	-	0.0328	71.5
63.0	-	0.0264	62.7
37.5	-	0.0203	54.7
26.5	-	0.0147	44.6
19.0	-	0.0111	40.4
13.2	-	0.0082	30.4
9.50	-	0.0060	22.2
6.70	-	0.0043	15.9
4.75	-	0.0030	13.4
2.36	-	0.0023	11.3
1.18	-	0.0012	7.1
0.600	-	0.0009	6.6
0.425	-	-	
0.300	100.0	-	
0.150	99.8	-	
0.075	90.8	-	
0.038		-	

CLAY	SILT			SAND			GRAVEL			COBBLES
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
	0.002	0.006	0.02	0.06	0.2	0.6	2	6	20	60

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: _____ Date Tested:17-19/03/2025

Name of Signatory: Luke Renkin Date Reported:19/03/2025

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Total Dissolved Solids and Fluid Density

Analysis of Water

TEST IN ACCORDANCE WITH IN-HOUSE TEST METHOD IHM4.0

Client: MMG Limited **Laboratory Report No.:R024425**

Address: MMG Dugald River Mine Site **Job No.:** 250542

Cloncurry QLD 4824

Project: Dugald River TSF Raise Design **Location:** QLD

Sample Register Number	Sample Description	Soil-suspension / Groundwater	Salt Content (g/g Water)
14425	Tailings Decant	Decant	0.005306

Sample Register Number	Sample Description	Soil-suspension / Groundwater	Density of Liquor (g/mL)
14425	Tailings Decant	Decant	0.9987

Sample Register Number	Sample Description	Soil-suspension / Groundwater	Total Dissolved Solids (mg/L)
14425	Tailings Decant	Decant	5272

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1.

☒ Sample provided by the client

The test results relate only to the items tested.

The test sample was prepared from a sub-sample of decant water recovered from a sample of tailings slurry.

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Signatory ..... Date Tested: 12/03/2025

Name of Signatory Luke Renkin Date Reported: 19/03/2025

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Solids Concentration of Tailings

TEST IN ACCORDANCE WITH AS 1289.2.1.1 (with modification)

Client: MMG Limited ..... **Laboratory Report No.:R023825** ....

Address: MMG Dugald River Mine Site..... **Job No.:** 250542.....

Cloncurry QLD 4824 .....

Project: Dugald River TSF Raise Design ..... **Location:** QLD.....

Sample Register Number	Sample Description	Condition	Solids Concentration (%)
14325	Tailings	Slurry- As Received	57.1

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1.

☒ Sample provided by the client

The test results relate only to the items tested.

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Signatory ..... Date19/03/2025.....

Name of Signatory Luke Renkin.....

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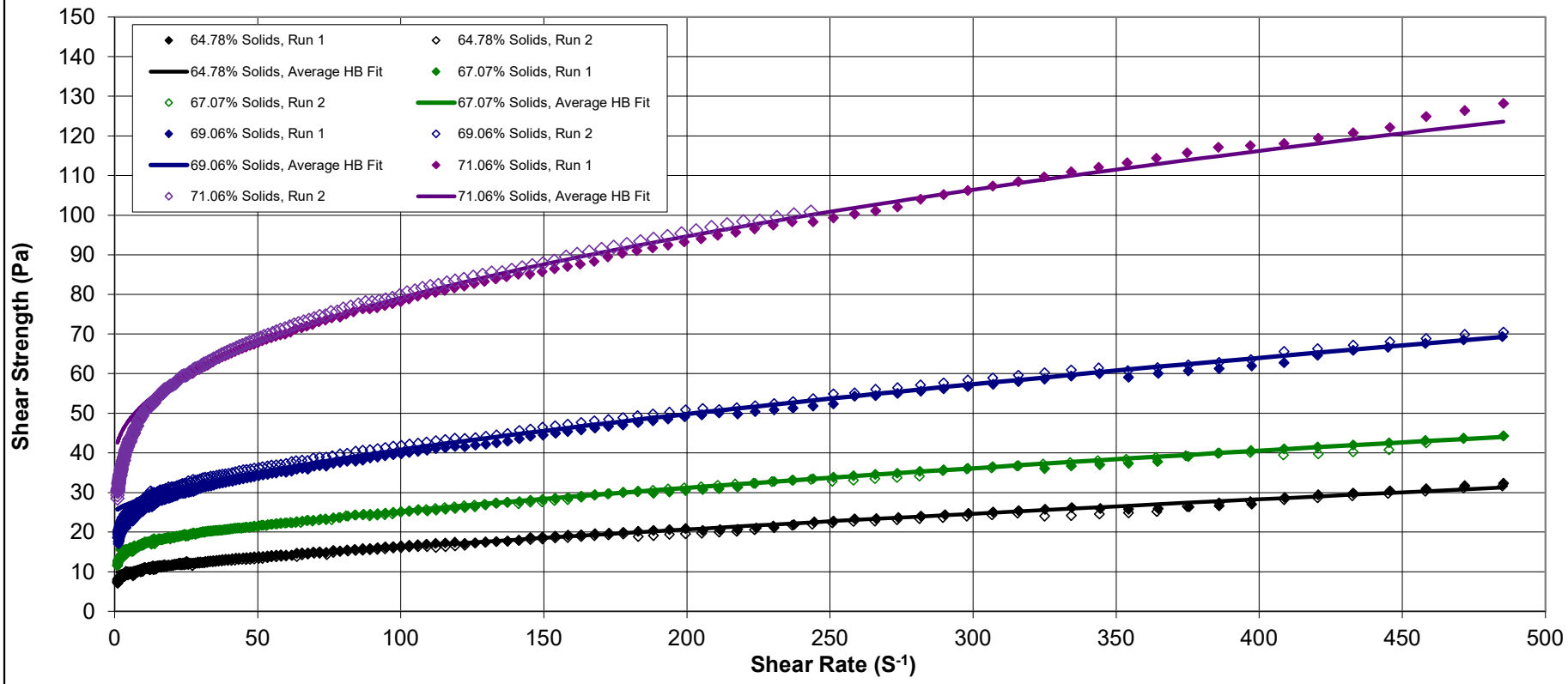
APPENDIX B – RHEOLOGY – SHEAR STRENGTH VS SHEAR RATE

250542 - Dugald River TSF Raise Design
Sample No. 14325
ALL FLOW CURVE RESULTS



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MMG Limited

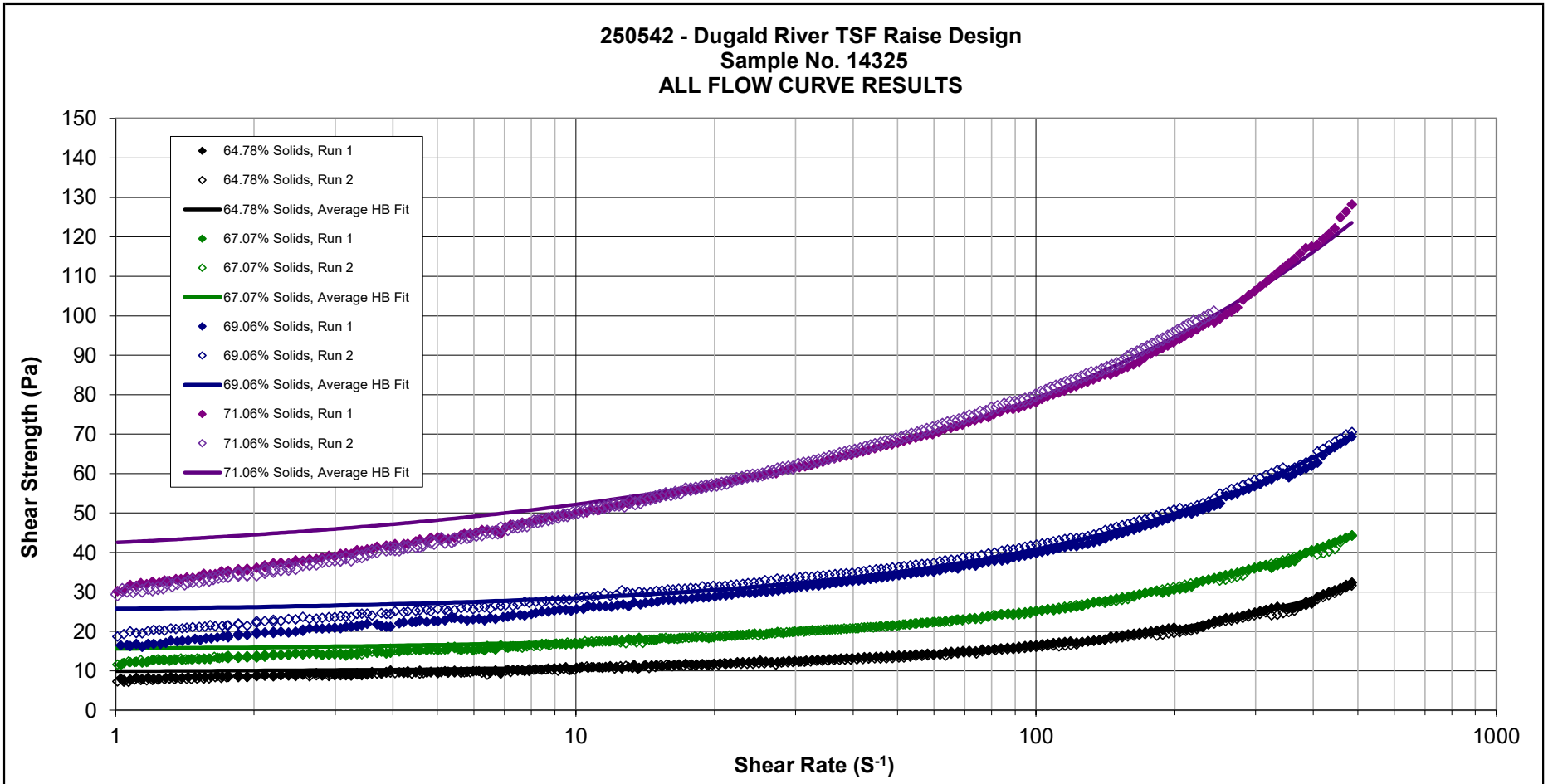
Dugald River TSF Raise Design

Tailings Sample No. 1 - Unflocculated

Rheology Testing

Date: 19/03/2025 **Job No:** 250542

Appendix B1



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MMG Limited

Dugald River TSF Raise Design

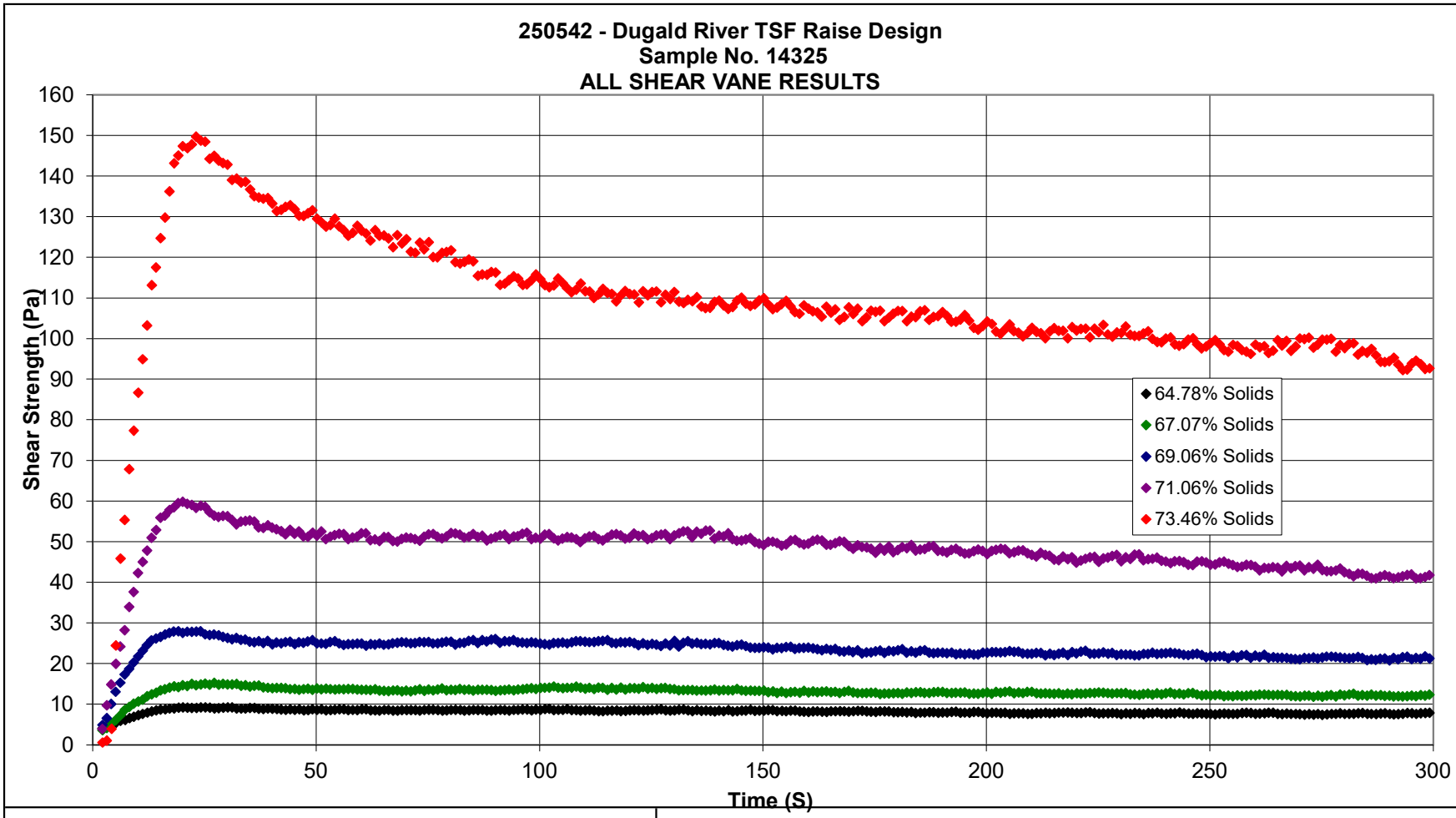
Tailings Sample No. 1 - Unflocculated

Rheology Testing

Date: 19/03/2025 **Job No:** 250542

Appendix B2

APPENDIX C – RHEOLOGY – SHEAR STRENGTH VS TIME



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MMG Limited

Dugald River TSF Raise Design

Tailings Sample No. 1 - Unflocculated

Rheology Testing

Date: 19/03/2025 **Job No:** 250542

Appendix C1

APPENDIX B – DAM BREAK AND CONSEQUENCE CATEGORY ASSESSMENT

TAILINGS.WATER.WASTE.

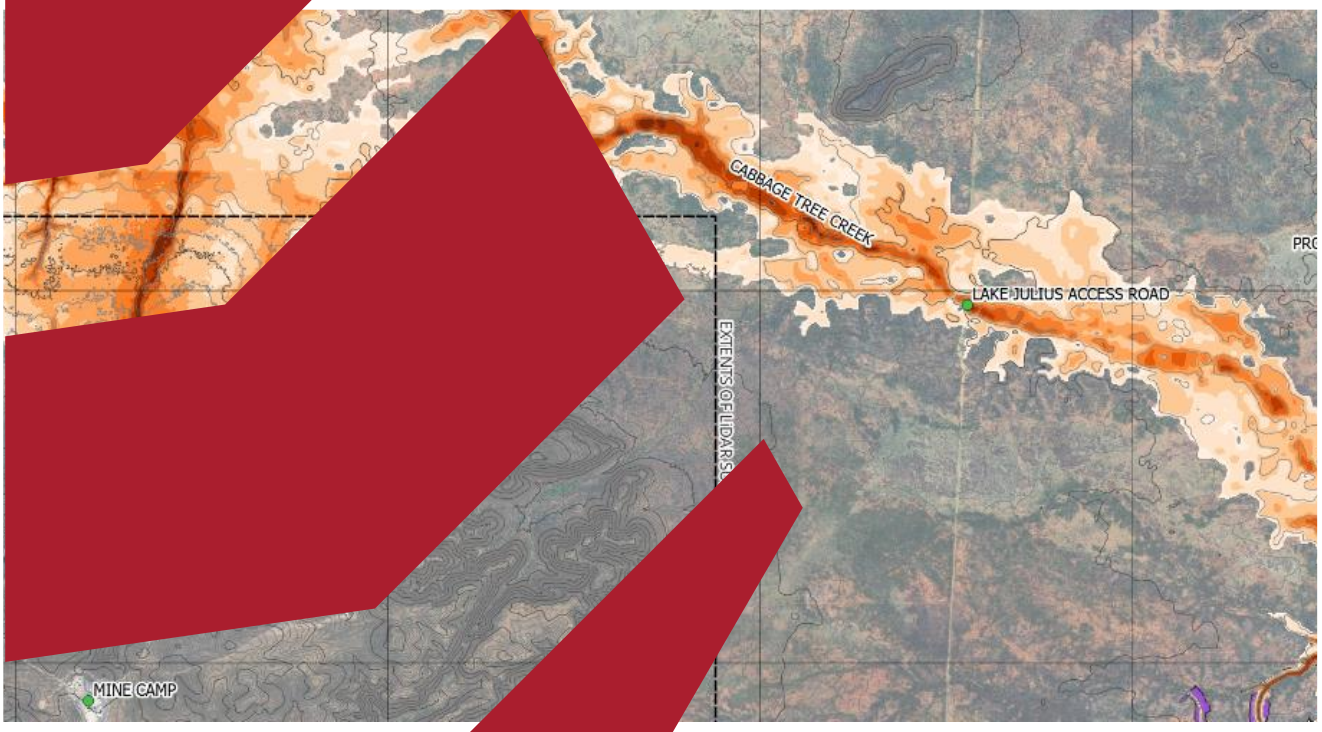
REPORT

MMG DUGALD RIVER
ABN: 19 083 405 556

DUGALD RIVER MINE

TAILINGS STORAGE FACILITY – STAGE 3 DAM BREAK AND CONSEQUENCE CATEGORY ASSESSMENT

250542-R03, REV 0
JANUARY 2026



TAILINGS.WATER.WASTE.

Document Control

Project Name:	Dugald River Mine TSF Stage 3 Raise Design
Project Number	250542
Document Title:	Dam Break and Consequence Category Assessment
File Location:	S:\Dugald\250542 - TSF Raise Design\Documents\R03 - Dam Break

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
A	Draft Issue	24/06/2025	Caiden Flannigan / Jason Leung	Thomas Lu / Craig Noske
0	Final Issue	05/01/2026	Jason Leung	Dale Ross

Issue Register

Distribution List	Date
MMG Dugald River	05/01/2026

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TAILINGS.WATER.WASTE.

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1 INTRODUCTION

1.1 Overview

MMG Limited (MMG) owns and operates the Dugald River Mine (DRM), located approximately 65 kilometres north-west of Cloncurry and 85 kilometres north-east of Mt Isa in Queensland, Australia.

MMG has engaged ATC Williams (ATCW) to produce a detailed design for a 9.25 m raise to the existing Dugald River (DR) Tailings Storage Facility (TSF) to a crest level of RL 253.5 m, hereafter referred to as 'Stage 3'.

This report documents the dam break and consequence category assessments undertaken as part of the Stage 3 detailed design works.

1.2 Scope of Works

The scope of work for this assessment is as follows:

- Dam break modelling and inundation mapping; and
- Consequence category determination.

The consequence category assessment has been carried out in accordance with the following guidelines:

- Queensland Department of Environment, Tourism, Science and Innovation (DETSI) – Manual for assessing consequence categories and hydraulic performance of structures **[1]**
- Australian National Committee on Large Dams (ANCOLD) – Guidelines on the Consequence Category for Dams **[2]**
- Global Industry Standard on Tailings Management (GISTM) **[3]**

2 PROJECT BACKGROUND

2.1 General

The TSF is located within the Knapdale Valley with tailings deposited in a down valley discharge method encapsulated by a cross-valley embankment.

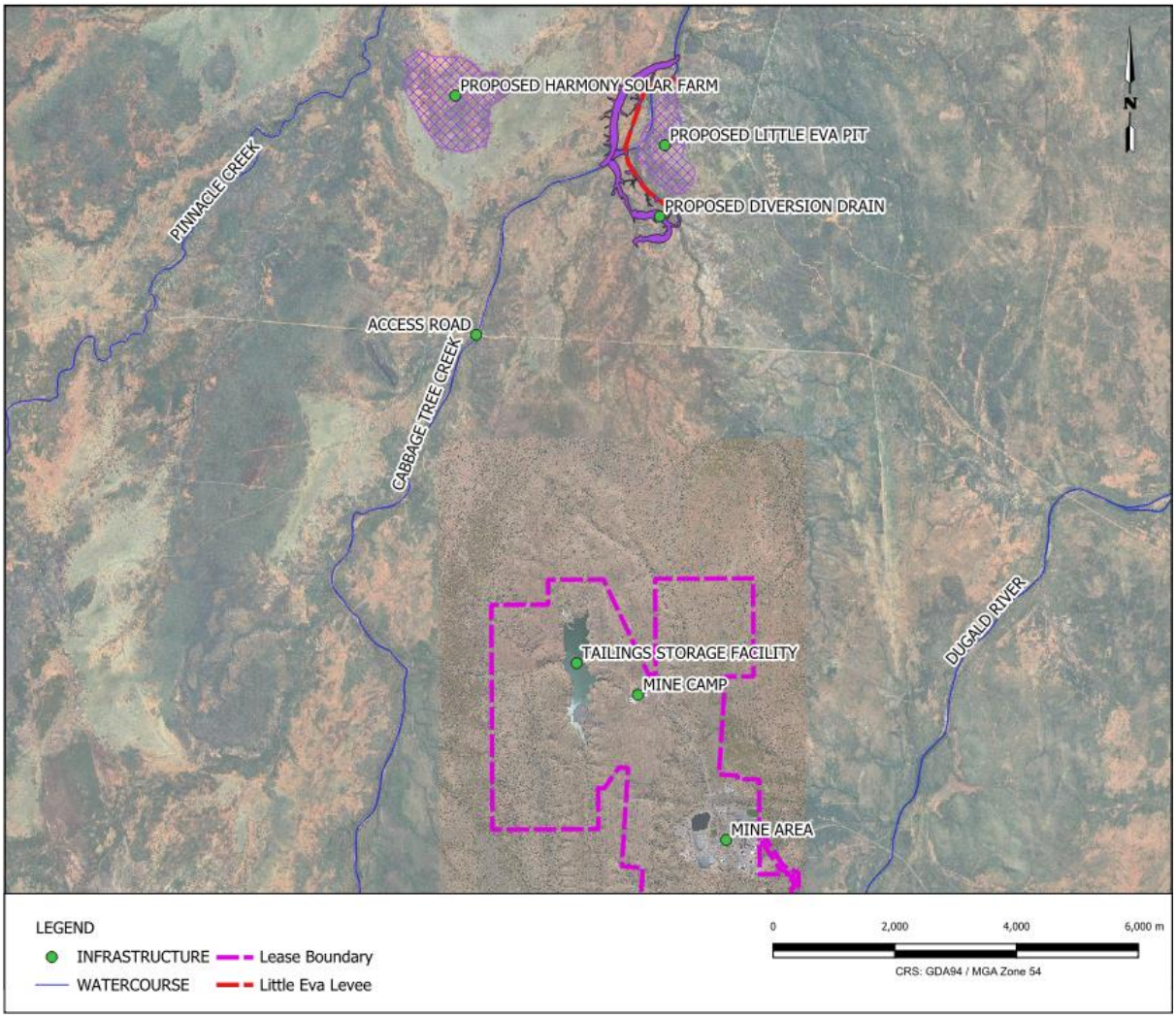
The main purpose of the TSF is to provide storage for tailings, which are produced at the DRM process plant. When the tailings are not transferred to the paste plant (to be used as backfill within the underground mine), the tailings are pumped via a 4 km long pipeline to the TSF.

Another function of the TSF is to provide temporary water storage for mineral processing and various other mining activities (dust sprays, mine service water streams, etc.). The water stored within the TSF originates from decant (bleed) water emerging from the deposited tailings, as well as from rainfall runoff from the catchment area.

A general layout of the existing DR TSF in relation to other mine infrastructure is illustrated in **Map 1** and **Figure 1**.

TAILINGS.WATER.WASTE.

MAP 1 – GENERAL LAYOUT



2.2 Basic Dam Details

The Stage 3 configuration comprises a downstream raise to the existing Stage 2 embankment. To accommodate the new height of the facility an additional bund (the Northern Discharge Bund) is proposed to be constructed at the northern end of the impoundment. The Northern Discharge Bund is approximately 7 m in height and 80 m in length. This bund has been designed to be used as a deposition platform for the continuation of deposition and has not been designed to be water retaining. The detailed design of Stage 3 is documented in the detailed design report **[4]**.

Details of the DR TSF under the Stage 2 (existing) and Stage 3 (design) configurations are summarised in **Table 1**.

TABLE 1 – BASIC DAM DETAILS

Item	Stage 1 & 2	Stage 3
Crest Level	RL 244.25 m	RL 253.5 m
Maximum Embankment Height	38.25 m	47.5 m
Crest Width	10 m	10 m
Crest Length	225 m	292 m

TAILINGS.WATER.WASTE.

Upstream Slope (H:V)	1.75:1	1.75:1 with a 3 m bench
Downstream Slope (H:V)	1.5:1 with two 5 m benches	1.5:1 with three 5 m benches
Spillway Width	10 m	50 m
Spillway Depth	2.15 m	2.15 m
Spillway Invert	RL 242.1 m	RL 251.35 m
Northern Discharge Bund Level	-	RL 253.5 m
Construction Method	Starter Embankment	Downstream Raise

2.3 Downstream Receiving Area

The TSF Embankment is located within a narrow gully which drains the Knapdale Range valley impoundment into an unnamed tributary of Cabbage Tree Creek. Cabbage Tree Creek is located in the Leichardt River Basin, which discharges north to the Gulf of Carpentaria. Apart from Cabbage Tree Creek, the downstream receiving area is considered generally flat, with a slight gradient dropping in a south to north direction.

A local access road is located approximately 5 km to the north of the TSF Embankment. This road is on an east west alignment, connecting Burke Development Rd to Lake Julius.

The nearest third-party asset is a future proposed mining project, owned by Harmony Gold Mining Co. Ltd. (Harmony). The project will consist of a mining pit, called “Little Eva” Pit, approximately 14 km downstream of the DR TSF Embankment and in close proximity to Cabbage Tree Creek. The Little Eva Pit infrastructure is proposed to include a diversion drain and a flood protection levee designed to divert the flood levels recorded during the extreme, 2009 wet season Cabbage Tree Creek flood event **[5]**.

2.4 Previous Studies

ATCW completed a dam break assessment in 2015 as part of the detailed design of the Stage 2 configuration **[6]**. The assessment was carried out for a Sunny Day Failure (SDF) scenario. The findings of the assessment can be summarised as follows:

- Tailings runout: Approximately 300,000 m^3 of tailings estimated to mobilise, travelling some 750 m downstream of the TSF embankment and inundating an area of 6 ha.
- Decant pond water: Approximately 3,500 ML of decant water released (predominantly comprising rainfall runoff), inundating a maximum area of approximately 2,100 ha.
- Harmony Gold Mining Co. Ltd. (Harmony) “Little Eva Pit” infrastructure is not expected to be impacted by the tailings runout. The maximum depth of water flow is estimated to be less than 1 m and maximum velocity estimated to be less than 0.3 m/s. These estimates do not consider the proposed diversion channel and flood protection levee around the pit.
- In terms of environmental damage to the Cabbage Tree Creek catchment, it is generally considered that significant erosion and stripping of vegetation would be limited to the 2.8 km long unnamed tributary of Cabbage Tree Creek. Once flows intersect Cabbage Tree Creek and flow north, the estimated maximum velocity does not exceed 1 m/s, which is not considered to be sufficient to do long-term damage to the low to moderately erosive surficial soils which overlay the floodplain.

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3 FAILURE MODE ASSESSMENT

3.1 Credible Failure Modes

In accordance with ANCOLD **[2]** and GISTM **[3]**, the dam break assessment shall be based on credible failure modes, and consider both Sunny Day Failure (SDF) and Flood Failure (FF) conditions to determine the worst-case scenario.

A Failure Mode and Effects Analysis (FMEA) workshop was conducted on 20th May 2025 which included representatives from ATCW, MMG, and the DRM Independent Tailings Review Board. The outcomes of the workshop are documented in the Stage 3 Quantitative Risk Assessment Report **[7]**.

In the workshop, all Potential Failure Modes (PFM) of the Stage 3 TSF were identified and consensus was reached on whether or not each PFM is credible or non-credible. The following credible failure mode was identified for the Stage 3 TSF embankment based on the FMEA workshop:

TABLE 2 – CREDIBLE FAILURE MODES

Failure Mode ID	Failure Mode	Scenario
DR TSF-Emb-SS-6	Overtopping due to instability of the downstream slope causing slumping and loss of freeboard	Sunny Day/Flood

The dam break analysis has been carried out to ensure that the credible failure mode listed in **Table 2** is represented accordingly in the modelling outcomes.

3.2 Modelled Scenarios

The following dam break scenarios are considered to be representative of the draft credible failure modes listed in **Section 3.1**:

- **Sunny Day Failure (SDF)** – Embankment instability causing significant deformation of the crest and a loss of freeboard. Water begins overtopping the embankment, resulting in gradual erosion of the embankment crest. The loss of confining stress also causes static liquefaction of the tailings, which begin overtopping the embankment once the crest erodes to the level of the tailings. The release of water and liquefied tailings is into a dry downstream environment.
- **Flood Failure (FF)** – Embankment instability failure during an extreme storm event, causing significant deformation of the crest and a loss of freeboard. Water begins overtopping the embankment, resulting in gradual erosion of the embankment crest. The loss of confining stress also causes static liquefaction of the tailings, which begin overtopping the embankment once the crest erodes to the level of the tailings. The release of water and liquefied tailings is into a flooded downstream environment.

Under an FF scenario, it is expected that all downstream receptors would have evacuated prior to the dam break; or be subject to pre-dam break flooding that already exceeds safe levels. Therefore, it is expected that the incremental impact from the dam break during an extreme flood event would be negligible and that the SDF outcomes will govern the Consequence Category assessment.

Hence, only modelling of the SDF scenario has been carried out. The dam failure consequence category assessments have been based upon the outcomes of the SDF assessments.

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3.3 Initial Conditions

The initial conditions that have been assumed for the DR TSF dam break modelling are summarised in **Table 3** and are shown in **Figure 2**.

TABLE 3 – INITIAL CONDITIONS PRIOR TO DAM BREAK

Parameter	SDF
Embankment	Stage 3 configuration RL 253.5 m
Tailings Level	Stage 3 end of filling
Decant Pond Level	Full Supply Level (Spillway Invert) RL 251.35 m
Downstream Conditions	Normal flow conditions (i.e., little to no water present in Cabbage Tree Creek)

3.4 Breach Location and Depth

The embankment breach is assumed to occur at the location coincident with the greatest embankment height in order to maximise the potential released volumes.

One of the key considerations in the dam break modelling is the vertical extent of the breach propagation. This is essentially an engineering judgement, based on an understanding of embankment construction materials; compaction methodology; and the erosive actions of mobilised materials flowing through the breach.

For the purpose of this study, the breach depth has been limited to approximately two-thirds of the full embankment height for the following reasons:

1. The identified credible failure mode relates to overtopping and progressive erosion of the crest, rather than a global failure of the entire structure, such as an instability failure through the foundation;
2. The embankment will be constructed predominantly from quarried quartzite rockfill and lined with a Bituminous Geomembrane Liner, and therefore will be less susceptible to erosion;
3. A portion of the liquefied tailings is assumed to mobilise and continue the breach propagation, however it is expected that a point of equilibrium will be reached with increased depth as higher strength, more consolidated tailings are exposed;
4. The embankment will be approximately 130 m wide at the base of the breach; and
5. A portion of the mobilised tailings and embankment materials will likely be deposited against the downstream toe of the embankment, providing additional resistance against continued breach propagation to the full height.

Notwithstanding, a sensitivity assessment has also been carried out assuming a full-height breach to understand the potential increase in the failure impact.

4 DAM BREAK MODELLING

4.1 Modelling Methodology

The dam break modelling undertaken for this study consists of the following primary steps:

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1. Topographic modelling assembly: establishment of the 3-dimensional topographic modelling of the potential impact area based on recent site survey and publicly available Digital Elevation Model (DEM);
2. Estimation of dam break released volumes: assessment of the proportion of stored tailings and water released for each respective failure scenario;
3. Breach geometry modelling: estimation of embankment breach parameters and derivation of the outflow hydrographs; and
4. Hydraulic dam break modelling: carrying out hydraulic modelling to route the breach outflow and generate flood inundation mapping.

4.2 Adopted Modelling Techniques

Various techniques have been used in combination to carry out the dam break modelling. The selected modelling techniques for each component of the dam break assessment are summarised in **Table 4**.

TABLE 4 – ADOPTED MODELLING TECHNIQUES

Component	Model
Breach Parameter Estimation	Froehlich (2016) Empirical Equations **[8]**
Breach Hydrograph Model	HEC-RAS **[9]**
Hydraulic Dam Break Model	FLO-2D **[10]**

4.3 Topographic Modelling Assembly

The following survey sources have been used to compile the topographic model domain:

- October 2024 site-wide LiDAR survey, provided by MMG (dated 15/10/24);
- July 2024 site-wide LiDAR survey, provided by MMG (dated 12/07/24); and
- Publicly available DEM **[11]**

In addition to the topographic survey data, design models have also been incorporated into the model, including:

- Little Eva Pit diversion drain and flood protection levee models, provided by Harmony (dated 08/12/2023); and
- Stage 3 embankment and tailings beach models, created by ATCW.

The compiled model topography is shown in **Map 2**.

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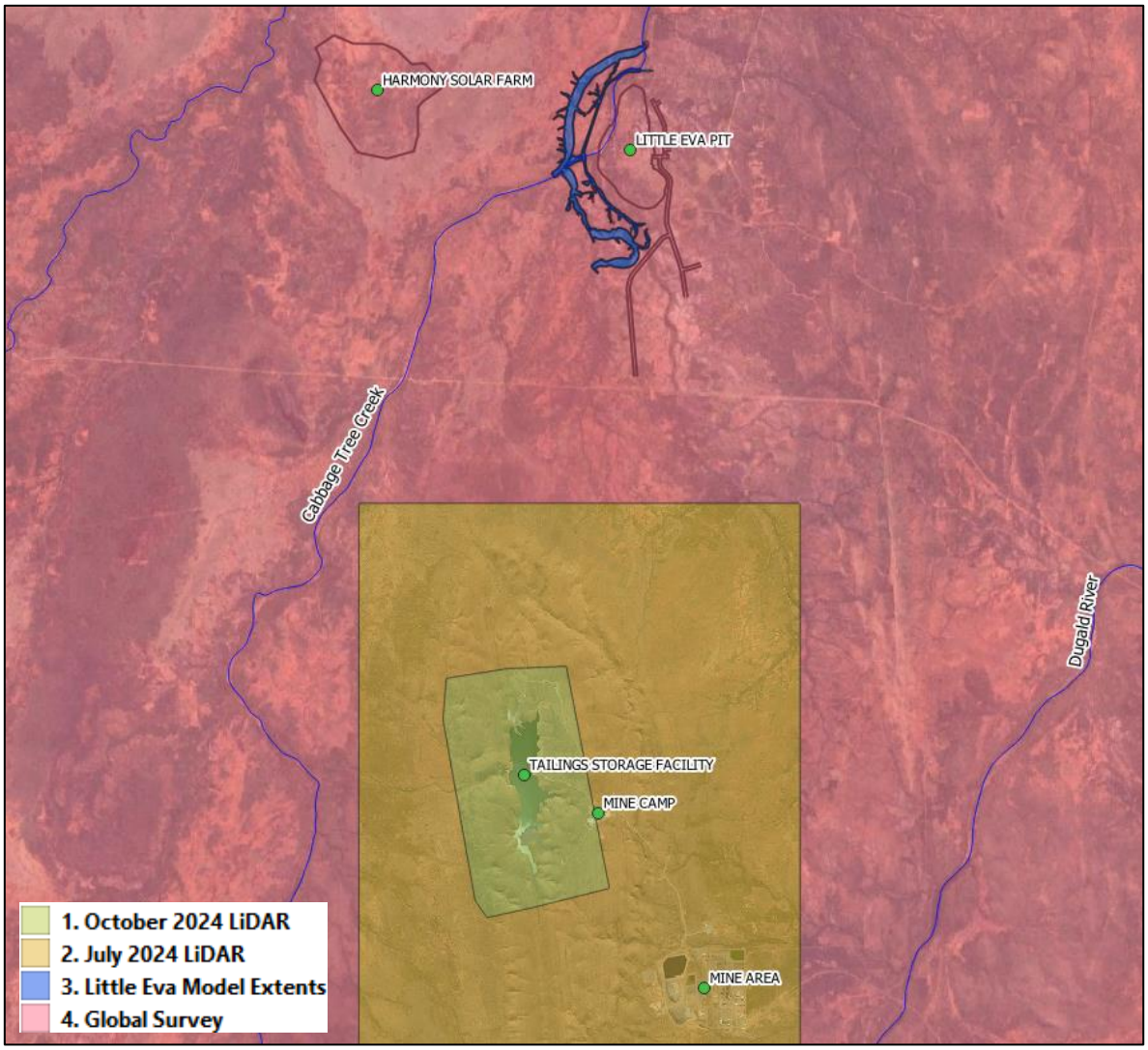
MAP 2 – TOPOGRAPHIC MODEL ASSEMBLY



4.4 Released Volume Assessment

4.4.1 Tailings Liquefaction

The DRM tailings have been deemed to be potentially liquefiable when saturated based upon the tailings characteristics **[12]**. It has therefore been conservatively assumed that for the purpose of this study, at the time of a hypothetical dam break event, the tailings are fully saturated and liquefied, and will consequently flow like a non-Newtonian fluid.

4.4.2 Post-failure Residual Slope

The adopted approach for the evaluation of the potential liquefied tailings released volume has been to estimate a post-failure residual surface of the liquefied tailings, with the gradient being a function of the consolidation density and shear strength profiles within the tailings storage.

When a dam breach scenario occurs, the embankment supporting the tailings deposit is removed, and the liquefied tailings will flow out until a stable residual storage condition is achieved. The post-failure residual condition of the deposit is normally defined by the stable slope of the tailings backscarp into the storage, which is then dependant on the in-situ conditions (deposits shear strength and density) at the time of the failure.

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This failure slope has been estimated using Infinite Slope Theory. The theory assumes that at the residual condition, the shear strength of the tailings will be the same as the weight component that triggers additional rejects mobilisation (i.e., a Factor of Safety of 1). This equation is given by:

$$S_u = \gamma h \sin\beta \cos\beta$$

where

S_u = *undrained, post-liquefaction shear strength,* $S_{u,res} = k\sigma'_{vo}$ *(kPa)*
k = *residual post-liquefaction shear strength ratio*
σ'_{vo} = *vertical effective stress (kPa)*
γ = *bulk unit weight of tailings (kN/m³)*
h = *depth of rejects (m)*
β = *failure slope angle (°)*

For fully saturated tailings, the infinite slope theory equation can be re-arranged to estimate the final stable slope angle of the tailings. A typical lower bound post-liquefied undrained shear strength ratio of 0.07 **[13]** has been conservatively adopted for the DRM tailings. Based on this assumption, the estimated failure slopes resulting from a breach-induced mobilisation of the stored tailings is approximately 3.3%.

It is recommended that the post-liquefied undrained shear strength ratio assumption is validated from site-specific investigations as part of a future study, if the decant pond is able to be drawn down and a CPT campaign undertaken.

4.4.3 Released Volume

The estimated released volume is dependent on the assumed breach depth. The estimated water released volume has been determined as the volume of stored decant water above the breach base.

The tailings released volume has been estimated from 3D modelling of the tailings backscarp based on the post-failure slope of 3.3% derived in **Section 4.4.2**. The calculated failure slope has been projected through the tailings mass as a cone of depression, and the tailings material within this cone of depression has been assessed as the mobilised failure volume. Schematics of the assumed post-failure residual condition for both the Base Case and Sensitivity Case are provided in **Diagram 1** and **Diagram 2**.

DIAGRAM 1 – FAILURE SCHEMATIC FOR BASE CASE

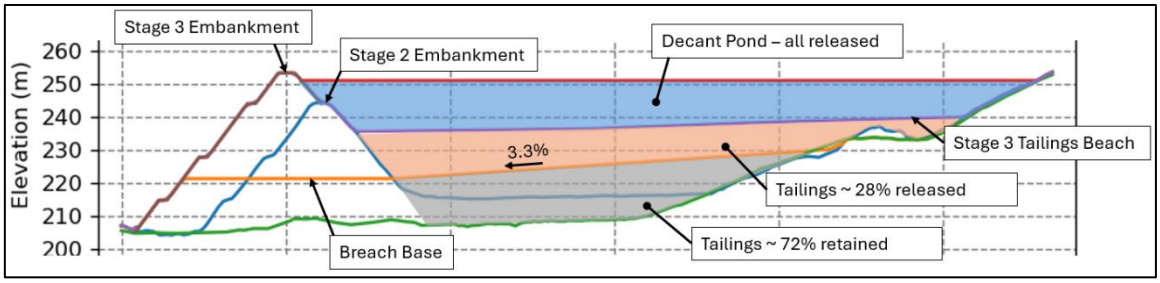
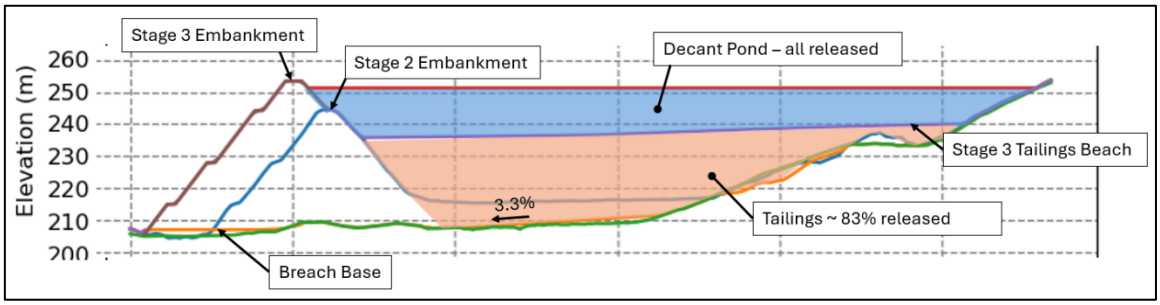


DIAGRAM 2 – FAILURE SCHEMATIC FOR SENSITIVITY CASE



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As illustrated in **Diagram 1**, the Base Case assessment is estimated to result in the release of approximately 28% of the total stored tailings, whilst the Sensitivity Case assessment is estimated to result in the release of approximately 83% of the stored tailings.

The estimated released volumes are summarised in **Section 4.5**.

4.5 Breach Geometry Modelling

For the assessed SDF scenario, it is assumed that embankment instability would lead to significant crest deformations and a loss of freeboard, resulting in the overtopping of decant water over the embankment. The overtopping is assumed to cause progressive erosion of the embankment face, until the breach progresses to the level of the tailings deposit. The loss of confining stress causes static liquefaction of the tailings, which begin overtopping and continuing the breach propagation.

The characteristics of the embankment breach have been estimated using Froehlich's empirical equations **[8]**. Froehlich's equations consist of estimator equations based on historical dam failure case studies. The equations estimate the breach width and breach development time and specify the breach geometry side slopes based on the failure mode (i.e. piping or overtopping). The equations are:

$$B_{AVE} = 0.28\, K_M K_H V_W^{1/3} W_{avg}^{-1/6} H_b^{1/6} \quad (1)$$

$$t_f = 50 \sqrt{\frac{V_W}{g H_b^2}} \left(\frac{W_{avg}}{H_b}\right)^{1/4} \quad (2)$$

where

B_{AVE} = *average breach width (m)*
K_M = *failure mode coefficient* ($K_{piping} = 1.0, K_{overtopping} = 1.5$)
V_W = *volume above breach level (m^3)*
H_b = *depth of breach measured from embankment crest level (m)*
t_f = *breach progression time (hrs)*
W_{avg} = *average width of the embankment (m)*

The adopted breach parameters are summarised in **Table 5**. The breach layouts for the Base Case and Sensitivity Case are shown **Figure 3** and **Figure 4** respectively.

TABLE 5 – ADOPTED BREACH PARAMETERS

Parameter	Base Case (Two Thirds Height Breach)	Sensitivity Case (Full Height Breach)
Tailings Release Volume	3,859,700 m^3	11,415,500 m^3
Water Release Volume	7,248,500 m^3	7,248,500 m^3
Breach Base Level	RL 221.5 m	RL 206.0 m
Breach Height	32.0 m	47.5 m
Average Breach Width	82.6 m	100.1 m
Breach Side Slopes	1H:1V	1H:1V
Breach Development Time	0.56 hrs (34 mins)	0.47 hrs (28 mins)

4.6 Hydraulic Model Setup

4.6.1 Background

To estimate the nature and extent of inundation and flooding caused by the dam break scenario, numerical modelling software HEC-RAS **[9]** and FLO-2D **[10]** have been used in combination to create the hydraulic models.

Most dam break numerical models have been developed for water dams and Newtonian fluids (water). These models intend to predict conventional flood characteristics depending on dam types, failure mechanisms and breach size. For the predictive modelling of tailings dam breaches, models need to account for the hyper-concentrated flow (i.e., non-Newtonian fluid) behaviours.

The predictive modelling of the DR TSF dam break has been conducted using the FLO-2D volume conservation flood routing program. This program is capable of simulating both Newtonian and non-Newtonian flows and can be used for modelling unconventional flood routing problems such as mine tailings, mud, and debris flows. The software models non-Newtonian flows by allowing the user to assign fluid concentration, dynamic viscosity, and yield stress parameters.

HEC-RAS has been used to establish the breach flow hydrographs to be used as input to the FLO-2D model. FLO-2D then routes the dam break flows resembling a fluid continuum by predicting viscous fluid motion as a function of solids concentration. A quadratic rheological model was used to define the viscosity and yield stress of the fluid as a function of solids concentration, and solids continuity is observed. This provides FLO-2D with the advantage over other programs in the capability of modelling tailings and rejects flow discharged into water and becoming diluted. As solids concentration changes for a given grid element, dilution effects, tailings flow cessation and remobilisation of deposits are simulated. Moreover, FLO-2D considers both turbulent and laminar flow in its governing energy loss equations, whilst most other commercially available tools consider only laminar flow. For these reasons, FLO-2D is considered to represent the best available, and most appropriate modelling tool to simulate non-Newtonian runout of the rejects.

4.6.2 Model Inputs

The FLO-2D models consist of a three-dimensional topographic domain, based on a 10 m x 10 m gridded elevation raster model for the dam break assessments. This computational grid has been sampled from the assembled data described in **Section 4.3** to form the base topographic model domain.

In the context of the tailings flow routing, relevant rheological and hydraulic inputs to FLO-2D software include the following:

- Tailings properties;
- Breach outflow hydrograph;
- Boundary conditions; and
- Surface roughness conditions.

FLO-2D does not require a pre-determined flow path, which helps to determine realistic failure impact zones. The model estimates the flow paths, velocities and depths based on the input hydrograph and topography and allows assessment of inundation of critical infrastructure and locations caused by dam break flows.

4.6.3 Tailings Properties

The material properties used in the FLO-2D dam break models have been derived from rheological testing undertaken by ATCW on thickener underflow samples from DRM. The results from the laboratory testing are presented in the Factual Report **[14]** and are reproduced in **Appendix A**.

The laboratory data **[14]** indicate a representative Specific Gravity (G_S) of 2.97 for the tailings. A representative in-situ dry density of 1.35 t/m^3 has been assumed, corresponding to the Overall In-situ Densities (OID) achieved to date **[15]**.

Exponential relationships have been derived for the rheological parameters (i.e., Yield Stress and Bingham Plastic Viscosity) of the tailings samples at different solids concentrations, and the data has

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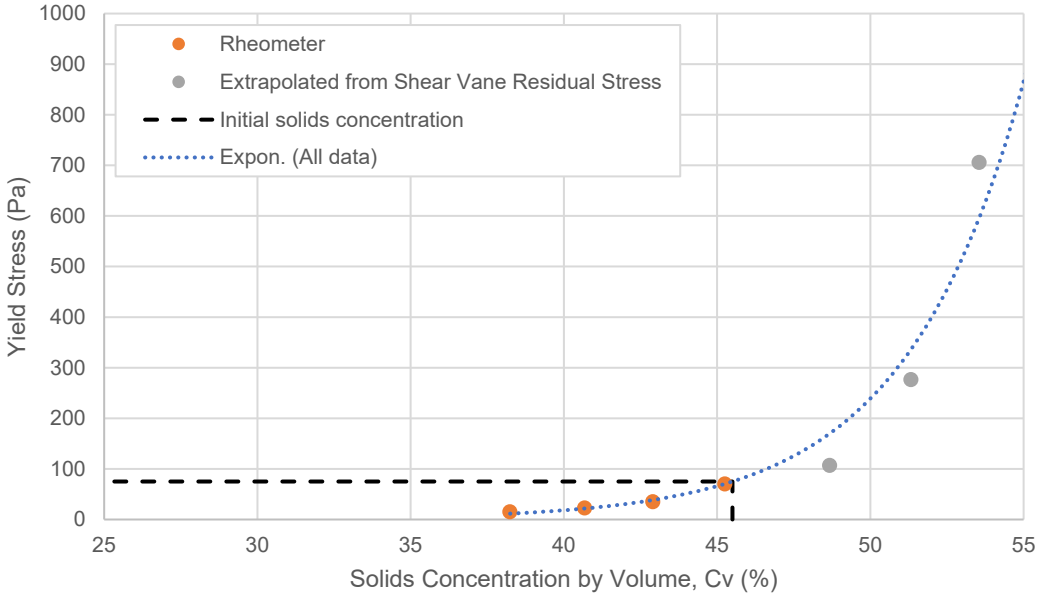
been extrapolated to estimate the rheology at higher solids concentrations. **Graph 1** and **Graph 2** display the estimated Yield Stress and Bingham Viscosity plots respectively. The adopted tailings parameters utilised in the dam break assessments are summarised in **Table 6**.

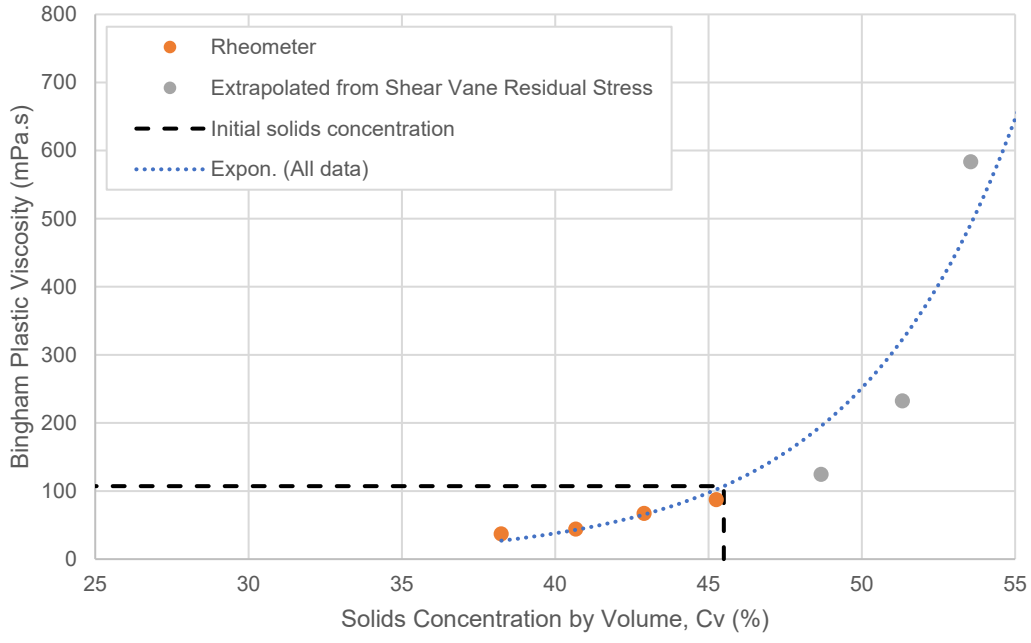
TABLE 6 – ADOPTED TAILINGS PARAMETERS FOR DAM BREAK MODELLING

Solids Specific Gravity	In-Situ Dry Density (t/m^3)	Solids Concentration by Weight (%)	Solids Concentration by Volume (%)	Rheology	
				Yield Stress (Pa)	Bingham Plastic Viscosity (Pa·s)
2.79	1.35	71.2	45.5	74.2	0.11

GRAPH 1 – BINGHAM PLASTIC YIELD STRESS



GRAPH 2 – BINGHAM PLASTIC VISCOSITY



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4.6.4 Breach Flow Hydrographs

FLO-2D routes the breach flow as inflow hydrographs in the two-dimensional model domain. To establish the breach flow hydrograph in a failure scenario, it is assumed that the shape of the hydrograph would be similar to water flow due to the rapid outflow rates (i.e., rapid shearing, low dynamic viscosity) at the breach opening. Hence, two-dimensional unsteady flow simulation software HEC-RAS has been used to establish the breach flow hydrographs to be used as input for FLO-2D.

In HEC-RAS, the dam is defined as a storage area with stage-volume information for the mixture of the tailings and water. The storage area is then connected to the 2D mesh floodplain using an embankment connection with the breach formation parameters defined in **Section 4.5**. The simulations are then run, in which the combined breach volume is gradually released from the storage area into the 2D mesh floodplain, to extract flow hydrographs at the connection.

The breach flow hydrographs for the assessed failure scenarios are shown in **Figure 5** and are summarised in **Table 7**.

TABLE 7 – PEAK BREACH OUTFLOW RATES

Scenario	Peak Outflow	Time to Peak
Base Case (Two Thirds Height Breach)	9,780 m^3/s	21 mins
Sensitivity Case (Full Height Breach)	18,490 m^3/s	26 mins

4.6.5 Boundary Conditions

The breach flow hydrographs described in **Section 4.6.4** are applied in the dam break modelling domain as inflow boundary conditions.

Outflow boundary conditions are defined along the model domain boundaries where flow is expected to remain steady. Normal flow conditions are defined at these flow boundaries to remove dam break flows that reach these locations from the modelling domain.

4.6.6 Surface Roughness

Manning's roughness coefficients (i.e., n-values) were assigned to different land uses within the modelled downstream receiving area. The information from Engineers Australia **[16]** has been adopted as a reference for the selection of these values.

The following Manning's roughness coefficients have been adopted:

- General downstream area – 0.04
- Waterways – 0.03
- Heavily Vegetated areas – 0.10

4.6.7 Modelling Duration and Time Steps

The FLO-2D model was run for a total duration of 24 hours to allow for the full propagation of the breach flow. The time steps used for modelling are dynamically adjusted by the software based on Courant condition (which define the stability of the model) dependant on the velocity of the released volume at any specific time step.

4.6.8 Modelling Output

The dam break simulation results are presented in terms of inundation maps as follows:

- Maximum Flow Depth – depicting maximum inundation depths at the downstream area during the model runtime;

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- Maximum Flow Velocity – depicting maximum flow velocity in the flood plain during the model runtime;
- Maximum Flow Impact – depicting the maximum product of inundation depth and velocity (i.e., D×V) at the downstream area during the model runtime;
- Arrival Time (300 mm) – depicting the time it takes after the breach for the flood to reach a flow depth of 300 mm in the downstream area;
- Maximum Flow Elevation – depicting maximum flow surface elevations in the downstream area throughout the model runtime; and

It is important to note that whilst these figures present the maximum impact in the downstream receiving area, the maximum values shown in the figures do not necessarily occur at the same time. They are rather a representation of the collective maximum values achieved during the model runtime.

4.7 Results and Discussion

4.7.1 Base Case

Figure 6 to **Figure 15** show the inundation maps from the dam break simulations for the Base Case assessment. A summary of the inundation characteristics at key locations is provided in **Table 8** and **Table 9**.

As seen from the figures, the dam break flows initially propagate westward through the unnamed tributary until intersecting the Cabbage Tree Creek drainage path. It is noted that the dam break flows may inundate multiple drainage paths before turning into Cabbage Tree Creek and flowing northwards towards the Little Eva Pit.

The results indicate that the proposed diversion drain and flood protection levee around Little Eva Pit are capable of diverting the majority of the mobilised flood volumes away from the Little Eva Pit. The results indicate that some minor overtopping of the proposed flood protection levee is anticipated at the northern extents where the crest of the proposed flood protection levee is at its lowest.

After being diverted away from the Little Eva Pit, the dam break flows continue northwards along the Cabbage Tree Creek before joining the Leichardt River at the Cabbage Tree Creek-Leichardt River confluence.

TABLE 8 – INUNDATION SUMMARY AT KEY AREAS-OF-INTEREST (BASE CASE)

Location	Inundation Length (m)	Max Depth (D) (m)	Max Velocity (V) (m/s)	Max D×V (m^2/s)	Arrival Time $(hrs)^2$
Unnamed Tributary of Cabbage Tree Creek	-	21.4	14.2	251.6	0.1
Cabbage Tree Creek (Upstream of Little Eva Pit)	-	8.7	6.6	27.0	0.3
Lake Julius Access Road	780	5.9	3.4	13.9	1.8
Little Eva Pit footprint[1]	-	2.6	1.4	0.8	4.9
Harmony Solar Farm	-	-	-	-	-
Cabbage Tree Creek (Downstream of Little Eva Pit)	-	4.6	3.2	4.2	3.9
Kajabbi Normanton Road	1,680	2.8	2.1	1.3	9.8

Note 1: Values represent flooding above the natural terrain; no topographic modelling of the proposed Little Eva Pit is available.
Note 2: Arrival time defined as time to reach 300 mm of inundation.

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TABLE 9 – INUNDATION SUMMARY AT KEY INFRASTRUCTURE (BASE CASE)

Location	Minimum Crest Level (AHD)	Max Flow Level (AHD)	Max Depth (m)	Length Overtopped (m)	Time to Overtopping (hrs)
Little Eva Pit Flood Protection Levee	RL 162.23 m	RL 163.30 m	1.3	720	4.9

4.7.2 Sensitivity Case

Figure 16 to **Figure 25** show the inundation maps from the dam break simulations for the Sensitivity Case assessment. A summary of the inundation characteristics at key locations is provided in **Table 10** and **Table 11**.

As seen from the figures, the dam break flows follow a similar flow path to the Base Case assessment, but with a wider footprint along both the unnamed Tributary of Cabbage Tree Creek and Cabbage Tree Creek itself.

The results indicate that the increased volume of liquefied tailings results in significant overtopping of the proposed Little Eva Pit flood protection levee. No topographic modelling of the Little Eva Pit has been included in the model domain, however flood depths of up to 4.3 m have been estimated above natural ground within the proposed Little Eva Pit footprint.

It is evident that the performance of the Little Eva Pit flood protection levee is sensitive to the mobilised tailings volume (and by extension the assumed breach depth).

It is understood that the design of the flood protection infrastructure surrounding the Little Eva Pit is ongoing. Based on the outcomes of the Sensitivity Case assessment, it is recommended that the dimensions of the flood protection levee are reviewed to ensure adequate protection from potential dam break flooding.

TABLE 10 – INUNDATION SUMMARY AT KEY AREAS-OF-INTEREST (SENSITIVITY CASE)

Location	Inundation Length (m)	Max Depth (D) (m)	Max Velocity (V) (m/s)	Max D×V (m^2/s)	Arrival Time (hrs)[1]
Unnamed Tributary of Cabbage Tree Creek	-	28.3	17.4	364.0	0.1
Cabbage Tree Creek (Upstream of Little Eva Pit)	-	9.8	6.9	31.6	0.3
Lake Julius Access Road	1,230	6.8	3.5	17.1	1.4
Little Eva Pit footprint[1]	-	4.3	2.2	2.3	3.9
Harmony Solar Farm	-	-	-	-	-
Cabbage Tree Creek (Downstream of Little Eva Pit)	-	5.7	3.7	7.1	3.3
Kajabbi Normanton Road	1,800	3.2	1.7	2.4	8.0

Note 1: Values represent flooding above the natural terrain; no topographic modelling of the proposed Little Eva Pit is available.
Note 2: Arrival time defined as time to reach 300 mm of inundation.

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TABLE 11 – INUNDATION SUMMARY AT KEY INFRASTRUCTURE (SENSITIVITY CASE)

Location	Minimum Crest Level (AHD)	Max Flow Level (AHD)	Max Depth (m)	Length Overtopped (m)	Time to Overtopping (hrs)
Little Eva Pit Flood Protection Levee	RL 162.23	RL 165.4 m	2.1	2,300	3.7

5 GROUNDWATER IMPACTS

5.1 Overview

A Groundwater Impact Assessment (GIA) was undertaken for the Dugald River TSF by CDM Smith in 2025 **[17]**. The outcomes of the GIA are summarised in the following sections.

5.2 Numerical Modelling

As part of the GIA, a numerical model was developed to predict the groundwater seepage rates in response to the Stage 3 TSF raise.

The modelling comprised both the Stage 2 and Stage 3 geometries to determine the impact of the Stage 3 raise (calculated as the difference between the two scenarios).

The numerical modelling indicated that the Stage 3 TSF raise will not result in increased groundwater levels, suggesting no significant impact on regional groundwater conditions. The modelling also indicated that there will be no increase in seepage from the TSF as a result of the proposed Stage 3 raise.

5.3 Impact Assessment

The GIA **[17]** concluded the following:

- No impacts to groundwater resources are predicted as a result of the Stage 3 raise;
- No groundwater supply bores are expected to experience any change to groundwater levels or groundwater quality as a result of the Stage 3 raise;
- The Stage 3 TSF raise is not predicted to have any impact on the baseflow or natural flow regime of Cabbage Tree Creek and its tributaries;
- The project is not expected to give rise to any adverse impacts on any aquatic habitats and ecosystems associated with creeks, nor any downstream surface water users;
- No impacts on wetlands or other surface water features are predicted;
- There will be no impacts to groundwater dependent ecosystems as a result of the Stage 3 TSF raise; and
- The Stage 3 TSF raise has the potential to affect local groundwater quality due to limited seepage of potential acid mine drainage contaminated water migrating from the TSF into the underlying groundwater regime. However, impacts on groundwater quality associated with local contamination from TSF seepage are considered highly unlikely.

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6 CONSEQUENCE CATEGORY ASSESSMENT

6.1 Overview

For tailings dams in Queensland, two primary Consequence Category Assessment (CCA) methodologies apply. The outcomes of the two assessments have different applications and are not necessarily the same, as different criteria apply.

The first CCA method is that which is required by the Queensland DETSI **[1]**, with the other being the approach described by ANCOLD **[2]**. MMG have also requested ATCW to assess the TSF consequence category against the GISTM **[3]**.

These applications can be summarised as follows:

- DETSI – three separate scenarios for which different design criteria apply
  - Failure to Contain (seepage) – sets the required containment and detection measures;
  - Failure to Contain (overtopping) – sets the required flood management criteria (i.e., Design Storage Allowance and Mandatory Reporting Level); and
  - Dam Break – sets the required spillway capacity.

    The DETSI assessment criteria does not consider the internal (i.e. mine site) Population At Risk (PAR), internal environmental damage, nor the owner's business risks.

    The highest CCA ("Significant" or higher) defines whether the dam becomes a Regulated Structure for licensing by DETSI.
- ANCOLD – two separate scenarios for which different design criteria apply
  - Dam Failure – sets the required spillway capacity and seismic design ground motions; and
  - Environmental Spill – sets the required flood management criteria (i.e., Design Storage Allowance, Extreme Storm Storage Allowance and Contingency Freeboard).

    The ANCOLD assessment differs from DETSI, in that the criteria includes the internal PAR, internal environmental damage, and the owner's business risks.
- GISTM
  - Dam Failure – sets the required earthquake and flood management criteria, differentiating between active care and passive care.

    The GISTM assessment methodology requires that the CCA is informed by a dam breach analysis based on a *credible failure mode* assessment.

In summary, the DETSI CCA is used as the basis for obtaining regulatory approvals for the TSF, and generates hydrological and hydraulic design criteria, provided they meet or exceed the requirements of ANCOLD. The ANCOLD CCA is used by MMG for internal business risk ranking and application of critical controls, whilst the GISTM CCA is assessed to demonstrate compliance with the GISTM.

6.2 Population at Risk (PAR)

Following ANCOLD guidelines **[2]**, the PAR is considered to be "all those persons who would be directly exposed to floodwaters within the dam break affected zone if they took no action to evacuate".

The ANCOLD and GISTM assessments consider both internal (i.e. MMG personnel) and external populations; whilst the DETSI assessments only consider third-party (external) populations.

A specific location is included in the PAR assessment if it is within the inundation zone, and insufficient warning time is provided for evacuation.

The assessment of PAR has been based upon information provided by MMG and considers the proportion of time the individual or group can be expected to be exposed to the dam break inundation area. Where there is limited information available with respect to PAR frequencies, conservative

assumptions have been made. Separate PAR estimates have been carried out for Day and Night periods.

MMG have advised that the potential PAR will comprise those listed in **Table 12.** The time-weighted estimate of the PAR is summarised in **Table 13**. ATCW consider that the PAR estimates listed in

Table 13 are representative of both the Base Case and Sensitivity Case in consideration of the comparable flooding extents and severity between the two scenarios.

TABLE 12 – POTENTIAL POPULATIONS AT RISK

Task	No. People	Frequency (day time)	Frequency (night time)
Daily Inspections	1 person	1 hrs per inspection, once per day	Day shift only
Weekly Inspections	2 people	2 hrs per inspection, once per week	Day shift only
Monthly Inspections	1 person	2 hrs per inspection, once per month	Day shift only
Annual Surveillance Inspections	5 people	10 hrs per inspection, once per year	Day shift only
SCP Pump Maintenance	2 people	2 hrs a week	Day shift only
Environmental Sampling	2 people	2 hrs, once per month 3 hrs, once per quarter	Day shift only
Land Owner Inspections	1 person	6 hrs, twice per year	Day shift only
Drilling	2 people	12 hrs, once per year	Day shift only
Ad hoc Inspections	2 people	2 hrs, once per month	Day shift only
Little Eva Pit[1]	10 people	12 hrs shift	Day shift and night shift

Note 1: Conservative assumptions due to limited available information.

TABLE 13 – ESTIMATED POPULATION AT RISK

Task	Frequency	People Hours/Week	
		Day Time	Night Time
Daily Inspections	1 person x 1 hrs per inspection x once per day	7.000	-
Weekly Inspections	2 people x 2 hrs per inspection x once per week	4.000	-
Monthly Inspections	1 person x 2 hrs per inspection x once per month	0.462	-

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Annual Surveillance Inspections	5 people x 10 hrs per inspection x once per year	0.962	-
SCP Pump Maintenance	2 people x 2 hrs a week	4.000	-
Environmental Sampling	(2 people x 2 hrs x once per month) + (2 people x 3 hrs x once per quarter)	1.385	-
Land Owner Inspections	1 person x 6 hrs x twice per year	0.231	-
Drilling	2 people x 12 hrs x once per year	0.462	-
Ad hoc Inspections	2 people x 2 hrs x once per month	0.923	-
Little Eva Pit	10 people x 12 hrs	840.000	840.000
	Total People Hours/Week	859.424	840.000
	Total Hours per Week	84	84
	Equivalent PAR (Time-Weighted)	**10.231**	**10.000**

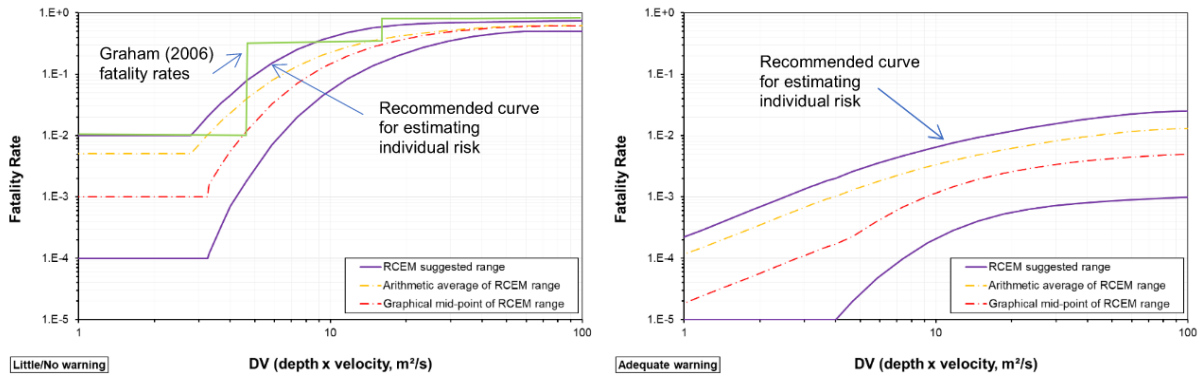
6.3 Potential Loss of Life (PLL)

Estimates of the PLL have been carried out in accordance with ANCOLD **[18]**. As recommended by ANCOLD, the RCEM approach **[19]** has been used to estimate the PLL.

6.3.1 RCEM Methodology

The RCEM methodology proposes a graphical approach to estimating the fatality rate due to dam failures, by considering flood severity and warning time. The charts are reproduced in **Graph 3** and have been developed based on an extensive database of case histories.

GRAPH 3 – RCEM FATALITY RATE GRAPHS [20]



Limited guidance is provided on what constitutes “Little/No Warning” or “Adequate Warning” within the RCEM methodology. For the purposes of the PLL assessment, it is conservatively assumed that

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"Little/No Warning" has been provided to the populations listed in **Table 12**. The upper bound of the RCEM suggested range has been considered to determine the fatality rates.

The Weighted PLL has been calculated as follows:

$$Weighted\ PLL = \sum (PAR \times Fatality\ Rate)$$

The fatality rates and Weighted PLL for each population is shown in **Table 14**.

TABLE 14 – ESTIMATED POTENTIAL LOSS OF LIFE

Task	People Hours/Week	Weighted PAR		Fatality Rate	Weighted PLL	
		Day	Night		Day	Night
Daily Inspections	7.000	0.083	-	0.8	0.067	-
Weekly Inspections	4.000	0.048	-	0.8	0.038	-
Monthly Inspections	0.462	0.005	-	0.8	0.004	-
Annual Surveillance Inspections	0.962	0.011	-	0.8	0.009	-
SCP Pump Maintenance	4.000	0.048	-	0.8	0.038	-
Environmental Sampling	1.385	0.016	-	0.8	0.013	-
Land Owner Inspections	0.231	0.003	-	0.8	0.002	-
Drilling	0.462	0.005	-	0.8	0.004	-
Ad hoc Inspections	0.924	0.011	-	0.8	0.009	-
Little Eva Pit	840.000	10.000	10.000	0.01	0.100	0.100
Total PAR		10.231	10.000	**Total PLL**	0.285	0.100

6.4 General Environmental Harm

The DETSI Manual **[1]** requires that consequence category assessments are undertaken in consideration of the following 'environmental harms':

- Harms to humans;
- General environmental harm; and
- General economic loss or property damage.

When considering general environmental harm, the receiving environment for the failure of a structure includes, but is not limited to, ephemeral waterways; creeks; and rivers. The main receiving environment for the Stage 3 TSF includes:

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- Unnamed tributary of Cabbage Tree Creek; and
- Cabbage Tree Creek.

Cabbage Tree Creek flows to the Leichardt River 36 km downstream of the TSF.

In accordance with the DETSI Manual **[1]**, a general environmental harm assessment is concerned with effects to areas with 'Significant Values' and 'Moderate Values' within the receiving environment. The values are defined as follows:

- Significant Values
  - Matters of National Environmental Significance (MNES)
  - Matters of State Environmental Significance (MSES)
  - High Ecological Value (HEV) waters as per the Queensland Environmental Protection (Water) Policy 2009 (EPP Water)
- Moderate Values
  - Slightly or moderately disturbed waters as per the EPP Water,
  - Wetland of general ecological significance (GES) as mapped on the Queensland Government referable wetland mapping,
  - Riverine areas, springs or lakes and associated flora and fauna.

An assessment of the general environmental harm from an overtopping scenario was carried out as part of the 2022 Consequence Category and Design Storage Allowance Review **[21]**. The following section summarises the outcomes from this assessment in the context of a Stage 3 dam break scenario.

6.4.1 Matters of National Environmental Significance

The Protected Matter Report (PMR) **[22]** for the project area is provided in **Appendix B.** The report lists the MNES that may occur within the estimated inundation extents.

There are no World Heritage Properties, National Heritage Places, Wetlands of International Importance, Great Barrier Reef Marine Park, Commonwealth Marine Areas, or Listed Threatened Ecological Communities listed for the receiving environment in the PMR.

The PMR identifies 17 Listed Threatened Species and 12 Listed Migratory Species within the potential receiving environment. The Listed Threatened Species identified in the PMR are summarised in **Table 15**.

TABLE 15 – MNES LISTED THREATENED SPECIES

Species ID	Common Name	Class	Threatened Category
856	Curlew Sandpiper	Bird	Critically Endangered
59350	Night Parrot	Bird	Endangered
1568	Mertens' Water Monitor, Mertens's Water Monitor	Reptile	Endangered
77037	Australian Painted Snipe	Bird	Endangered
942	Red Goshawk	Bird	Endangered
67197	Gulf Snapping Turtle	Reptile	Endangered
558	Carpentarian Grasswren	Bird	Endangered

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90091	Gouldian Finch	Bird	Endangered
60756	Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish	Shark	Vulnerable
305	Julia Creek Dunnart	Mammal	Vulnerable
282	Greater Bilby	Mammal	Vulnerable
863	Latham's Snipe, Japanese Snipe	Bird	Vulnerable
83821	Plains Death Adder	Reptile	Vulnerable
929	Grey Falcon	Bird	Vulnerable
470	Painted Honeyeater	Bird	Vulnerable
174	Ghost Bat	Mammal	Vulnerable
874	Sharp-tailed Sandpiper	Bird	Vulnerable

6.4.2 Matters of State Environmental Significance

There are several areas of Matters of State Environmental Significance (MSES) **[23]** within ML90211 (which extends 1.2 km to the west of the TSF) and Lot 59 on TG40, which extends 11 km to the north of the TSF pertaining to:

- Regulated vegetation (intersecting a watercourse) along the unnamed tributary of Cabbage Tree Creek; and
- Regulated vegetation (essential habitat) downstream of the TSF on the unnamed tributary of Cabbage Tree Creek and along Cabbage Tree Creek.

These areas are shown in the MSES documentation in **Appendix C – Map 4**.

6.4.3 High Ecological Value Wetlands and Waterways

Assessment of the available data MSES data **[23]** (**Appendix C**) showed that no High Ecological Value (HEV) wetlands or waterways were identified in the receiving environment within ML90211 and Lot 59 on TG40.

6.4.4 Aquatic Conservation Significance

Cabbage Tree Creek (and its unnamed tributary on which the TSF is located) is in the Northwest Highlands bioregion, the Mount Isa Inlier subregion, which falls within the Flinders and Leichardt River catchments. Cabbage Tree Creek and its unnamed tributary were assessed against the characteristics for riverine areas, lakes and springs, as per the Queensland Government Wetland Maps **[23]**.

Review of the available wetland mapping, MNES **[22]**, MSES **[23]**, Biodiversity and Conservation Values **[24]** and Regional Ecosystems **[25]** identified riverine waterbodies along the unnamed tributary of Cabbage Tree Creek and Cabbage Tree Creek.

Cabbage Tree Creek and its unnamed tributary were identified as areas of 'Medium' riverine subcatchment significance as depicted in **Appendix D – Map 5**. 'Medium' riverine values refer to riverine wetlands in deep-water habitat in a natural or artificial channel.

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6.4.5 Groundwater Supply

An assessment of the local registered private boreholes within ML90211 and Lot 59 on TG40 was carried out in 2022 **[21]** and is summarised in **Table 16**. The identified boreholes to the west of the TSF and are shown on

Map 3.

TABLE 16 – REGISTERED LOCAL BOREHOLES ON ML90211 AND LOT 59 ON TG40

Local Bore Locations and Details				
Bore[1]	**Coordinates (GDA94, Zone 54)**	**Location on Site**	**Date Drilled**	**Type/Role**
RN7082	404621 E 7765062 N	4.7 km west northwest of TSF	No data	Sub-Artesian Facility, Abandoned/Destroyed
RN13684	400858 E 7768422 N	9.5 km northwest of TSF	2/07/1958	Sub-Artesian Facility
RN13728	401452 E 7761047 N	7.9 km west south of TSF	28/07/1958	Sub-Artesian Facility, Abandoned/Destroyed
RN37118	400860 E 7768115 N	9.5 km northwest of TSF	14/12/1971	Sub-Artesian Facility
RN38685	407250 E 7767382 N	4.2 km north northwest of TSF	1/01/1972	Sub-Artesian Facility
RN51644	400442 E 7765038 N	8.6 km west of TSF	1/01/1982	Sub-Artesian Facility
RN93944	403422 E 7756784 N	8.7 km southwest of TSF	6/10/2004	Sub-Artesian Facility
RN118594	402946 E 7761669 N	6.4 km west southwest of TSF	7/10/2004	Sub-Artesian Facility
RN146106	408287 E 7763224 N	790 m west of TSF	25/11/2008	Sub-Artesian Facility
RN146107	408537 E 7763364 N	510 m west of TSF	26/11/2008	Sub-Artesian Facility
RN163656	409148 E 7763508 N	120 m east of TSF	1/12/2010	Sub-Artesian Facility
RN163657	409149 E 7763509 N	120 m east of TSF	1/12/2010	Sub-Artesian Facility
RN163658	408956 E 7763501 N	At base of TSF	1/12/2010	Sub-Artesian Facility
RN163659	408958 E 7763502 N	At base of TSF	1/12/2010	Sub-Artesian Facility
RN163660	408724 E 7763433 N	310 m west of TSF	1/12/2010	Sub-Artesian Facility
RN163661	408723 E 7763433 N	310 m west of TSF	1/12/2010	Sub-Artesian Facility

Note 1: Details provided by Queensland Globe **[26]** and Business Queensland **[27]**. Accessed 29 July 2022.

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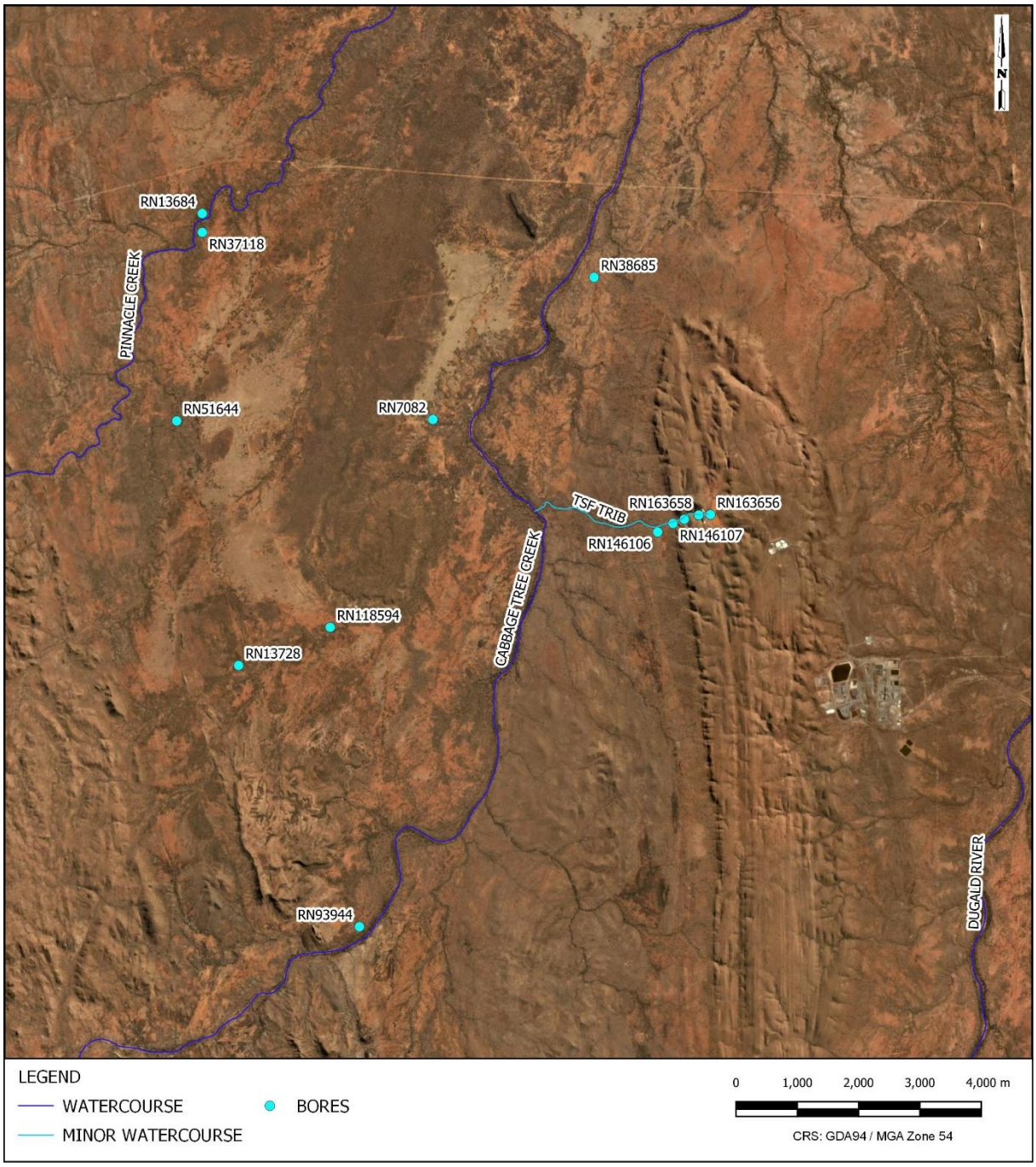
MAP 3 – BORES TO THE WEST OF THE TSF AND WITHIN CABBAGE TREE CREEK



6.5 DETSI Consequence Category

The DETSI Manual **[1]** sets out the requirements for consequence category assessments for the following failure event scenarios:

- 'Failure to contain – seepage': concerning spills or releases to ground and/or groundwater via seepage from the floor and/or sides of the structure;
- 'Failure to contain – overtopping': concerning spills or releases from the structure that result from loss of containment due to overtopping of the structure; and
- 'Dam break': concerning collapse of the structure due to any possible cause.

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A review of the 'failure to contain – overtopping' scenario was carried out in 2022 **[21]**. It is considered that the outcomes from this study are also representative of the Stage 3 geometry. A summary of the outcomes from the 2022 study, alongside assessments for the 'failure to contain – seepage' and 'dam break' scenarios is provided in **Table 17**.

TABLE 17 – DETSI CONSEQUENCE CATEGORY ASSESSMENT (STAGE 3)

Failure Scenario	Harm Category	Consequence Category	Rationale
Failure to Contain - Seepage	Harm to humans	LOW	Contamination of water used for human consumption is not expected to occur as a result of impoundment seepage (**Section 5.3**).
	General environmental	LOW	Seepage from the Knapdale Valley TSF impoundment entering the Cabbage Tree Creek catchment is not expected (**Section 5.3**).
	General economic loss	LOW	No risk of harm to third party assets costing > $1M.
Failure to Contain - Overtopping	Harm to humans	LOW	Overtopping flows (uncontrolled spillway release) would not impact public roads or areas where non-site personnel would be expected to be routinely present. Bores located within the overtopping failure impact zone are not used for human consumption.
	General environmental	**SIGNIFICANT**	Overtopping flows (uncontrolled spillway release) would be directed to the unnamed tributary of Cabbage Tree Creek and Cabbage Tree Creek. These watercourses contain MSES. There are also areas of state biodiversity significance which may be impacted. Impacts would likely involve remediation of damage that takes more than 6 months but less than 3 years; and result in an impact area of between 1 km^2 to 5 km^2.
	General economic loss	LOW	No risk of harm to third party assets costing > $1M.
Dam Break	Harm to humans	LOW	People are routinely in the failure path (Little Eva Pit) however loss of life is not expected. Estimated PLL of <1 as discussed in **Section 6.3.**
	General environmental	**HIGH**	Dam break flows would be directed to the unnamed tributary of Cabbage Tree Creek and Cabbage Tree Creek. These watercourses contain MSES. There are also areas of state biodiversity significance which may be impacted. Impacts would likely involve permanent alteration to existing ecosystems; and result in an impact area of greater than 5 km^2.
	General economic loss	**HIGH**	Dam break flows are estimated to reach the Little Eva Pit diversion drain and flood protection levee. Some overtopping of the flood protection levee is expected. The harm to these third-party assets is estimated to require $10M or more in rehabilitation, compensation, repair, or rectification costs.

Hence, the overall assigned DETSI Consequence Categories for both the Base Case and Sensitivity Case are as follows:

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- Failure to Contain – Seepage: **'Low**'
- Failure to Contain – Overtopping: **'Significant'**
- Dam Break: **'High'**

6.6 ANCOLD Consequence Category

6.6.1 Severity of Damage and Loss

A severity level impact assessment has been carried out for the Base Case and Sensitivity assessments. The estimation of the severity of damage and loss has been determined in accordance with the ANCOLD Consequence Category Guidelines **[2]**.

This method requires the grouping of the potential severity of damage and losses into like consequences related to:

- Total infrastructure costs;
- Impact on dam owner's business;
- Health and social impacts; and
- Environmental impacts.

Estimates of the Severity of Damage and Loss for the Base Case and Sensitivity Case are presented in **Table 18**.

A 'Medium' severity has been selected for estimating the total infrastructure costs for both the Base Case and Sensitivity Case. This represents the potential damage and subsequent repair of the TSF embankment; Seepage Collection System; access roads; and the Little Eva Pit diversion drain and flood protection levee.

A 'Major' severity has been selected for estimating the total impact on MMG's operations for both the Base Case and the Sensitivity Case. This represents the fact that the DRM will no longer be able to operate following the failure and loss of function of the TSF.

A 'Minor' severity has been selected for estimating the health and social impacts for both the Base Case and Sensitivity Case. This represents the fact that there are no areas of human habitation or infrastructure within the estimated inundation footprint.

A 'Major' severity has been selected for estimating the environmental impacts for both the Base Case and Sensitivity Case. This represents an estimated impact area of less than 20 km^2 and significant effects on MSES. It should be noted that the impact area defined by ANCOLD excludes land prone to natural flooding (i.e., the Unnamed tributary of Cabbage Tree Creek and Cabbage Tree Creek).

An overall severity of damage and loss of 'Major' has been selected for both the Base Case and Sensitivity Case.

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TABLE 18 – DAM FAILURE SEVERITY OF DAMAGE AND LOSS (ANCOLD)

Damage Type	Minor	Medium	Major	Catastrophic
Infrastructure (dam, houses, commerce, farms, community)	<$10M	$10M - $100M	$100M - $1B	>$1B
Business importance	Some restrictions	Significant impacts	Severe to crippling	Business dissolution, bankruptcy
Public health	<100 people affected	100 - 1000 people affected	<1000 people affected for more than one month	>10,000 people affected for over one year
Social dislocation	<100 person or <20 business months	100 – 1000 person months or 20 – 2000 business months	>1000 person months or >200 business months	>10,000 person months or numerous business failure
Impact area	<1km^2	<5km^2	<20km^2	>20km^2
Impact duration	<1 (wet) year	<5 years	<20 years	>20 years
Impact on natural environment	Damage limited to items of low conservation value (e.g., degraded or cleared land, ephemeral streams, non-endangered flora and fauna). Reclamation possible	Significant effects on rural land and local flora & fauna. Limited effects on: A. Item(s) of local & state natural heritage B. Native flora and fauna within forestry, aquatic and conservation reserves, or recognised habitat corridors, wetlands or fish breeding areas	Extensive rural effects. Significant effects on river system and areas A & B. Limited effects on: C. Item(s) of National or World natural heritage D. Native flora and fauna within national parks, recognised wilderness areas, RAMSAR wetlands and nationally protected aquatic reserves. Remediation difficult	Extensively effects areas A & B. Significantly affects areas C & D. Remediation involves significantly altered ecosystems.

6.6.2 Dam Failure Consequence Category

The ANCOLD Dam Failure Consequence Category is determined by evaluating the consequences of a dam failure resulting in the release of stored water and tailings. The Dam Failure Consequence Category has been assessed based on the PLL assessment (**Table 19**).

The DRM TSF Stage 3 dam failure consequence category, in accordance with **Table 19**, given a PLL < 1 and a 'Major' severity of damage or loss is **'High C'** for both the Base Case and Sensitivity Case.

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TABLE 19 – ASSESSED ANCOLD DAM FAILURE CONSEQUENCE CATEGORY

Potential Loss of Life (PLL)	Severity of Damage and Loss			
	Minor	Medium	Major	Catastrophic
<0.1	Very Low	Low	Significant	High C
≥0.1 to <1	Significant	Significant	High C	High B
≥1 to <5	(Note 1)	High C	High B	High A
≥5 to <50		High A (Note 2)	High A	Extreme
≥50		(Note 1)	Extreme	Extreme

Note 1: With a PLL equal to or greater than one (1), it is unlikely Damage will be minor. Similarly with a PLL in excess of 50 it is unlikely Damage will be classified as Medium.
Note 2: Where PLL is in the range ≥5 to<10, the Category level can be reduced to High B.

6.6.3 Environmental Spill Consequence Category

The ANCOLD Environmental Spill Consequence Category is determined by evaluating the consequences of spilling of water from the dam during a flood event or extreme wet weather period.

An overall severity of damage and loss is assessed to be 'Medium' in consideration of the potentially acidic decant water and the presence of MSES within the receiving environment; and the estimated impact area of between 1 km^2 to 5 km^2 based on the 2022 study for Stage 2 **[21]**.

No loss of life is expected as water spilling from the facility is controlled by the emergency spillway.

Hence an Environmental Spill Consequence Category of **'Low'** is considered appropriate for the DR Stage 3 TSF as summarised in **Table 20**.

TABLE 20 – ASSESSED ANCOLD ENVIRONMENTAL SPILL CONSEQUENCE CATEGORY

Potential Loss of Life (PLL)	Severity of Damage and Loss			
	Minor	Medium	Major	Catastrophic
<0.1	Very Low	Low	Significant	High C
≥0.1 to <1	Significant	Significant	High C	High B
≥1 to <5	(Note 1)	High C	High B	High A
≥5 to <50		High A (Note 2)	High A	Extreme
≥50		(Note 1)	Extreme	Extreme

Note 1: With a PLL equal to or greater than one (1), it is unlikely Damage will be minor. Similarly with a PLL in excess of 50 it is unlikely Damage will be classified as Medium.
Note 2: Where PLL is in the range ≥5 to<10, the Category level can be reduced to High B.

6.7 GISTM Consequence Category

The GISTM consequence category assessment methodology considers the resulting incremental losses to the environment, community, infrastructure and economics, and the potential PAR and PLL.

The GISTM consequence category assessment is summarised in **Table 21** in consideration of the commentary provided in **Section 6.5** and **Section 6.6**.

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TABLE 21 – ASSESSED GISTM CONSEQUENCE CATEGORY

Dam Failure CC	Incremental Losses				
	PAR	PLL	Environment	Health, Social and Cultural	Infrastructure and Economics
Low	None	None expected	Minimal short-term loss or deterioration of habitat or rare and endangered species.	Minimal effects and disruption of business and livelihoods. No measurable effect on human health. No disruption of heritage, recreation, community or cultural assets.	Low economic losses: area contains limited infrastructure or services. <US$1M
Significant	1–10	Unspecified	No significant loss or deterioration of habitat. Potential contamination of livestock/fauna water supply with no health effects. Process water low potential toxicity. Tailings not potentially acid generating and have low neutral leaching potential. Restoration possible within 1 to 5 years.	Significant disruption of business, service or social dislocation. Low likelihood of loss of regional heritage, recreation, community, or cultural assets. Low likelihood of health effects.	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes. <US$10M.
High	10–100	Possible (1–10)	Significant loss or deterioration of critical habitat or rare and endangered species. Potential contamination of livestock/ fauna water supply with no health effects. Process water moderately toxic. Low potential for acid rock drainage or metal leaching effects of released tailings. Potential area of impact 10 km^2 – 20 km^2. Restoration possible but difficult and could take > 5 years.	500-1,000 people affected by disruption of business, services or social dislocation. Disruption of regional heritage, recreation, community or cultural assets. Potential for short term human health effects.	High economic losses affecting infrastructure, public transportation, and commercial facilities, or employment. Moderate relocation/compensation to communities. <US$100M.
Very High	100–1,000	Likely (10 – 100)	Major loss or deterioration of critical habitat or rare and endangered species. Process water highly toxic. High potential for acid rock drainage or metal leaching effects from released tailings. Potential area of impact > 20 km^2. Restoration or compensation possible but very difficult and requires a long time (5 years to 20 years).	1,000 people affected by disruption of business, services or social dislocation for more than one year. Significant loss of national heritage, community or cultural assets. Potential for significant long-term human health effects.	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities, for dangerous substances), or employment. High relocation/ compensation to communities. < US$1B

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Dam Failure CC	Incremental Losses				
	PAR	PLL	Environment	Health, Social and Cultural	Infrastructure and Economics
Extreme	> 1,000	Many (> 100)	Catastrophic loss of critical habitat or rare and endangered species. Process water highly toxic. Very high potential for acid rock drainage or metal leaching effects from released tailings. Potential area of impact > 20 km^2. Restoration or compensation in kind impossible or requires a very long time (> 20 years).	5,000 people affected by disruption of business, services or social dislocation for years. Significant National heritage or community facilities or cultural assets destroyed. Potential for severe and/or long- term human health effects.	Extreme economic losses affecting critical infrastructure or services, (e.g., hospital, major industrial complex, major storage facilities for dangerous substances) or employment. Very high relocation/compensation to communities and very high social readjustment costs. >US$1B

6.8 Consequence Category Summary

A summary of the adopted Consequence Categories is provided in **Table 22**.

TABLE 22 – ASSESSED CONSEQUENCE CATEGORY SUMMARY

Methodology	Scenario	Base Case	Sensitivity Case
DETSI	Failure to Contain - Seepage	**Low**	
	Failure to Contain – Overtopping	**Significant**	
	Dam Break	**High**	**High**
ANCOLD	Dam Failure	**High C**	**High C**
	Environmental Spill	**Low**	
GISTM	Consequence Classification	**High**	**High**

7 DISCUSSION AND CONCLUSIONS

In consideration of the dam break assessment outcomes discussed above, the following should be noted:

- The resolution of the downstream topography between the Unnamed Tributary / Cabbage Tree Creek confluence and the Little Eva Pit infrastructure (and beyond) is limited. In particular, the Cabbage Tree Creek watercourse is not accurately defined, specifically at the tie-in with the proposed Little Eva Pit diversion drains. Better resolution of Cabbage Tree Creek may result in the dam break flows being more confined within the creek banks than the current results indicate, and hence less potential for overtopping of the proposed flood protection levee.
- The current dam break modelling results incorporate the design tailings beach from the Stage 3 Detailed Design, which makes assumptions on the achieved tailings beach slopes and the total stored volumes at the end of deposition. It is recommended that the dam break assessment is updated in the future under a separate work scope if the achieved tailings beach slopes and the stored tailings volumes are notably different to the Stage 3 design assumptions.

TAILINGS.WATER.WASTE.

- The specific gravity and rheological properties of the tailings have been derived from laboratory testing on thickener underflow samples and are unlikely to differ significantly with time. However, the assumed OID and post-liquefied shear strength parameters have the potential to influence the released volumes and flow characteristics of the tailings. Conservative estimates of these parameters have been adopted for the purpose of the current dam break assessments. However, it is likely that the achieved densities and shear strength characteristics will improve with time as tailings consolidation occurs and more sub-aerial deposition is carried out. If efforts are successful to reduce the decant pond size, it is recommended that CPT field investigation is carried out through the exposed tailings beach to inform the density and shear strength profiles within the tailings deposit to confirm these assumptions. It is likely that the results of the CPT investigation would improve the angle of the post-failure tailings backscarp and consequently reduce the estimated released volumes.
- The results of the Sensitivity Case assessments indicate that the Consequence Category assessments **are not sensitive** to the assumed released volumes – and by extension, the assumed failure height. However, the Consequence Category assessment may be sensitive to the assumed number of Harmony personnel frequenting the Little Eva Pit area. It is recommended that the assumptions made in this Consequence Category assessment be reviewed frequently to ensure that they are representative and current.

8 CLOSURE

Your attention is drawn to the “Conditions of Report” which are located at the end of this document.

TAILINGS.WATER.WASTE.

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TAILINGS.WATER.WASTE.

FIGURES

7760000N
7765000N
7770000N
7775000N
405000E
410000E
415000E
N
CABBAGE TREE CREEK
PINNACLE CREEK
LAKE JULIUS ACCESS ROAD
PROPOSED HARMONY SOLAR FARM
EXTENTS OF LiDAR SURVEY
TAILINGS STORAGE FACILITY
MINE CAMP
MINE AREA
POWER CORRIDOR
PROPOSED DIVERSION DRAIN
PROPOSED LITTLE EVA PIT
DUGALD RIVER
0 1,000 2,000 3,000 4,000 m
CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND
- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee
- Lease Boundary

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

LOCALITY PLAN

ATC WILLIAMS

FIGURE 1

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:50000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762000N 7763000N 7764000N

409000E 409000E

410000E 410000E

PROPOSED STAGE 3 SEEPAGE COLLECTION SUMP

PROPOSED STAGE 3 SPILLWAY

PROPOSED STAGE 3 EMBANKMENT

NORTHERN DISCHARGE BUND

TAILINGS STORAGE FACILITY

RETURN WATER SYSTEM

0 200 400 600 800 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND
- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Full Supply Level (RL 251.35 m)
- Lease Boundary

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

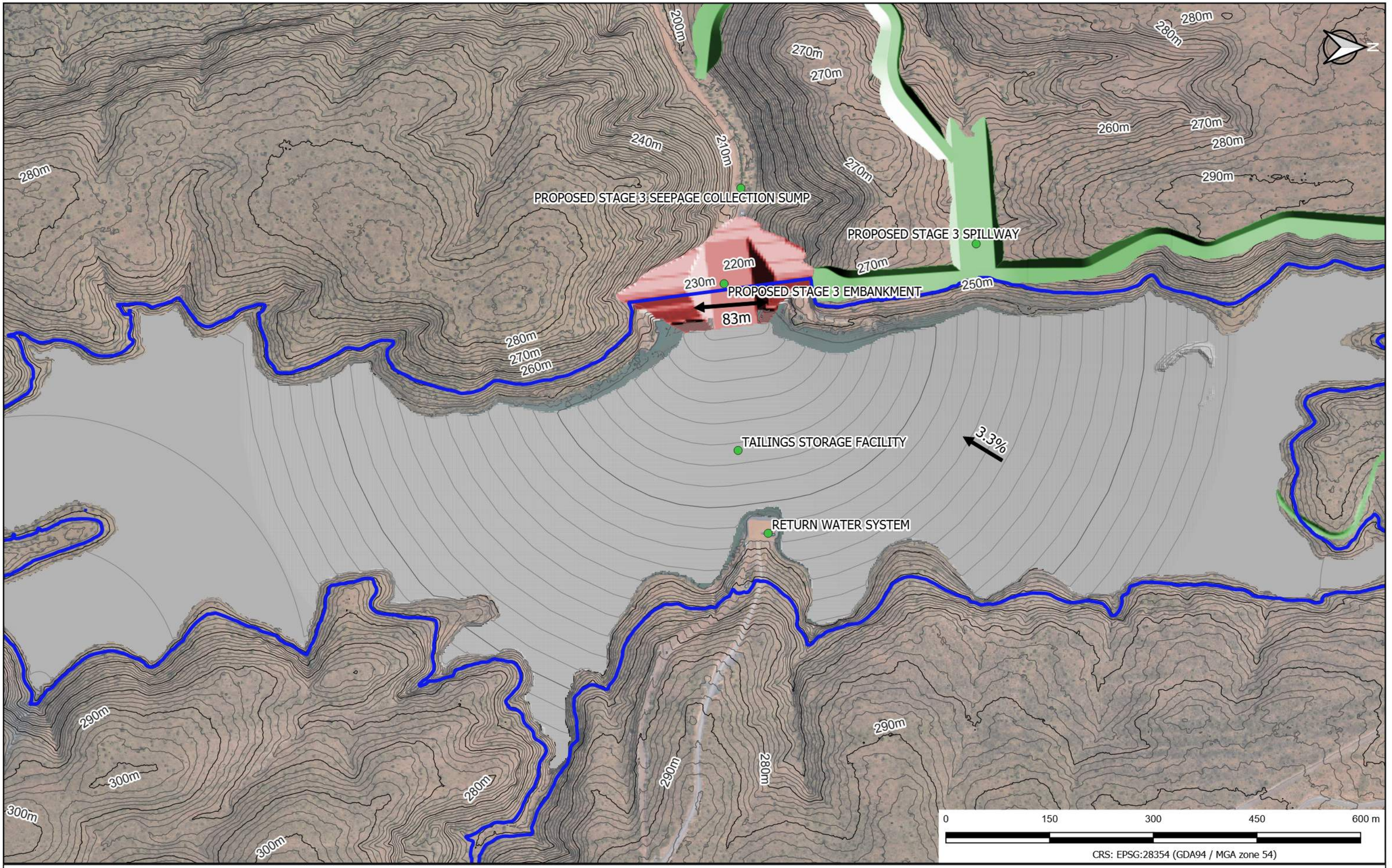
GENERAL ARRANGEMENT

ATC WILLIAMS

FIGURE 2

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:7500 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz



LEGEND
- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Full Supply Level (RL 251.35 m)

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TAILINGS STORAGE FACILITY - STAGE 3

SDF BREACH LAYOUT (BASE CASE)

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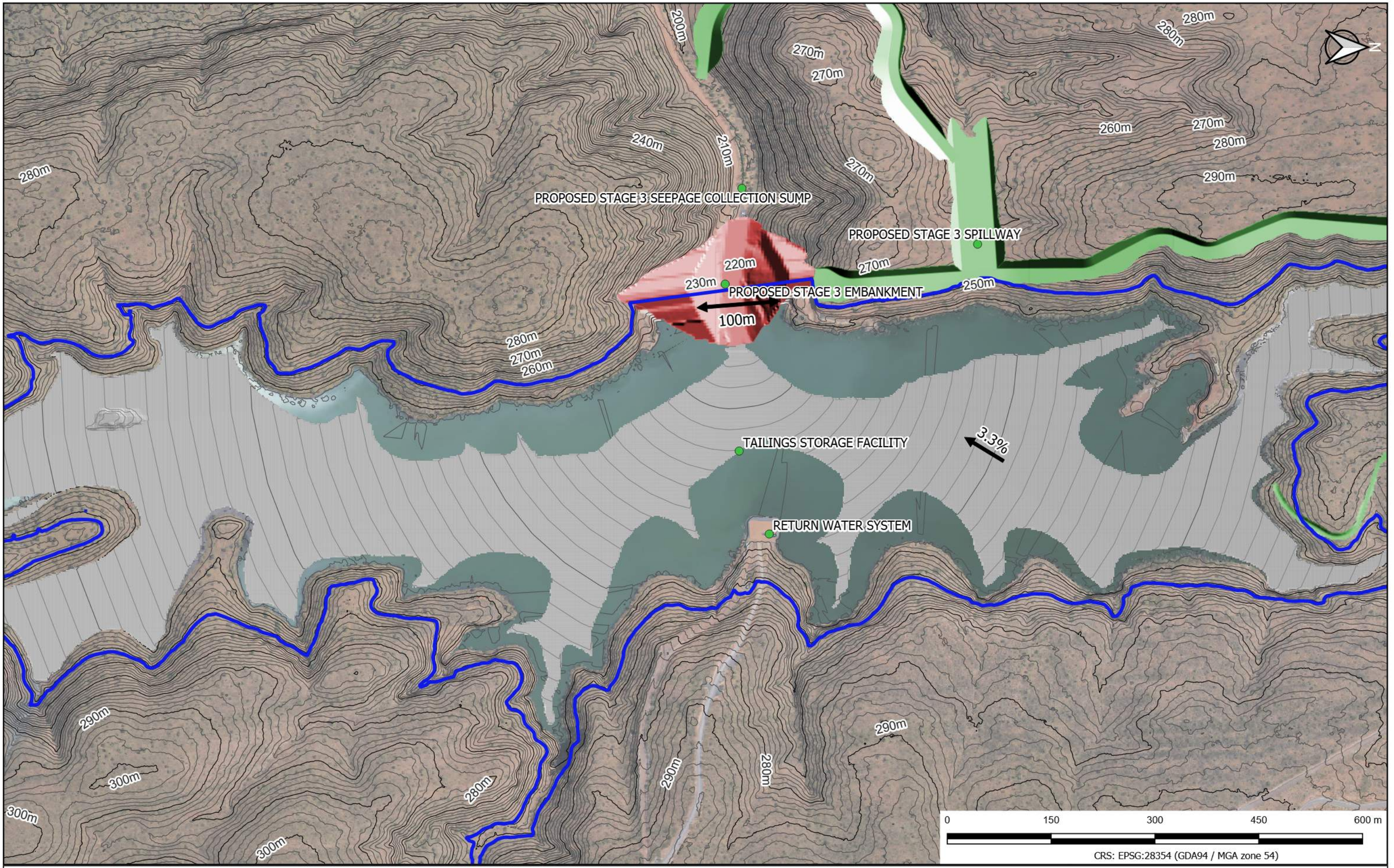
FIGURE 3
JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:5000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz



LEGEND
- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Full Supply Level (RL 251.35 m)

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TAILINGS STORAGE FACILITY - STAGE 3

SDF BREACH LAYOUT (SENSITIVITY CASE)

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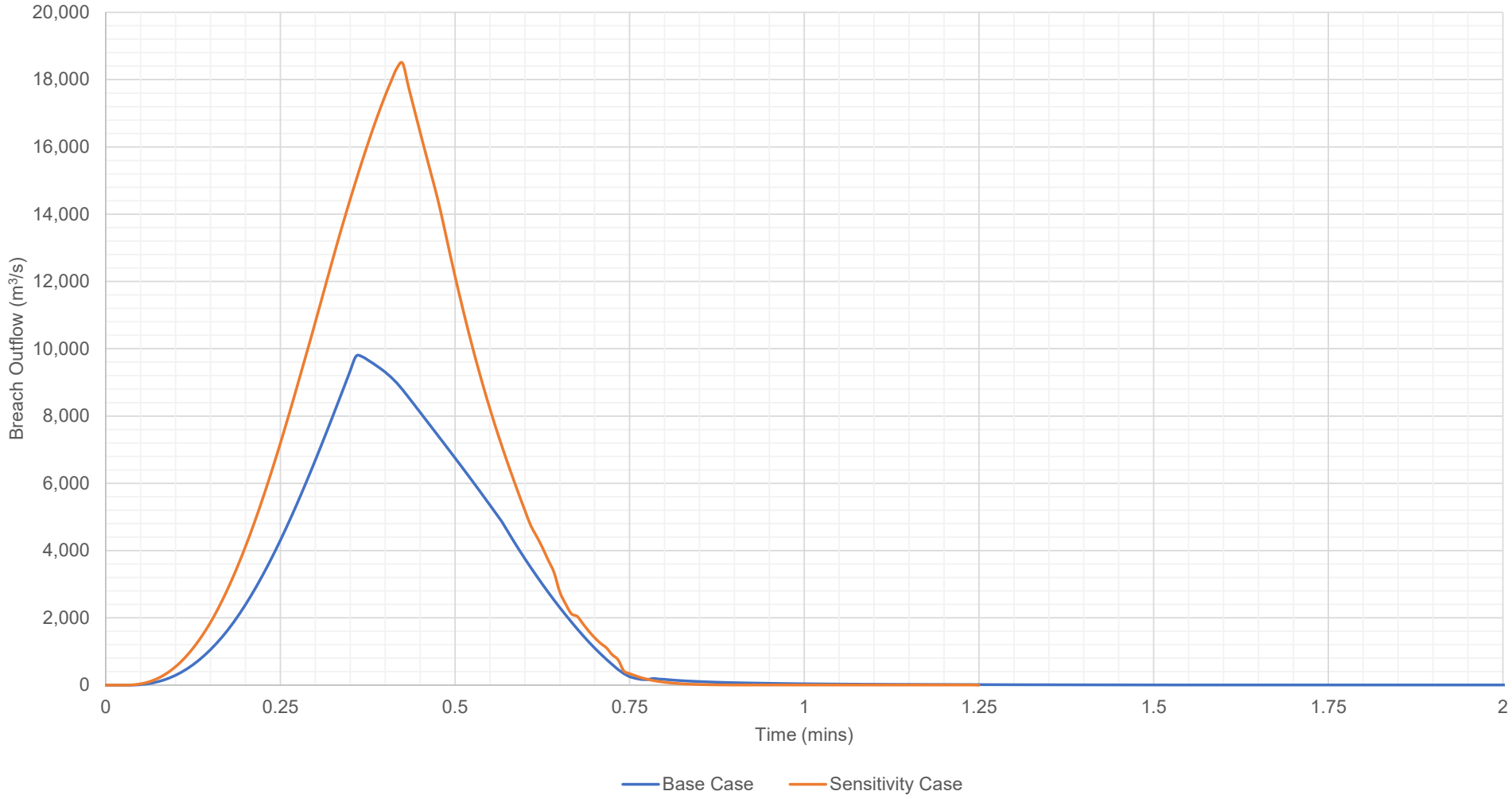
FIGURE 4

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:5000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz



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TAILINGS STORAGE FACILITY - STAGE 3

DAM BREAK HYDROGRAPHS

Date: 19/06/2025 **Job No:** 250542.00

FIGURE 5

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\TDBA Summary and Calcs Dugald v2 Breach Hydrograph

7760000N
7770000N
7780000N
7790000N
400000E
410000E
420000E
N
PINNACLE CREEK
CABBAGE TREE CREEK
LAKE JULIUS ACCESS ROAD
TAILINGS STORAGE FACILITY
MINE CAMP
PROPOSED DIVERSION DRAIN
PROPOSED LITTLE EVA PIT
MINE AREA
REFER FIGURE 7
PROPOSED HARMONY SOLAR FARM
KAJABBI NORMANTON RD
LEICHHARDT RIVER
SALLY CREEK
DUGALD RIVER
0
2,500
5,000
7,500
10,000 m
CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Depth

- <= 0.3 m
- 0.3 - 1.0 m
- 1.0 - 2.0 m
- 2.0 - 3.0 m
- 3.0 - 4.0 m
- 4.0 - 5.0 m
- 5.0 - 6.0 m
- 6.0 - 7.0 m
- > 7.0 m

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TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM INUNDATION DEPTH (1 OF 2)

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FIGURE 6

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

PROPOSED HARMONY SOLAR FARM

LAKE JULIUS ACCESS ROAD

EXTENTS OF LIDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

N

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Depth

- <= 0.3 m
- 0.3 - 1.0 m
- 1.0 - 2.0 m
- 2.0 - 3.0 m
- 3.0 - 4.0 m
- 4.0 - 5.0 m
- 5.0 - 6.0 m
- 6.0 - 7.0 m
- > 7.0 m

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TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM INUNDATION DEPTH (2 OF 2)

ATC WILLIAMS

FIGURE 7

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

TAILINGS STORAGE FACILITY

MINE CAMP

MINE AREA

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

REFER FIGURE 9

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

SALLY CREEK

DUGALD RIVER

N

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Velocity

- <= 0.5 m/s
- 0.5 - 1.0 m/s
- 1.0 - 1.5 m/s
- 1.5 - 2.0 m/s
- 2.0 - 2.5 m/s
- 2.5 - 3.0 m/s
- 3.0 - 3.5 m/s
- 3.5 - 4.0 m/s
- > 4.0 m/s

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DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM INUNDATION VELOCITY (1 OF 2)

ATC WILLIAMS

FIGURE 8

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

PROPOSED HARMONY SOLAR FARM

LAKE JULIUS ACCESS ROAD

EXTENTS OF LIDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Velocity

- <= 0.5 m/s
- 0.5 - 1.0 m/s
- 1.0 - 1.5 m/s
- 1.5 - 2.0 m/s
- 2.0 - 2.5 m/s
- 2.5 - 3.0 m/s
- 3.0 - 3.5 m/s
- 3.5 - 4.0 m/s
- > 4.0 m/s

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DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM INUNDATION VELOCITY (2 OF 2)

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FIGURE 9

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

MINE AREA

REFER FIGURE 11

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

SALLY CREEK

DUGALD RIVER

N

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Depth x Velocity

- <= 1.0 m2/s
- 1.0 - 2.0 m2/s
- 2.0 - 4.0 m2/s
- 4.0 - 6.0 m2/s
- 6.0 - 8.0 m2/s
- 8.0 - 10.0 m2/s
- 10.0 - 15.0 m2/s
- 15.0 - 20.0 m2/s
- > 20.0m2/s

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DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM DEPTH TIMES VELOCITY (1 OF 2)

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FIGURE 10

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

PROPOSED HARMONY SOLAR FARM

LAKE JULIUS ACCESS ROAD

EXTENTS OF LIDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Depth x Velocity

- <= 1.0 m2/s
- 1.0 - 2.0 m2/s
- 2.0 - 4.0 m2/s
- 4.0 - 6.0 m2/s
- 6.0 - 8.0 m2/s
- 8.0 - 10.0 m2/s
- 10.0 - 15.0 m2/s
- 15.0 - 20.0 m2/s
- > 20.0m2/s

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DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM DEPTH TIMES VELOCITY (2 OF 2)

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FIGURE 11

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

MINE AREA

REFER FIGURE 13

SALLY CREEK

DUGALD RIVER

N

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Time For 300 mm Inundation

- <= 0.5 hr
- 0.5 - 1.0 hr
- 1.0 - 2.0 hr
- 2.0 - 4.0 hr
- 4.0 - 6.0 hr
- 6.0 - 8.0 hr
- 8.0 - 10.0 hr
- 10.0 - 12.0 hr
- 12.0 - 24.0 hr

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TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
TIME FOR 300 mm INUNDATION (1 OF 2)

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FIGURE 12

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

EXTENTS OF LIDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Time For 300 mm Inundation

- <= 0.5 hr
- 0.5 - 1.0 hr
- 1.0 - 2.0 hr
- 2.0 - 4.0 hr
- 4.0 - 6.0 hr
- 6.0 - 8.0 hr
- 8.0 - 10.0 hr
- 10.0 - 12.0 hr
- 12.0 - 24.0 hr

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TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
TIME FOR 300 mm INUNDATION (2 OF 2)

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FIGURE 13

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

MINE AREA

REFER FIGURE 15

SALLY CREEK

DUGALD RIVER

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Level (RL)

- <= 145 m
- 145 - 155 m
- 155 - 165 m
- 165 - 175 m
- 175 - 185 m
- 185 - 195 m
- 195 - 205 m
- 205 - 215 m
- > 215 m

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TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM INUNDATION LEVEL (1 OF 2)

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FIGURE 14

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

PROPOSED HARMONY SOLAR FARM

LAKE JULIUS ACCESS ROAD

EXTENTS OF LIDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

N

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Level (RL)

- <= 145 m
- 145 - 155 m
- 155 - 165 m
- 165 - 175 m
- 175 - 185 m
- 185 - 195 m
- 195 - 205 m
- 205 - 215 m
- > 215 m

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM INUNDATION LEVEL (2 OF 2)

ATC WILLIAMS

FIGURE 15

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

TAILINGS STORAGE FACILITY

MINE CAMP

MINE AREA

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

REFER FIGURE 17

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

SALLY CREEK

DUGALD RIVER

N

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Depth

- <= 0.3 m
- 0.3 - 1.0 m
- 1.0 - 2.0 m
- 2.0 - 3.0 m
- 3.0 - 4.0 m
- 4.0 - 5.0 m
- 5.0 - 6.0 m
- 6.0 - 7.0 m
- > 7.0 m

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM INUNDATION DEPTH (1 OF 2)

ATC WILLIAMS

FIGURE 16

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

PROPOSED HARMONY SOLAR FARM

LAKE JULIUS ACCESS ROAD

EXTENTS OF LiDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Depth

- <= 0.3 m
- 0.3 - 1.0 m
- 1.0 - 2.0 m
- 2.0 - 3.0 m
- 3.0 - 4.0 m
- 4.0 - 5.0 m
- 5.0 - 6.0 m
- 6.0 - 7.0 m
- > 7.0 m

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM INUNDATION DEPTH (2 OF 2)

ATC WILLIAMS

FIGURE 17

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

MINE AREA

REFER FIGURE 19

SALLY CREEK

DUGALD RIVER

N

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Velocity

- <= 0.5 m/s
- 0.5 - 1.0 m/s
- 1.0 - 1.5 m/s
- 1.5 - 2.0 m/s
- 2.0 - 2.5 m/s
- 2.5 - 3.0 m/s
- 3.0 - 3.5 m/s
- 3.5 - 4.0 m/s
- > 4.0 m/s

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM INUNDATION VELOCITY (1 OF 2)

ATC WILLIAMS

FIGURE 18

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

EXTENTS OF LiDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Velocity

- <= 0.5 m/s
- 0.5 - 1.0 m/s
- 1.0 - 1.5 m/s
- 1.5 - 2.0 m/s
- 2.0 - 2.5 m/s
- 2.5 - 3.0 m/s
- 3.0 - 3.5 m/s
- 3.5 - 4.0 m/s
- > 4.0 m/s

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM INUNDATION VELOCITY (2 OF 2)

ATC WILLIAMS

FIGURE 19

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

MINE AREA

REFER FIGURE 21

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

SALLY CREEK

DUGALD RIVER

N

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Depth x Velocity

- <= 1.0 m2/s
- 1.0 - 2.0 m2/s
- 2.0 - 4.0 m2/s
- 4.0 - 6.0 m2/s
- 6.0 - 8.0 m2/s
- 8.0 - 10.0 m2/s
- 10.0 - 15.0 m2/s
- 15.0 - 20.0 m2/s
- > 20.0m2/s

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM DEPTH TIMES VELOCITY (1 OF 2)

ATC WILLIAMS

FIGURE 20

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

EXTENTS OF LiDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Depth x Velocity

- <= 1.0 m2/s
- 1.0 - 2.0 m2/s
- 2.0 - 4.0 m2/s
- 4.0 - 6.0 m2/s
- 6.0 - 8.0 m2/s
- 8.0 - 10.0 m2/s
- 10.0 - 15.0 m2/s
- 15.0 - 20.0 m2/s
- > 20.0m2/s

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM DEPTH TIMES VELOCITY (2 OF 2)

ATC WILLIAMS

FIGURE 21

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

LEICHHARDT RIVER

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

MINE AREA

REFER FIGURE 23

SALLY CREEK

DUGALD RIVER

N

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Time For 300 mm Inundation

- <= 0.5 hr
- 0.5 - 1.0 hr
- 1.0 - 2.0 hr
- 2.0 - 4.0 hr
- 4.0 - 6.0 hr
- 6.0 - 8.0 hr
- 8.0 - 10.0 hr
- 10.0 - 12.0 hr
- 12.0 - 24.0 hr

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
TIME FOR 300 mm INUNDATION (1 OF 2)

ATC WILLIAMS

FIGURE 22

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

EXTENTS OF LIDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Time For 300 mm Inundation

- <= 0.5 hr
- 0.5 - 1.0 hr
- 1.0 - 2.0 hr
- 2.0 - 4.0 hr
- 4.0 - 6.0 hr
- 6.0 - 8.0 hr
- 8.0 - 10.0 hr
- 10.0 - 12.0 hr
- 12.0 - 24.0 hr

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
TIME FOR 300 mm INUNDATION (2 OF 2)

ATC WILLIAMS

FIGURE 23

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7760000N 7770000N 7780000N 7790000N

400000E 410000E 420000E

PINNACLE CREEK

CABBAGE TREE CREEK

LAKE JULIUS ACCESS ROAD

TAILINGS STORAGE FACILITY

MINE CAMP

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

MINE AREA

REFER FIGURE 25

PROPOSED HARMONY SOLAR FARM

LEICHHARDT RIVER

SALLY CREEK

DUGALD RIVER

0 2,500 5,000 7,500 10,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Level (RL)

- <= 145 m
- 145 - 155 m
- 155 - 165 m
- 165 - 175 m
- 175 - 185 m
- 185 - 195 m
- 195 - 205 m
- 205 - 215 m
- > 215 m

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM INUNDATION LEVEL (1 OF 2)

ATC WILLIAMS

FIGURE 24

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:100000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

7762500N 7765000N 7767500N 7770000N 7772500N

405000E 407500E 410000E

CABBAGE TREE CREEK

PINNACLE CREEK

N

EXTENTS OF LIDAR SURVEY

TAILINGS STORAGE FACILITY

MINE CAMP

LAKE JULIUS ACCESS ROAD

PROPOSED HARMONY SOLAR FARM

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

0 1,000 2,000 3,000 4,000 m

CRS: EPSG:28354 (GDA94 / MGA zone 54)

LEGEND

- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Watercourse
- Little Eva Levee

Max Inundation Level (RL)

- <= 145 m
- 145 - 155 m
- 155 - 165 m
- 165 - 175 m
- 175 - 185 m
- 185 - 195 m
- 195 - 205 m
- 205 - 215 m
- > 215 m

MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (SENSITIVITY CASE)
MAXIMUM INUNDATION LEVEL (2 OF 2)

ATC WILLIAMS

FIGURE 25

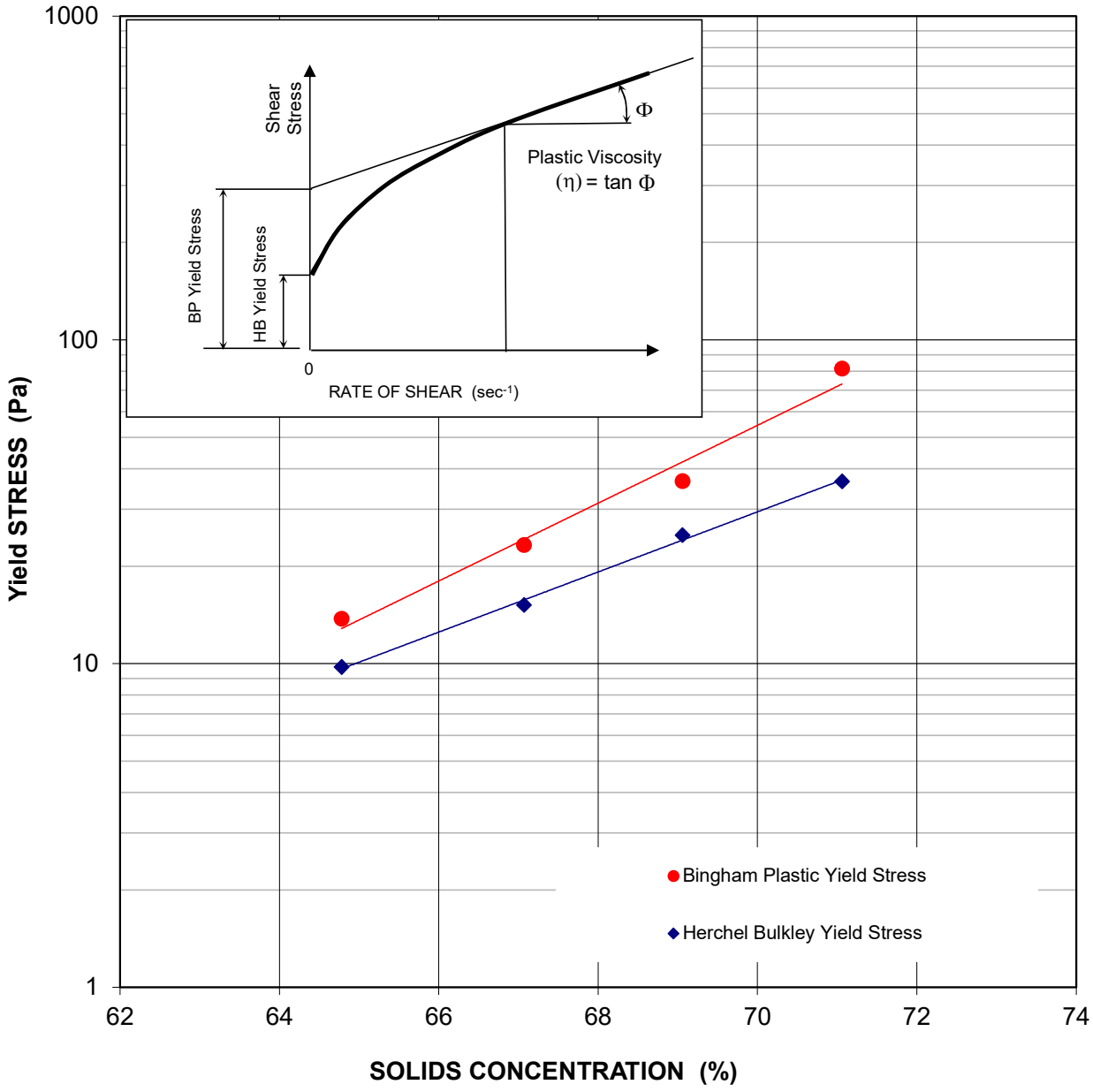
JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

APPENDICES

APPENDIX A – RHEOLOGY TESTING

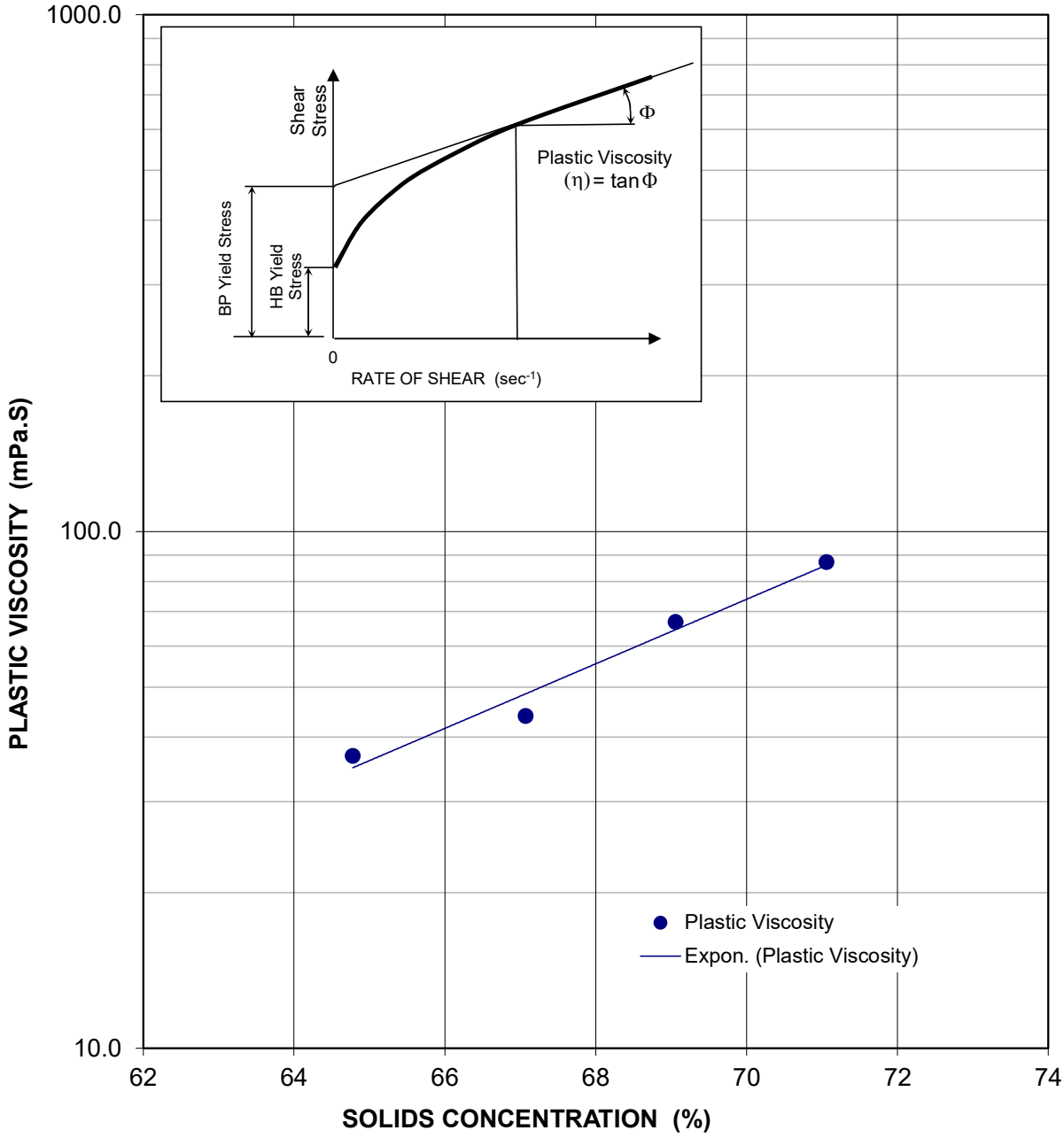
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Yield Stress Versus** **Solids Concentration**
ATC WILLIAMS ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 9**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/Rheology - 14325/14325 - Rheology Report

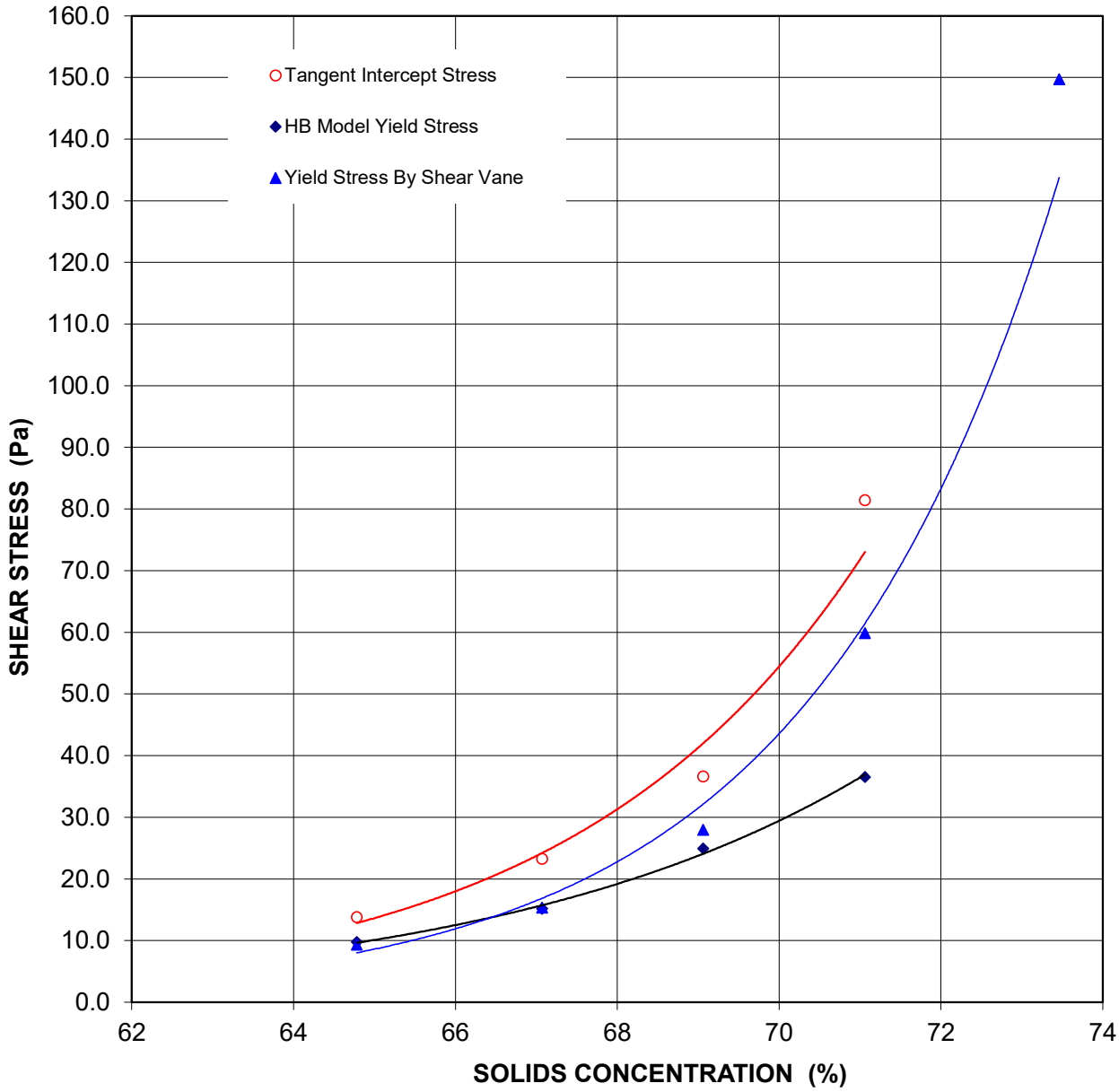
250542 - Dugald River TSF Raise Design
Sample No. 14325
PLASTIC VISCOSITY



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Plastic Viscosity Versus Solids Concentration**
ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 10**

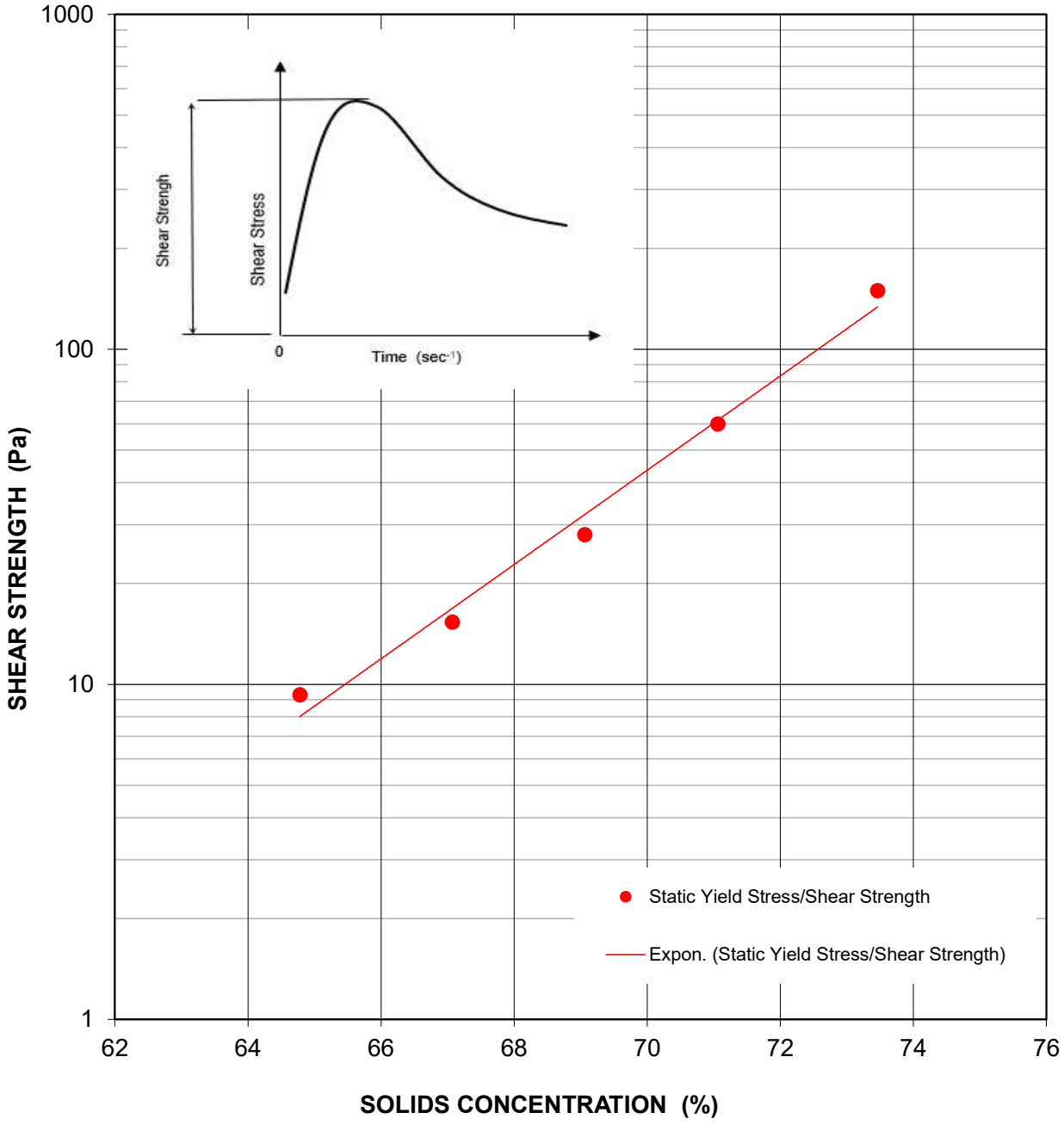
https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/Rheology - 14325/14325 - Rheology Report

250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Yield Stress Versus** **Solids Concentration**
ATC WILLIAMS ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 11**

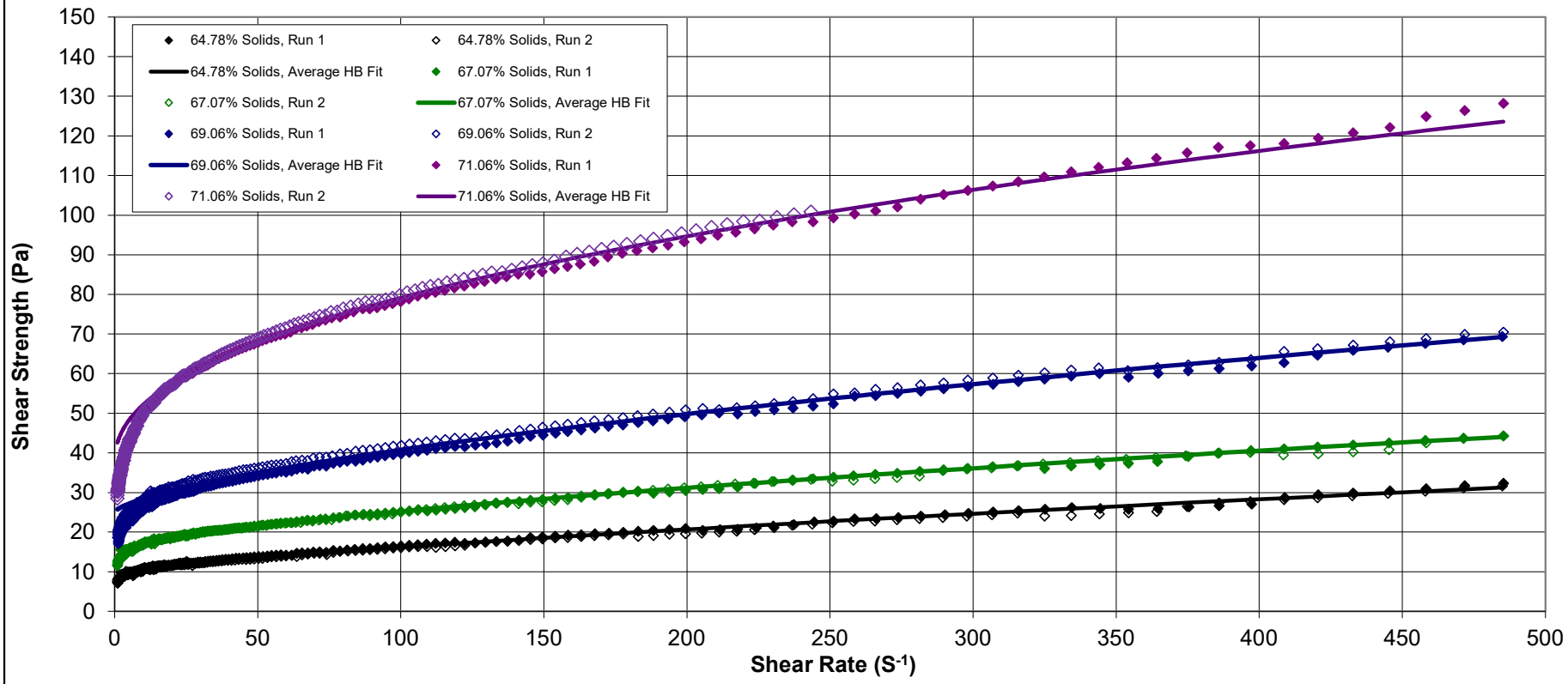
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRENGH



MMG Limited **Dugald River TSF Raise Design** **Tailings Sample No. 1 - Unflocculated**	**Rheology Testing** **Static Yield Stress Versus Solids Concentration**
ATC WILLIAMS ATC Williams Pty Ltd 19 Beach Avenue Mordialloc Vic 3195 AUSTRALIA T +61 3 9590 9222 melbourne@atcwilliams.com.au www.atcwilliams.com.au	**Job No:** 250542 **Date:** 19/03/2025 **FIGURE 12**

https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/Rheology - 14325/14325 - Rheology Report

250542 - Dugald River TSF Raise Design
Sample No. 14325
ALL FLOW CURVE RESULTS



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MMG Limited

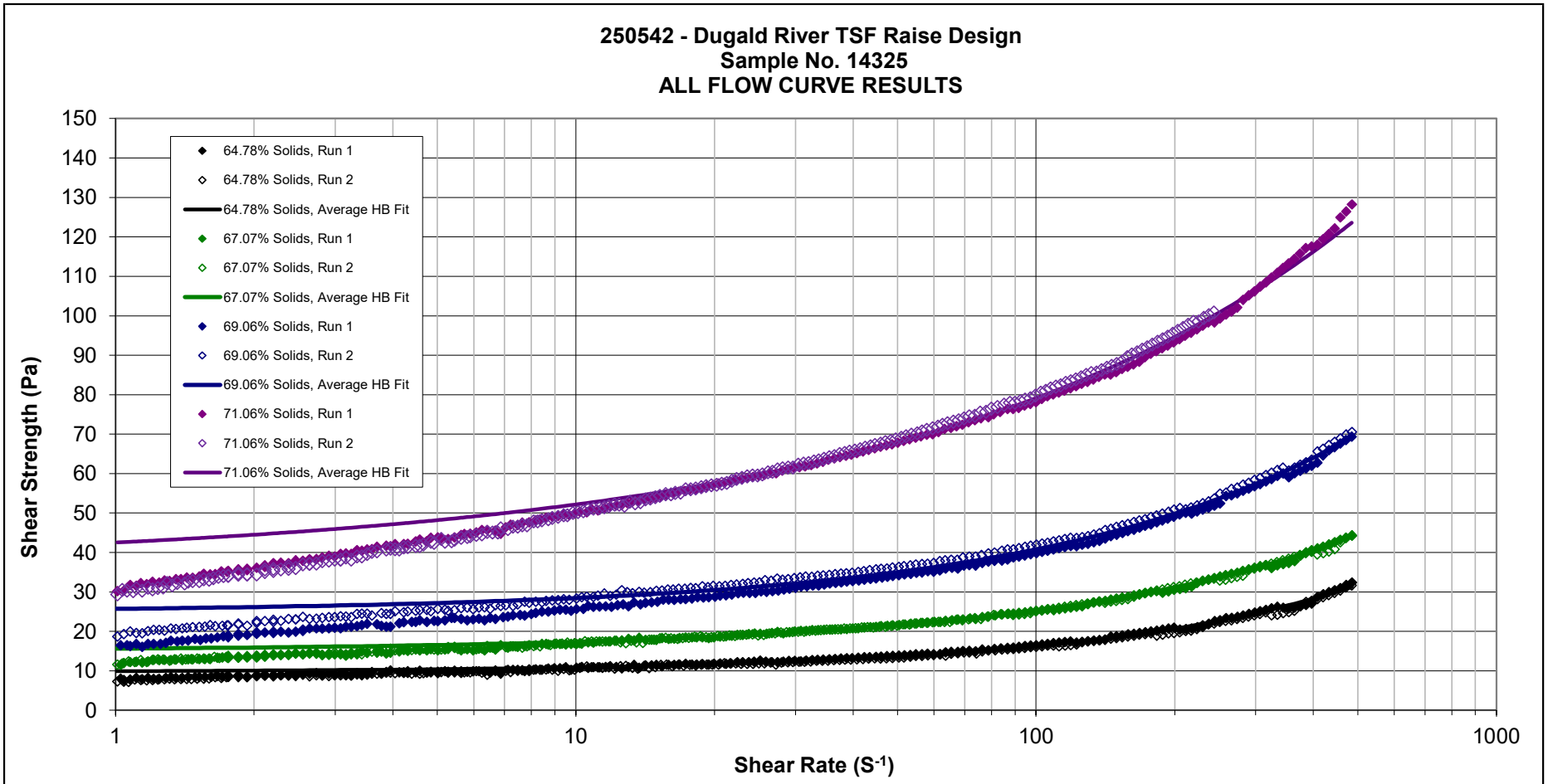
Dugald River TSF Raise Design

Tailings Sample No. 1 - Unflocculated

Rheology Testing

Date: 19/03/2025 **Job No:** 250542

Appendix B1



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www.atcwilliams.com.au

MMG Limited

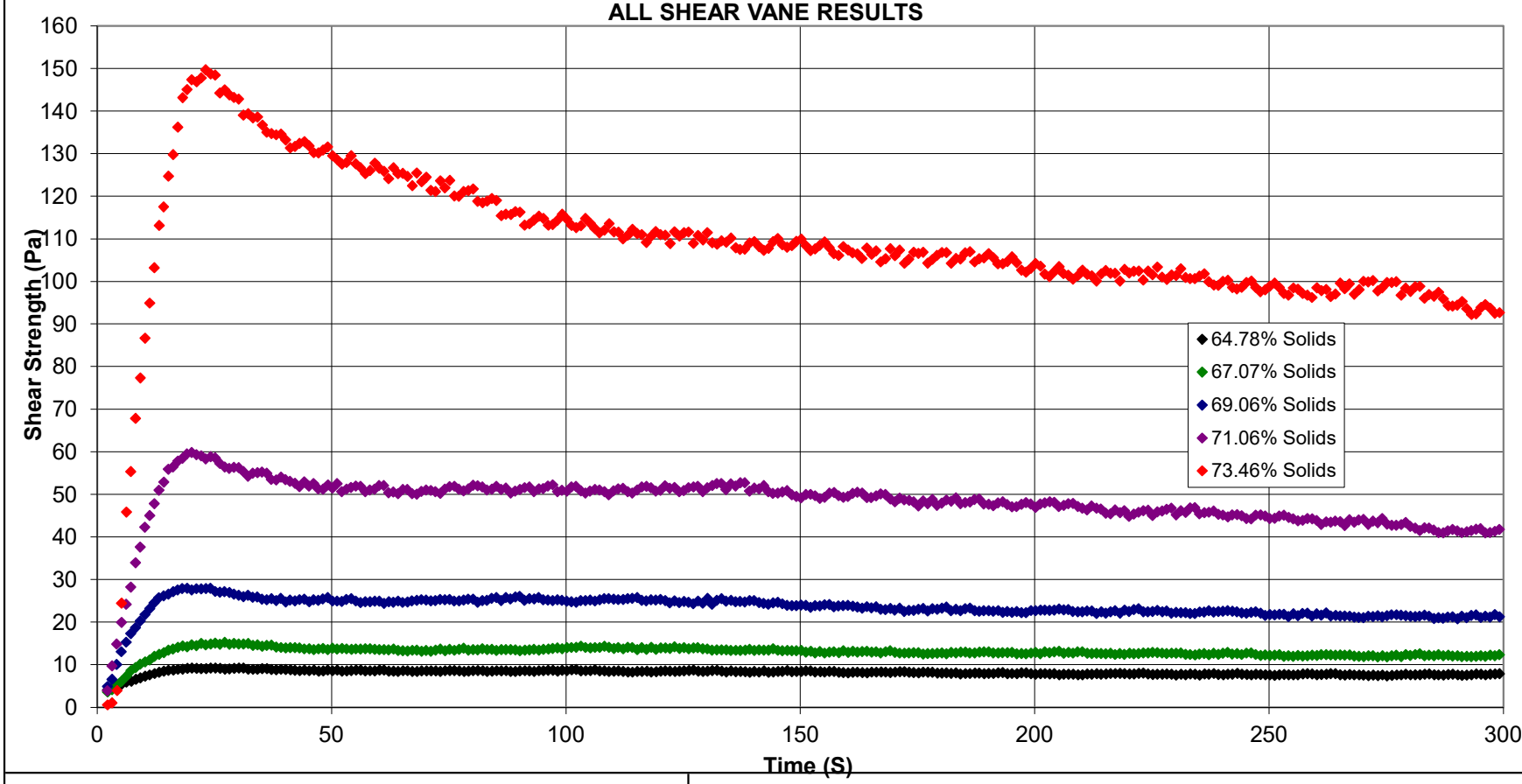
Dugald River TSF Raise Design

Tailings Sample No. 1 - Unflocculated

Rheology Testing

Date: 19/03/2025 **Job No:** 250542

Appendix B2



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MMG Limited

Dugald River TSF Raise Design

Tailings Sample No. 1 - Unflocculated

Rheology Testing

Date: 19/03/2025 **Job No:** 250542

Appendix C1

APPENDIX B – EPBC ACT PROTECTED MATTER REPORT

TAILINGS.WATER.WASTE.

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 01-Apr-2025

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	17
Listed Migratory Species:	12

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	17
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	None
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	5
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Listed Threatened Species			[Resource Information]
Status of Conservation Dependent and Extinct are not MNES under the EPBC Act. Number is the current name ID.			
Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Amytornis dorotheae Carpentarian Grasswren [558]	Endangered	Species or species habitat known to occur within area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
Chloebia gouldiae listed as Erythrura gouldiae Gouldian Finch [90091]	Endangered	Species or species habitat may occur within area	In feature area
Erythrotriorchis radiatus Red Goshawk [942]	Endangered	Species or species habitat may occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Pezoporus occidentalis](#) Night Parrot [59350]	Endangered	Species or species habitat likely to occur within area	In feature area
[Rostratula australis](#) Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area	In feature area
MAMMAL			
[Macroderma gigas](#) Ghost Bat [174]	Vulnerable	Species or species habitat may occur within area	In feature area
[Macrotis lagotis](#) Greater Bilby [282]	Vulnerable	Species or species habitat may occur within area	In feature area
[Sminthopsis douglasi](#) Julia Creek Dunnart [305]	Vulnerable	Species or species habitat may occur within area	In feature area
REPTILE			
[Acanthophis hawkei](#) Plains Death Adder [83821]	Vulnerable	Species or species habitat likely to occur within area	In feature area
[Elseya lavarackorum](#) Gulf Snapping Turtle [67197]	Endangered	Species or species habitat may occur within area	In feature area
[Varanus mertensi](#) Mertens' Water Monitor, Mertens's Water Monitor [1568]	Endangered	Species or species habitat likely to occur within area	In feature area
SHARK			
[Pristis pristis](#) Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area	In feature area

Listed Migratory Species			[Resource Information]
Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
[Apus pacificus](#) Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Migratory Marine Species			

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Pristis pristis](#) Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area	In feature area
Migratory Terrestrial Species			
[Hirundo rustica](#) Barn Swallow [662]		Species or species habitat may occur within area	In feature area
[Motacilla cinerea](#) Grey Wagtail [642]		Species or species habitat may occur within area	In feature area
[Motacilla flava](#) Yellow Wagtail [644]		Species or species habitat may occur within area	In feature area
Migratory Wetlands Species			
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
[Calidris acuminata](#) Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
[Calidris ferruginea](#) Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area	In feature area
[Calidris melanotos](#) Pectoral Sandpiper [858]		Species or species habitat may occur within area	In feature area
[Charadrius veredus](#) Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area	In feature area
[Gallinago hardwickii](#) Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area	In buffer area only
[Glareola maldivarum](#) Oriental Pratincole [840]		Species or species habitat may occur within area	In feature area

Other Matters Protected by the EPBC Act

Listed Marine Species			[Resource Information]
Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat may occur within area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]	Vulnerable	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area	In feature area
Chalcites osculans as Chrysococcyx osculans Black-eared Cuckoo [83425]		Species or species habitat likely to occur within area overfly marine area	In feature area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Gallinago hardwickii](#) Latham's Snipe, Japanese Snipe [863]	Vulnerable	Species or species habitat may occur within area overfly marine area	In buffer area only
[Glareola maldivarum](#) Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area	In feature area
[Haliaeetus leucogaster](#) White-bellied Sea-Eagle [943]		Species or species habitat likely to occur within area	In feature area
[Hirundo rustica](#) Barn Swallow [662]		Species or species habitat may occur within area overfly marine area	In feature area
[Merops ornatus](#) Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area
[Motacilla cinerea](#) Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area	In feature area
[Motacilla flava](#) Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area	In feature area
[Rostratula australis as Rostratula benghalensis (sensu lato)](#) Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Reptile			
[Crocodylus johnstoni](#) Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area	In feature area

Extra Information

EPBC Act Referrals				[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Dugald River Wind Farm	2024/09807		Completed	In feature area
Dugald River Wind Farm ? Optimised Design	2024/10090		Completed	In feature area
Controlled action				
CopperString Project	2010/5581	Controlled Action	Completed	In feature area
Not controlled action				
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area
Not controlled action (particular manner)				
Dugald River Zinc and Lead Mine extension, Qld	2015/7573	Not Controlled Action (Particular Manner)	Post-Approval	In feature area

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data is available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on the contents of this report.

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions when time permits.

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded breeding sites; and
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

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APPENDIX C – ENVIRONMENTAL REPORTS – MATTERS OF STATE ENVIRONMENTAL SIGNIFICANCE

TAILINGS.WATER.WASTE.

Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
Lot: 59 Plan: TG40

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

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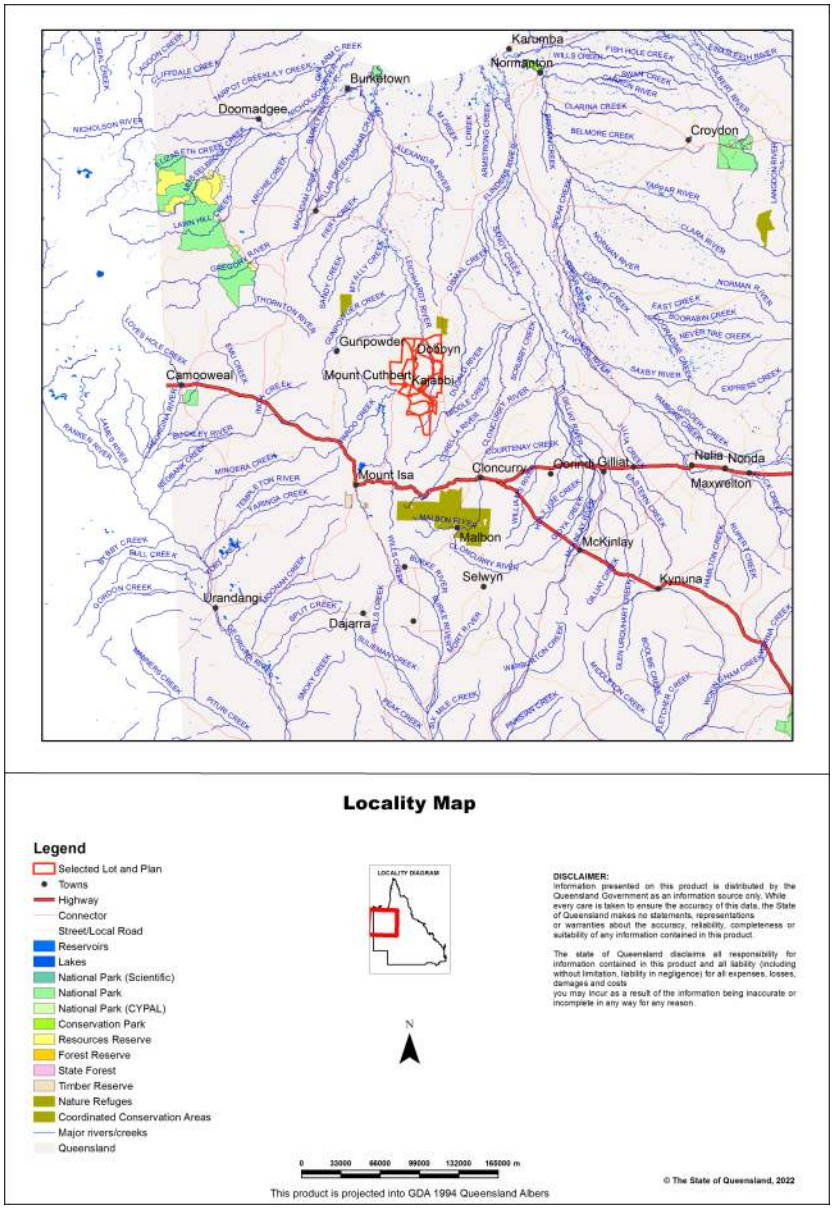
Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI Lot: 59 Plan: TG40

Size (ha)	213,915.93
Local Government(s)	Cloncurry Shire
Bioregion(s)	Northwest Highlands, Gulf Plains
Subregion(s)	Armraynald Plains, Donors Plateau, Mount Isa Inlier
Catchment(s)	Flinders, Leichhardt



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the Nature Conservation Act 1992 ;

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the Marine Parks Act 2004 ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- Threatened wildlife under the Nature Conservation Act 1992 and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the Vegetation Management Act 1999 that is:

    • Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;

    • Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;

    • Category R areas on the regulated vegetation management map;

    • Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;

    • Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the Regional Planning Interests Act 2014 ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Queensland Wetland Environmental Values under the Environment Protection Regulation 2019;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;

- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	0.0 ha	0.0 %
1c Protected Areas- special wildlife reserves	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	0.0 ha	0.0 %
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways	0.0 km	Not applicable
7a Threatened (endangered or vulnerable) wildlife	2122.39 ha	1.0%
7b Special least concern animals	264.07 ha	0.1%
7c i Koala habitat area - core (SEQ)	0.0 ha	0.0 %
7c ii Koala habitat area - locally refined (SEQ)	0.0 ha	0.0 %
7d Sea turtle nesting areas	0.0 km	Not applicable
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	1368.77 ha	0.6%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	0.0 ha	0.0 %
8c Regulated Vegetation - Category R (GBR riverine regrowth)	0.0 ha	0.0 %
8d Regulated Vegetation - Essential habitat	1924.11 ha	0.9%
8e Regulated Vegetation - intersecting a watercourse	3228.5 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	25.95 ha	0.0%
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

(no results)

1c. Protected Areas - special wildlife reserves

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values

(no results)

6a. Wetlands in High Ecological Value (HEV) waters

(no results)

6b. Waterways in High Ecological Value (HEV) waters

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7a. Threatened (endangered or vulnerable) wildlife

Values are present

7b. Special least concern animals

Values are present

7c i. Koala habitat area - core (SEQ)

Not applicable

7c ii. Koala habitat area - locally refined (SEQ)

Not applicable

7d. Wildlife habitat (sea turtle nesting areas)

Not applicable

Threatened (endangered or vulnerable) wildlife habitat suitability models

Species	Common name	NCA status	Presence
Boronia keysii		V	None
Calyptorhynchus lathami	Glossy black cockatoo	V	None
Casuarius casuarius johnsonii	Sthn population cassowary	E	None
Crinia tinnula	Wallum froglet	V	None
Denisonia maculata	Ornamental snake	V	None
Litoria freycineti	Wallum rocketfrog	V	None
Litoria olongburensis	Wallum sedgefrog	V	None
Macadamia integrifolia		V	None
Macadamia ternifolia		V	None
Macadamia tetraphylla		V	None
Melaleuca irbyana		E	None
Petaurus gracilis	Mahogany Glider	E	None
Petrogale persephone	Proserpine rock-wallaby	E	None
Pezoporus wallicus wallicus	Eastern ground parrot	V	None
Phascolarctos cinereus	Koala - outside SEQ*	V	None
Taudactylus pleione	Kroombit tinkerfrog	E	None
Xeromys myoides	Water Mouse	V	None

*For koala model, this includes areas outside SEQ. Check 7c SEQ koala habitat for presence/absence.

Threatened (endangered or vulnerable) wildlife species records

Scientific name	Common name	NCA status	EPBC status	Migratory status
Petrogale purpureicollis	purple-necked rock-wallaby	V		
Grantiella picta	painted honeyeater	V	V	
Falco hypoleucos	grey falcon	V	V	

Special least concern animal species records

Scientific name	Common name	Migratory status
Tachyglossus aculeatus	short-beaked echidna	None

Shorebird habitat (critically endangered/endangered/vulnerable)

Not applicable

Shorebird habitat (special least concern)

Not applicable

*Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)

Migratory status (M) - China and Australia Migratory Bird Agreement (C), Japan and Australia Migratory Bird Agreement (J), Republic of Korea and Australia Migratory Bird Agreement (R), Bonn Migratory Convention (B), Eastern Flyway (E)

To request a species list for an area, or search for a species profile, access Wildlife Online at:
https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals, Map 3b - MSES - Species - Koala habitat area (SEQ)** and **Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)** for an overview of the relevant MSES.

MSES - Regulated Vegetation

For further information relating to regional ecosystems in general, go to:
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/
For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:
https://environment.ehp.qld.gov.au/regional-ecosystems/

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
2.3.49	O-dom	rem_oc
1.11.2a/1.11.7	O-subdom	rem_oc
1.11.2a/1.11.3a/1.11.7	O-subdom	rem_oc

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Not applicable

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Not applicable

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Regulated vegetation map category	Map number
B	6958

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

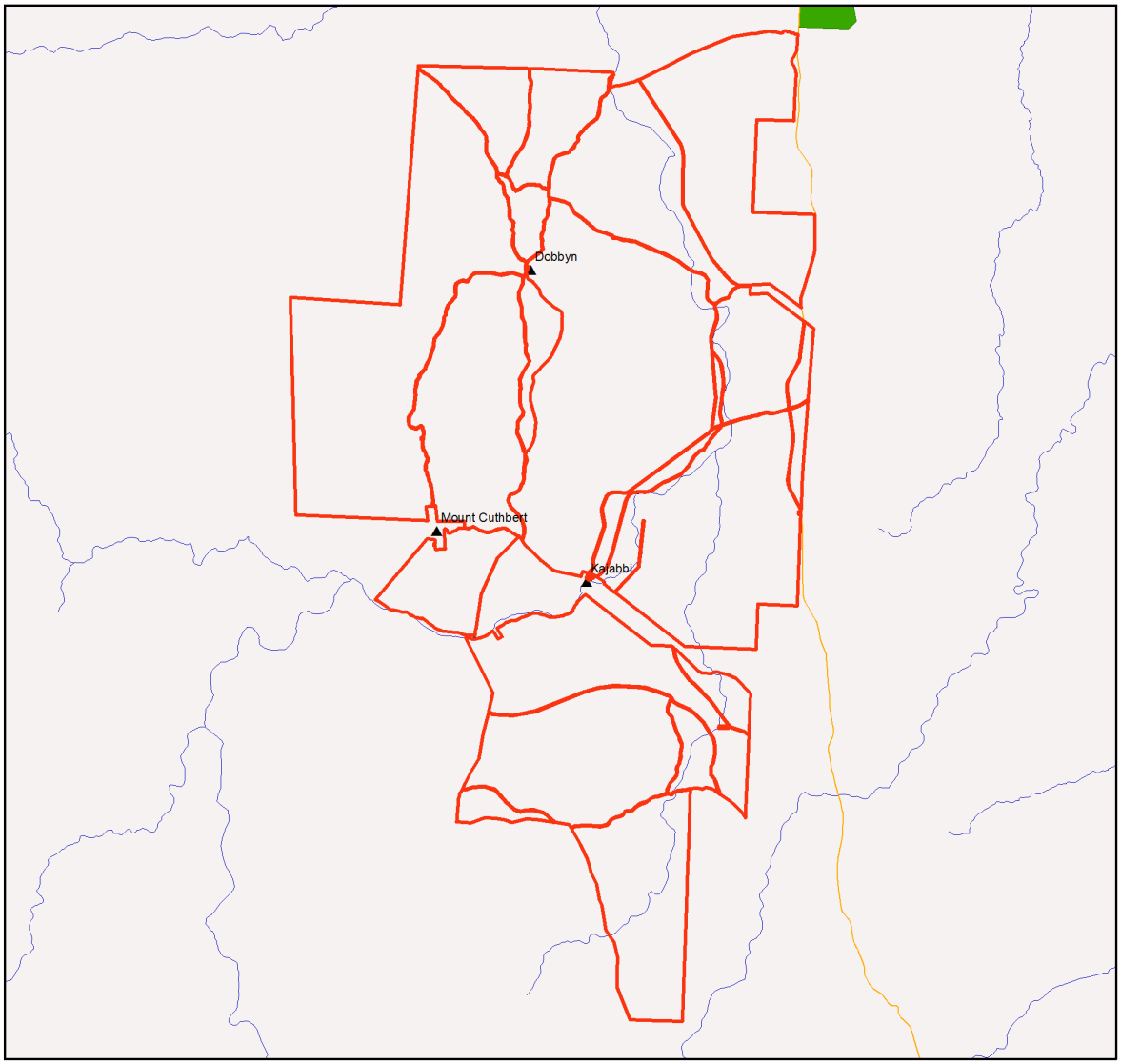
(no results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

(no results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

Map 1 - MSES - State Conservation Areas

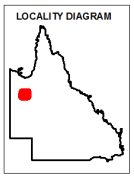


MSES - State Conservation Areas

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Protected area (estates, nature refuges, special wildlife reserves)
- Declared fish habitat area (A and B areas)
- Marine park (highly protected)

LOCALITY DIAGRAM



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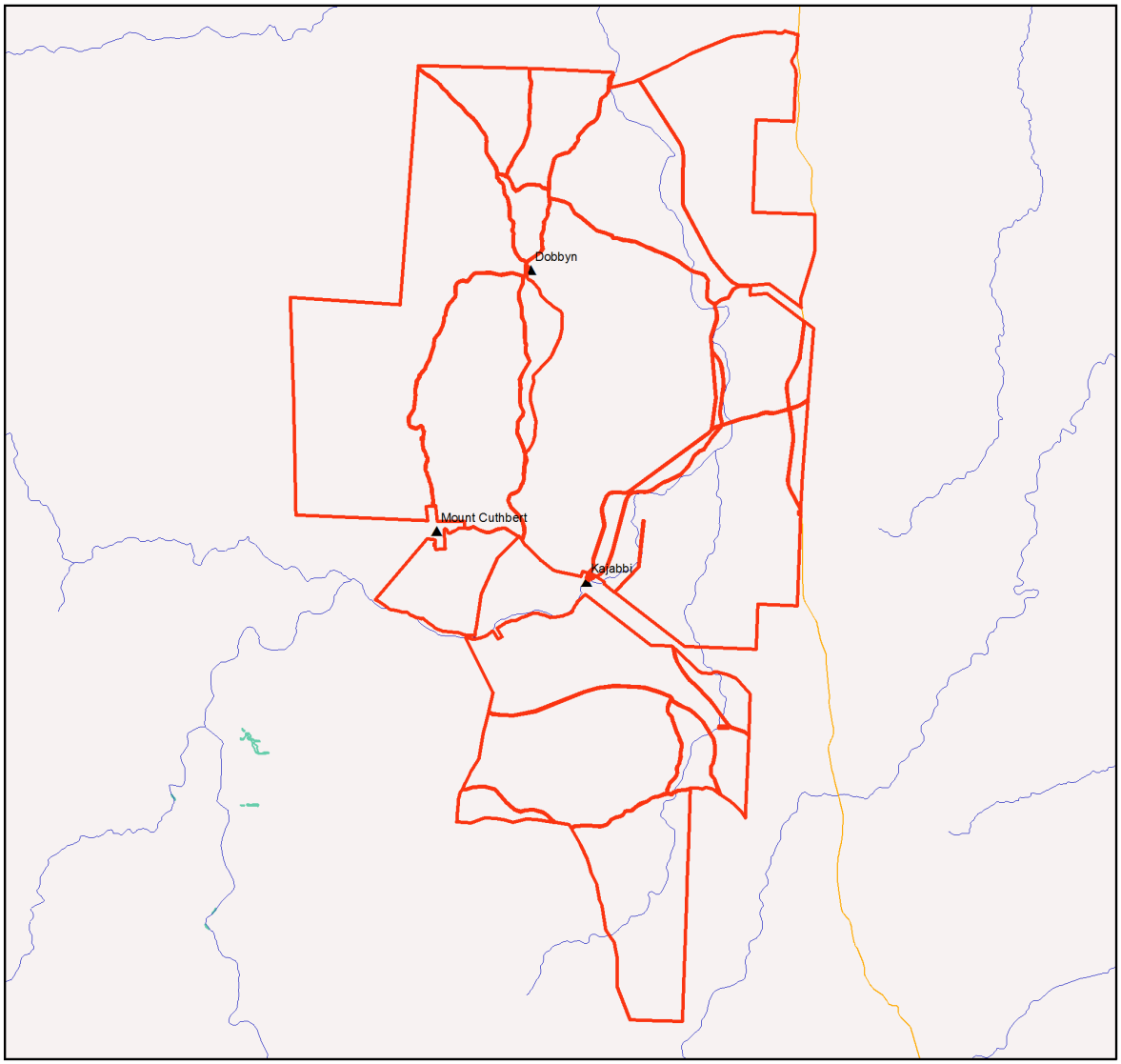
Map 2 - MSES - Wetlands and Waterways

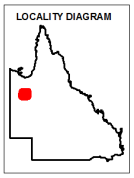


MSES - Wetlands and Waterways

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Declared high ecological value waters (watercourse)
- Strategic environmental area (designated precinct)
- Declared high ecological value waters (wetland)
- High ecological significance wetlands

LOCALITY DIAGRAM



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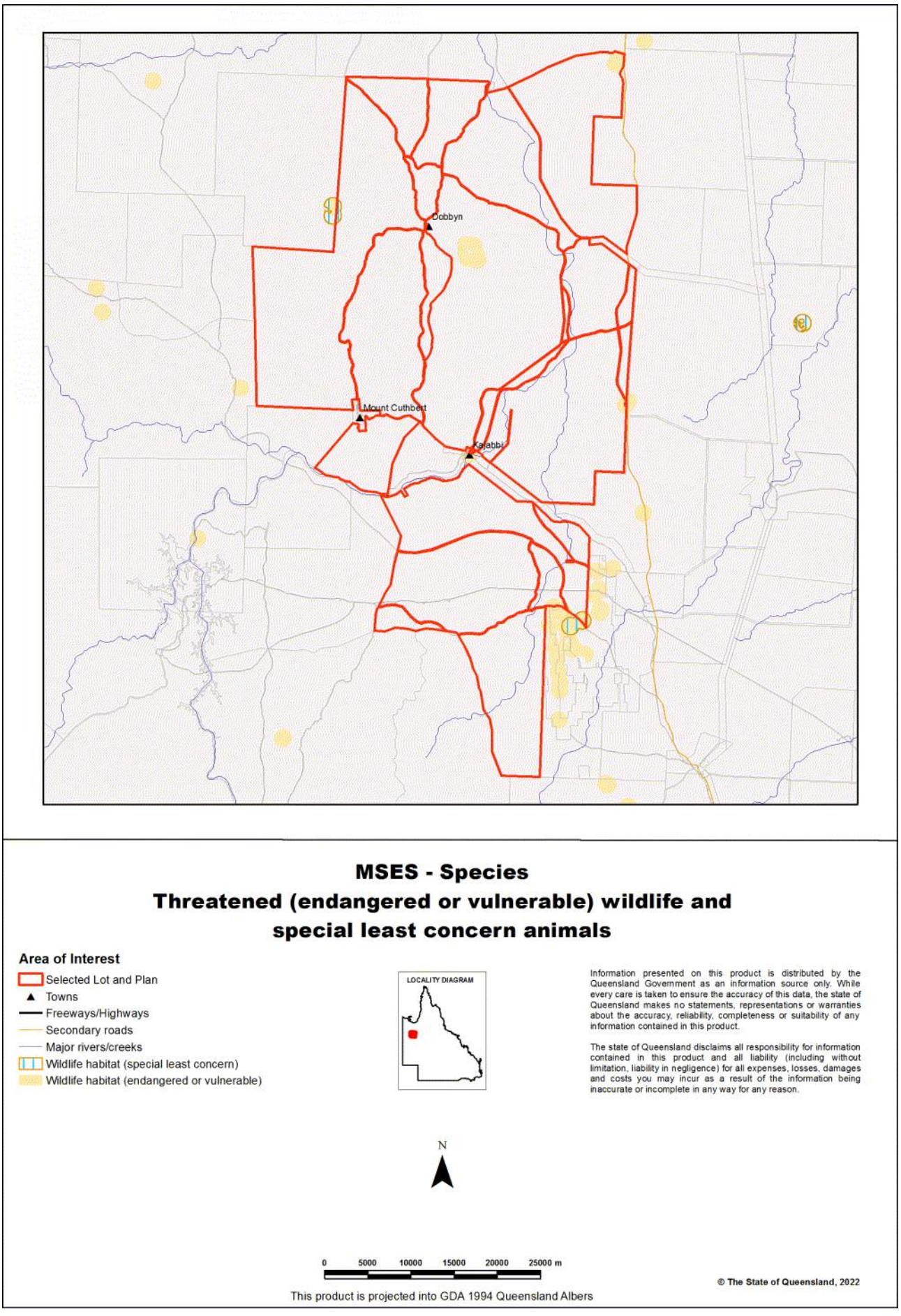
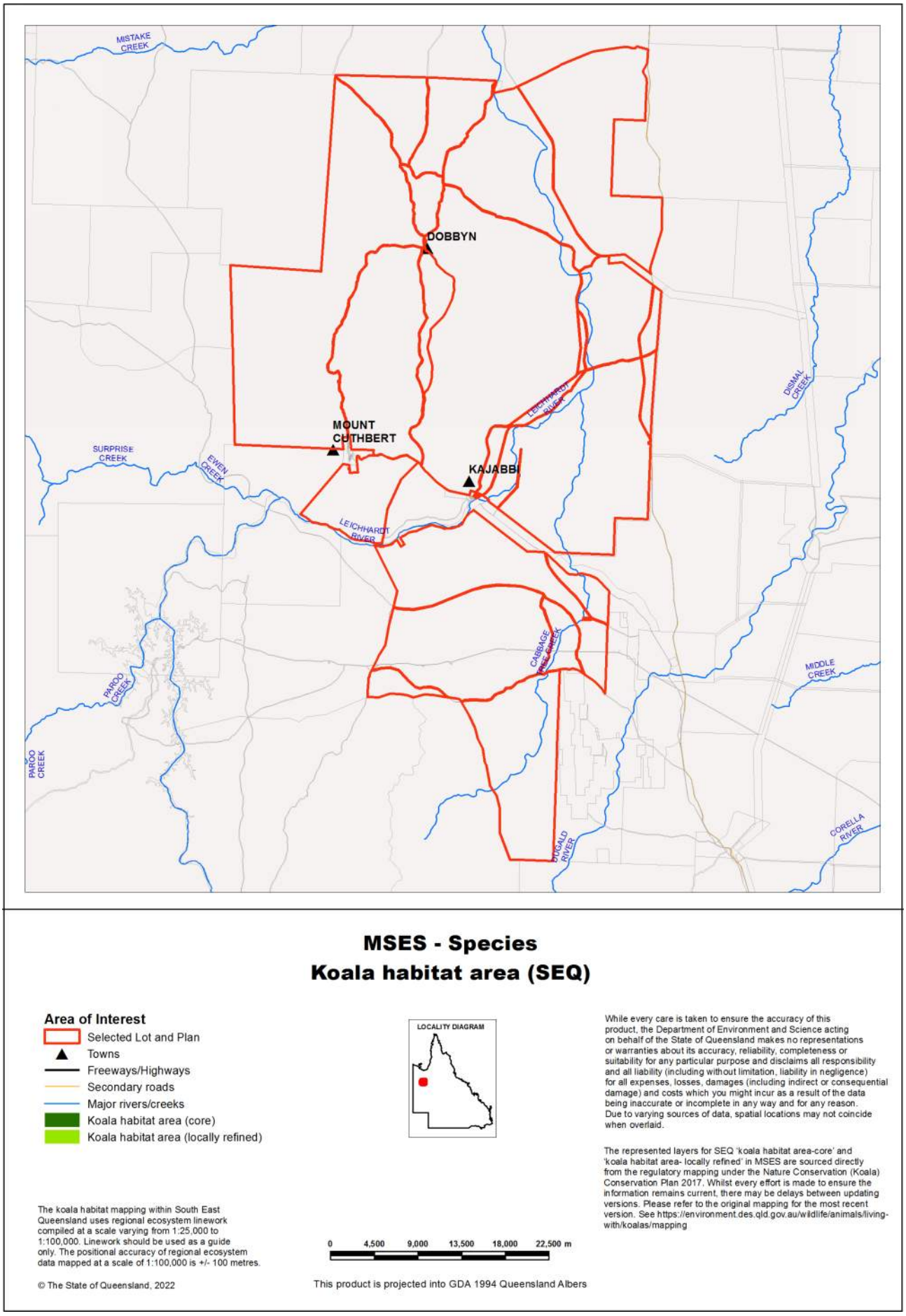
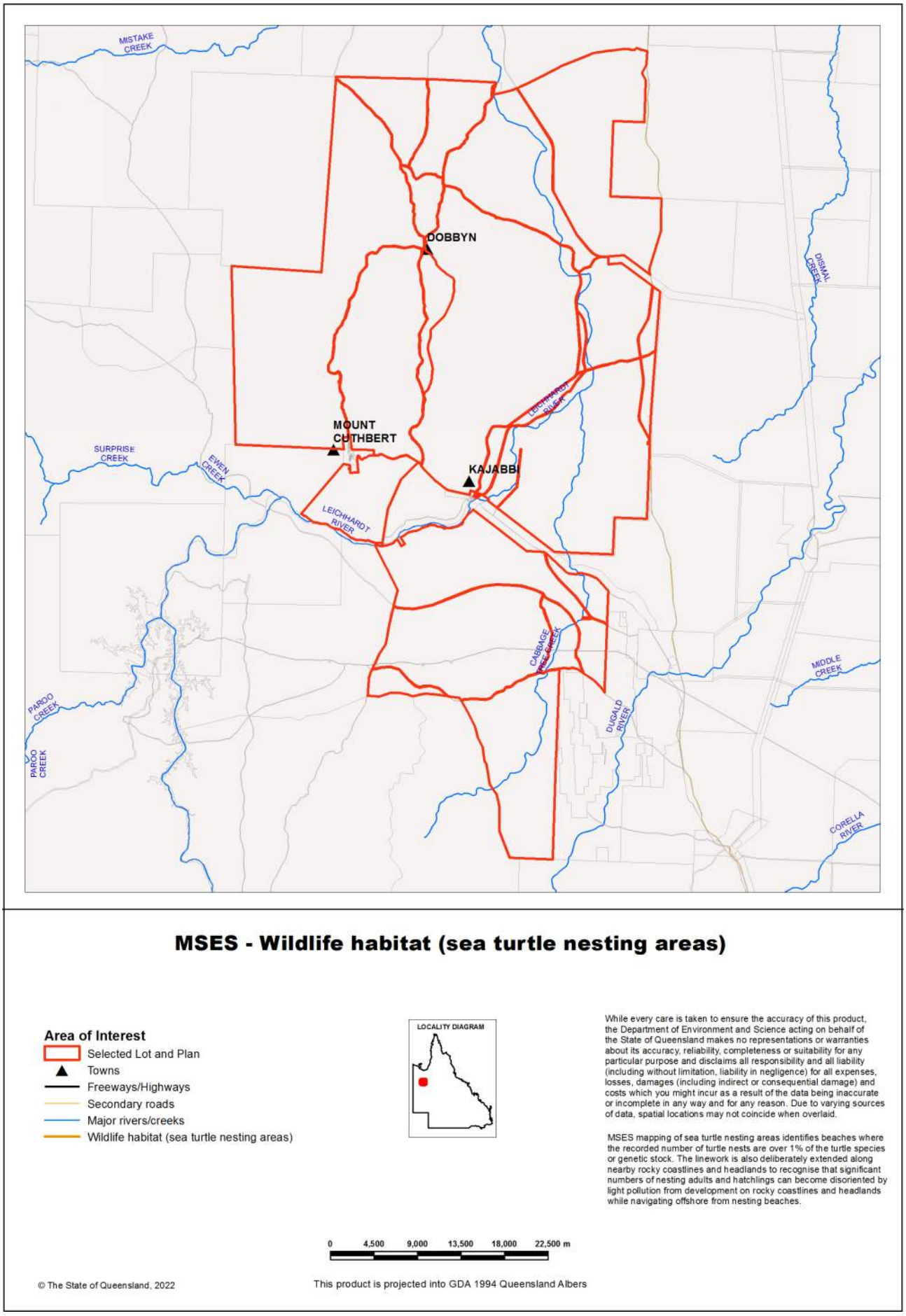
Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals



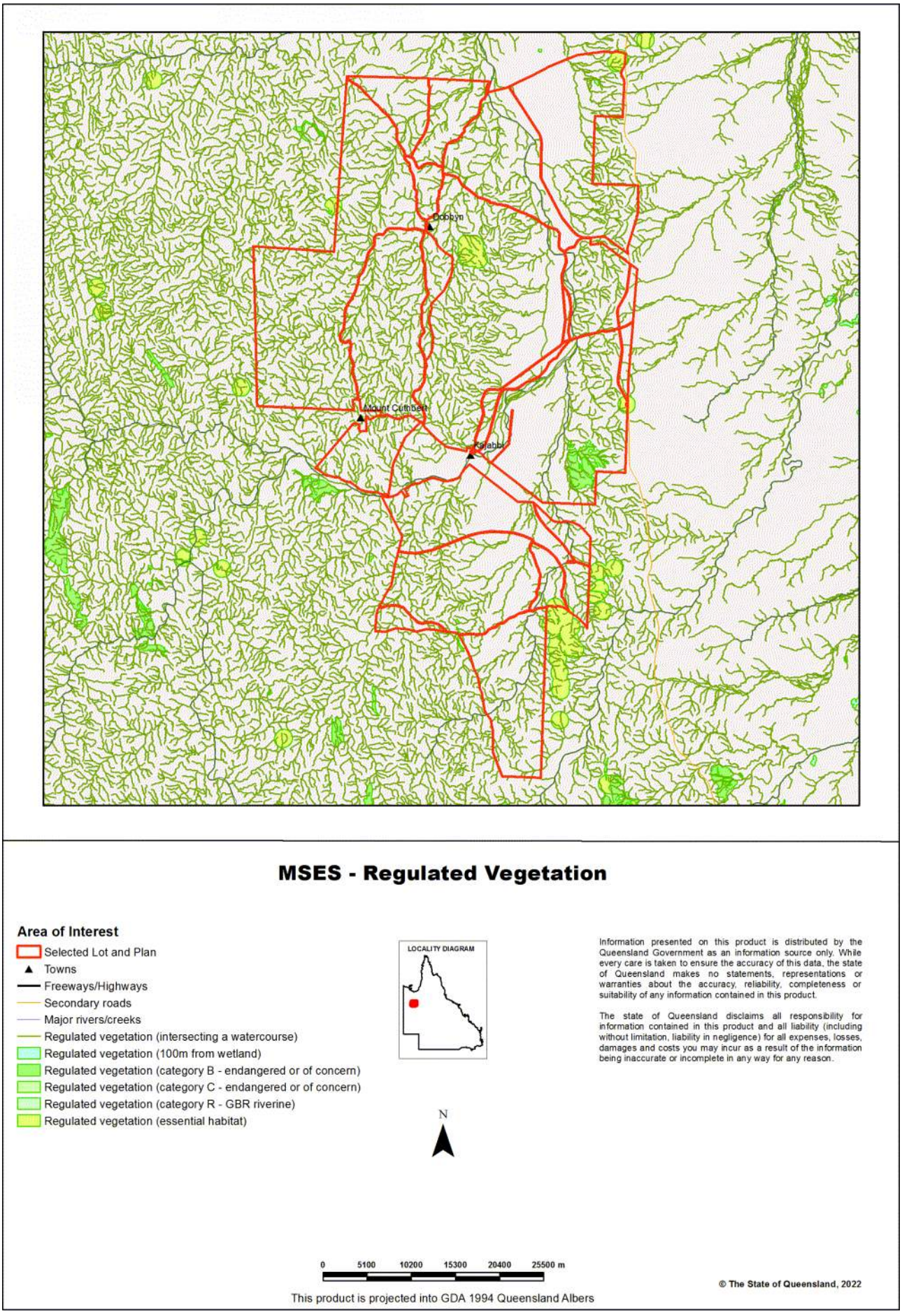
Map 3b - MSES - Species - Koala habitat area (SEQ)



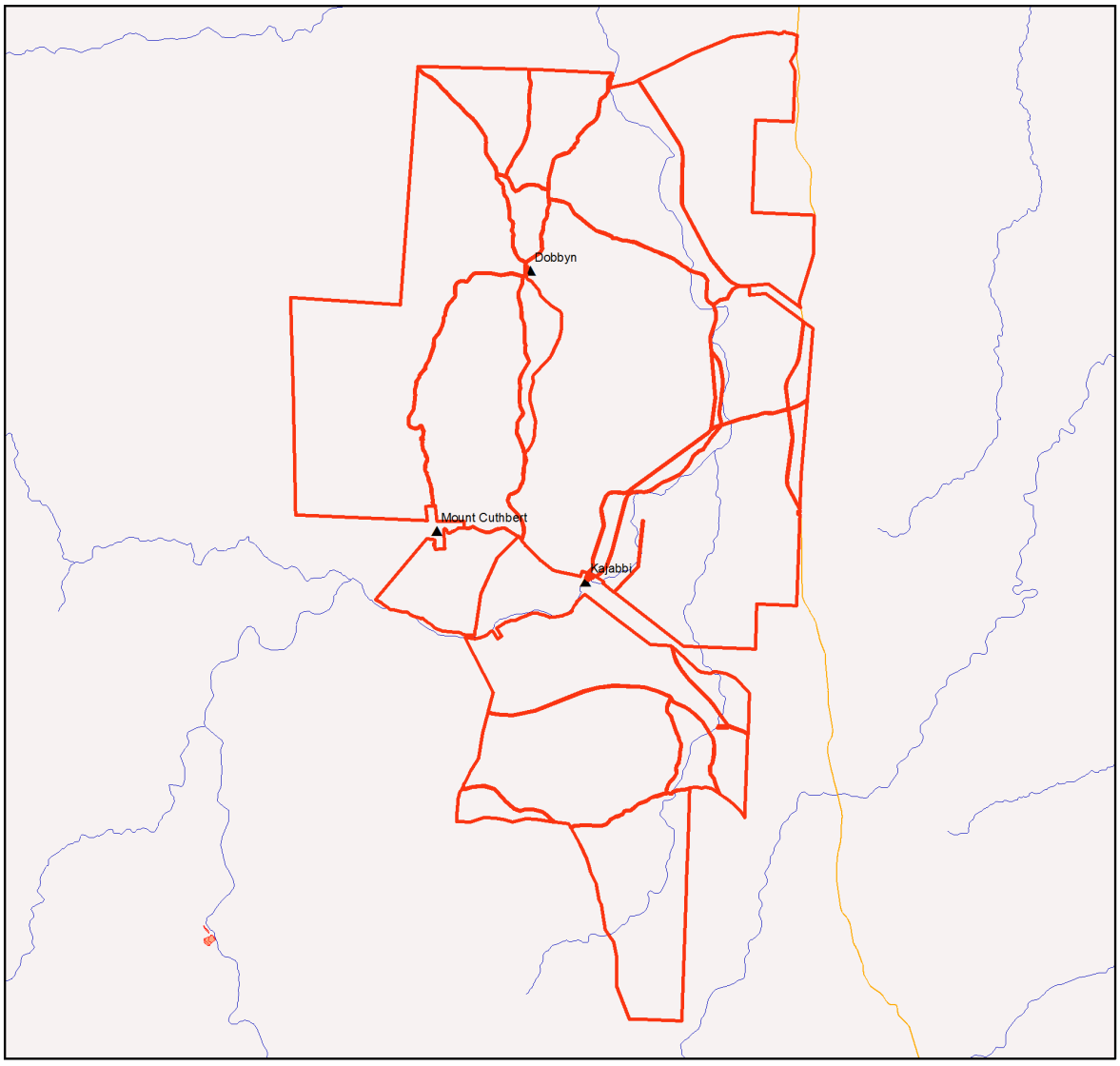
Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)



Map 4 - MSES - Regulated Vegetation



Map 5 - MSES - Offset Areas

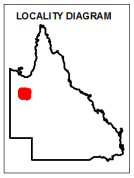


MSES - Offsets

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Legally secured offset area (offset register)
- Legally secured offset area (vegetation offsets)

LOCALITY DIAGRAM



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Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.information.qld.gov.au)**
Protected Areas-Estates, Nature Refuges, Special Wildlife Reserves	- Protected areas of Queensland - Nature Refuges - Queensland - Special Wildlife Reserves- Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Queensland Wetland Environmental Values
Wetlands in HEV waters	HEV waters: - EPP Water intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 5) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000)
Wildlife habitat (threatened and special least concern)	- WildNet database species records - habitat suitability models (various) - SEQ koala habitat areas under the Koala Conservation Plan 2019 - Sea Turtle Nesting Areas records
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map
VMA Essential Habitat	Vegetation management - essential habitat map
VMA Wetlands	Vegetation management wetlands map
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- Environmental Protection Act 1994
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- Nature Conservation Act 1992
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- Vegetation Management Act 1999

APPENDIX D – ENVIRONMENTAL REPORTS – BIODIVERSITY AND CONSERVATION VALUES – BIODIVERSITY PLANNING ASSESSMENTS AND AQUATIC CONSERVATION ASSESSMENTS

TAILINGS.WATER.WASTE.

Queensland Government

Department of Environment and Science

Environmental Reports

Biodiversity and Conservation Values

Biodiversity Planning Assessments and Aquatic Conservation Assessments

For the selected area of interest
Lot: 59 Plan: TG40

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or Area of Interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "Central co-ordinates" option, the resulting assessment area encompasses an area extending from 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: biodiversity.planning@des.qld.gov.au

Disclaimer

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Summary Information

Tables 1 to 8 provide an overview of the AOI with respect to selected topographic and environmental values.

Table 1: Area of interest details: Lot: 59 Plan: TG40

Size (ha)	213,915.93
Local Government(s)	Cloncurry Shire
Bioregion(s)	Northwest Highlands, Gulf Plains
Subregion(s)	Armraynald Plains, Donors Plateau, Mount Isa Inlier
Catchment(s)	Flinders, Leichhardt

The following table identifies available Biodiversity Planning Assessments (BPAs) and Aquatic Conservation Assessments (ACAs) with respect to the AOI.

Table 2: Available Biodiversity Planning and Aquatic Conservation Assessments

Assessment Type	Assessment Area and Version
Biodiversity Planning Assessment(s)	Northwest Highlands v1.1, Gulf Plains v1.1
Aquatic Conservation Assessment(s) (riverine)	Eastern Gulf of Carpentaria v1.1, Southern Gulf Catchments v1.1
Aquatic Conservation Assessment(s) (non-riverine)	Eastern Gulf of Carpentaria v1.1, Southern Gulf Catchments v1.1

Table 3: Remnant regional ecosystems within the AOI as per the Qld Herbarium's 'biodiversity status'

Biodiversity Status	Area (Ha)	% of AOI
Endangered	4,053.28	1.89
Of concern	13,681.21	6.4
No concern at present	195,826.07	91.54

The following table identifies the extent and proportion of the user specified area of interest (AOI) which is mapped as being of "State", "Regional" or "Local" significance via application of the Queensland Department of Environment and Science's Biodiversity Assessment and Mapping Methodology (BAMM).

Table 4: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	3,052.13	1.43
State	52,362.38	24.48
Regional	24,976.20	11.68
Local or Other Values	132,222.25	61.81

Table 5: Non-riverine wetlands intersecting the AOI

Non-riverine wetland types intersecting the area of interest	#
Number of Palustrine wetlands	1
Number of Lacustrine wetlands	0
Total number of non-riverine wetlands	1

NB. The figures presented in the table above are derived from the relevant non-riverine Aquatic Conservation Assessment(s). Later releases of wetland mapping produced via the Queensland Wetland Mapping Program may provide more recent information in regards to wetland extent.

Table 6: Named waterways intersecting the AOI

Name	Permanency
BULL CREEK	Non-perennial
CABBAGE TREE CREEK	Non-perennial
CENTIPEDE CREEK	Non-perennial
COPPERMINE CREEK	Non-perennial
DIORITE CREEK	Non-perennial
EIGHT MILE CREEK	Non-perennial
EUREKA CREEK	Non-perennial
HARE CREEK	Non-perennial
LADY CLAYRE CREEK	Non-perennial
LEICHHARDT RIVER	Non-perennial
MCLEAN CREEK	Non-perennial
OLD MAN CREEK	Non-perennial
PINNACLE CREEK	Non-perennial
PROSPECTOR CREEK	Non-perennial
SAINT PAUL CREEK	Non-perennial
SALLY CREEK	Non-perennial
SIX MILE CREEK	Non-perennial
SLAUGHTER CREEK	Non-perennial
SUNDAY CREEK	Non-perennial
TARGET CREEK	Non-perennial
WHITE GORGE CREEK	Non-perennial

Refer to **Map 1** for general locality information.

The following two tables identify the extent and proportion of the user specified AOI which is mapped as being of "Very High", "High", "Medium", "Low", or "Very Low" aquatic conservation value for riverine and non-riverine wetlands via application of the Queensland Department of Environment and Science's Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM).

Table 7: Summary table, aquatic conservation significance (riverine)

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	2,419.71	1.13
High	123,195.32	57.59
Medium	88,301.26	41.28
Low	0.0	0.0
Very Low	0.0	0.0

Table 8: Summary table, aquatic conservation significance (non-riverine)

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0
High	8.27	0.0
Medium	0.0	0.0
Low	0.0	0.0
Very Low	0.0	0.0

Biodiversity Planning Assessments

Introduction

The Department of Environment and Science (DES) attributes biodiversity significance on a bioregional scale through a Biodiversity Planning Assessment (BPA). A BPA involves the integration of ecological criteria using the Biodiversity assessment and Mapping Methodology (BAMM) and is developed in two stages: 1) **diagnostic criteria**, and 2) **expert panel criteria**. The diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion, while the expert panel criteria allows for the refinement of the mapped information from the diagnostic output by incorporating local knowledge and expert opinion.

The BAMM methodology has application for identifying areas with various levels of significance solely for biodiversity reasons. These include threatened ecosystems or taxa, large tracts of habitat in good condition, ecosystem diversity, landscape context and connection, and buffers to wetlands or other types of habitat important for the maintenance of biodiversity or ecological processes. While natural resource values such as dryland salinity, soil erosion potential or land capability are not dealt with explicitly, they are included to some extent within the biodiversity status of regional ecosystems recognised by the DES.

Biodiversity Planning Assessments (BPAs) assign three levels of overall biodiversity significance.

- **State significance** - areas assessed as being significant for biodiversity at the bioregional or state scales. They also include areas assessed by other studies/processes as being significant at national or international scales. In addition, areas flagged as being of State significance due to the presence of endangered, vulnerable and/or near threatened taxa, are identified as "State Habitat for EVNT taxa".
- **Regional significance** - areas assessed as being significant for biodiversity at the subregional scale. These areas have lower significance for biodiversity than areas assessed as being of State significance.
- **Local significance and/or other values** - areas assessed as not being significant for biodiversity at state or regional scales. Local values are of significance at the local government scale.

For further information on released BPAs and a copy of the underlying methodology, go to:

http://www.qld.gov.au/environment/plants-animals/biodiversity/planning/

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

The following table identifies the extent and proportion of the user specified AOI which is mapped as being of "State", "Regional" or "Local" significance via application of the BAMM.

Table 9: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	3,052.13	1.43
State	52,362.38	24.48
Regional	24,976.20	11.68
Local or Other Values	132,222.25	61.81

Refer to **Map 2** for further information.

Diagnostic Criteria

Diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion. These criteria are diagnostic in that they are used to filter the available data and provide a "first-cut" or initial determination of biodiversity significance. This initial assessment is then combined through a second group of other essential criteria.

A description of the individual diagnostic criteria is provided in the following sections.

Criteria A. Habitat for EVNT taxa: Classifies areas according to their significance based on the presence of endangered, vulnerable and/or rare (EVNT) taxa. EVNT taxa are those scheduled under the Nature Conservation Act 1992 and/or the

Environment Protection and Biodiversity Conservation Act 1999. It excludes highly mobile fauna taxa which are instead considered in Criterion H and brings together information on EVNT taxa using buffering of recorded sites or habitat suitability models (HSM) where available.

Criteria B. Ecosystem value: Classifies on the basis of biodiversity status of regional ecosystems, their extent in protected areas (presence of poorly conserved regional ecosystems), the presence of significant wetlands; and areas of national importance such as the presence of Threatened Ecological Communities, World Heritage areas and Ramsar sites. Ecosystem value is applied at a bioregional (**B1**) and regional (**B2**) scale.

Criteria C. Tract size: Measures the relative size of tracts of vegetation in the landscape. The size of any tract is a major indicator of ecological significance, and is also strongly correlated with the long-term viability of biodiversity values. Larger tracts are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller tracts.

Criteria D. Relative size of regional ecosystems: Classifies the relative size of each regional ecosystem unit within its bioregion (**D1**) and its subregion (**D2**). Remnant units are compared with all other occurrences with the same regional ecosystem. Large examples of a regional ecosystem are more significant than smaller examples of the same regional ecosystem because they are more representative of the biodiversity values particular to the regional ecosystem, are more resilient to the effects of disturbance, and constitute a significant proportion of the total area of the regional ecosystem.

Criteria F. Ecosystem diversity: Is an indicator of the number of regional ecosystems occurring within an area. An area with high ecosystem diversity will have many regional ecosystems and ecotones relative to other areas within the bioregion.

Criteria G. Context and connection: Represents the extent to which a remnant unit incorporates, borders or buffers areas such as significant wetlands, endangered ecosystems; and the degree to which it is connected to other vegetation.

A summary of the biodiversity status based upon the diagnostic criteria is provided in the following table.

Table 10: Summary of biodiversity significance based upon diagnostic criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant contains an RE that is one of the largest of its type in the bioregion (D1) & Remnant has Ecosystem diversity in the top quartile (F)	11,431.55	5.34
State	Remnant contains an RE that is one of the largest of its type in the bioregion (D1) & Remnant has high connectivity or buffers an endangered RE or Sig. Wetland (G)	30,377.33	14.2
State	Remnant contains at least 1 Endangered or 2 Vulnerable or Near Threatened species (A)	3,052.13	1.43
State	Remnant contains at least 1 Endangered RE (B1)	4,882.00	2.28
State	Remnant contains at least one Of Concern RE (B1) & Remnant contains an RE that is one of the largest of its type in the bioregion (D1)	1,168.27	0.55
State	Remnant contains at least one Of Concern RE (B1) & Remnant is part of moderately large Tract (C) & Remnant contains a RE that is a moderately large RE of its type in the bioregion (D1) & Remnant has Ecosystem diversity in the top quartile (F)	41.35	0.02
Regional	Remnant contains an RE that is one of the largest of its type in the subregion (D2)	3,070.09	1.44
Regional	Remnant contains at least 1 RE with <10 pc extent remaining or rare in subregion (B2)	674.01	0.32
Regional	Remnant contains at least 1 RE with 10-30 percent extent remaining in the subregion (B2) & Remnant is part of moderately large Tract (C)	49.87	0.02
Regional	Remnant contains at least 1 RE with 10-30 percent extent remaining in the subregion (B2) & Remnant is part of moderately large Tract (C) & Remnant has high connectivity or buffers an endangered RE or Significant Wetland (G)	559.46	0.26
Regional	Remnant contains at least 1 Vulnerable or Near Threatened species (A)	4,511.72	2.11
Regional	Remnant contains at least one Of Concern RE (B1)	12,878.15	6.02
Local or Other Values	Refer to diagnostic data for additional information	139,911.09	65.4

Assessment of diagnostic criteria with respect to the AOI

The following table reflects an assessment of the individual diagnostic criteria noted above in regards to the AOI.

Table 11: Assessment of individual diagnostic criteria with respect to the AOI

Diagnostic Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
A: Habitat for EVNT Taxa	3,052.13	1.4	10,622.50	5.0	146,174.79	68.3	52,757.52	24.7
B1: Ecosystem Value (Bioregion)	4,882.01	2.3	14,087.72	6.6	193,637.21	90.5		
B2: Ecosystem Value (Subregion)	3,089.28	1.4	1,882.23	0.9	207,635.43	97.1		

Diagnostic Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
C: Tract Size			212,606.94	99.4				
D1: Relative RE Size (Bioregion)	44,990.57	21.0	16,310.50	7.6	39,550.67	18.5	111,755.20	52.2
D2: Relative RE Size (Subregion)	49,111.46	23.0	18,840.25	8.8	41,788.07	19.5	102,867.16	48.1
F: Ecosystem Diversity	112,202.70	52.5	96,394.86	45.1	3,997.64	1.9	11.74	
G: Context and Connection	211,317.49	98.8	1,271.49	0.6	17.96			

Other Essential Criteria

Other essential criteria (also known as expert panel criteria) are based on non-uniform information sources and which may rely more upon expert opinion than on quantitative data. These criteria are used to provide a "second-cut" determination of biodiversity significance, which is then combined with the diagnostic criteria for an overall assessment of relative biodiversity significance. A summary of the biodiversity status based upon the other essential criteria is provided in the following table.

Table 12: Summary of biodiversity significance based upon other essential criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant contains Core Habitat for Priority Taxa (H) & Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I) & Remnant forms part of a bioregional corridor (J)	152.05	0.07
State	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	3,833.18	1.79
State	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I) & Remnant forms part of a bioregional corridor (J)	843.47	0.39
State	Remnant forms part of a bioregional corridor (J)	3,120.23	1.46
Regional	Refer to Expert Panel data for additional information	930.95	0.44
Regional	Remnant contains Core Habitat for Priority Taxa (H)	417.6	0.2
Regional	Remnant contains Core Habitat for Priority Taxa (H) & Remnant forms part of a bioregional corridor (J)	9.65	0.0
Regional	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	4,128.11	1.93
Regional	Remnant forms part of a bioregional corridor (J)	5,848.88	2.73
Local	Refer to Expert Panel data for additional information	5,010.51	2.34

A description of each of the other essential criteria and associated assessment in regards to the AOI is provided in the following sections.

Criteria H. Essential and general habitat for priority taxa: Priority taxa are those which are at risk or of management concern, taxa of scientific interest as relictual (ancient or primitive), endemic taxa or locally significant populations (such as a flying fox camp or heronry), highly specialised taxa whose habitat requirements are complex and distributions are not well correlated with any particular regional ecosystem, taxa important for maintaining genetic diversity (such as complex spatial patterns of genetic variation, geographic range limits, highly disjunct populations), taxa critical for management or monitoring

of biodiversity (functionally important or ecological indicators), or economic and culturally important taxa.

Criteria I. Special biodiversity values: areas with special biodiversity values are important because they contain multiple taxa in a unique ecological and often highly biodiverse environment. Areas with special biodiversity values can include the following:

- Ia - centres of endemism - areas where concentrations of taxa are endemic to a bioregion or subregion are found.
- Ib - wildlife refugia (Morton et al. 1995), for example, islands, mound springs, caves, wetlands, gorges, mountain ranges and topographic isolates, ecological refuges, refuges from exotic animals, and refuges from clearing. The latter may include large areas that are not suitable for clearing because of land suitability/capability.
- Ic - areas with concentrations of disjunct populations.
- Id - areas with concentrations of taxa at the limits of their geographic ranges.
- Ie - areas with high species richness.
- If - areas with concentrations of relictual populations (ancient and primitive taxa).
- Ig - areas containing REs with distinct variation in species composition associated with geomorphology and other environmental variables.
- Ih - an artificial waterbody or managed/manipulated wetland considered by the panel/s to be of ecological significance.
- Ii - areas with a high density of hollow-bearing trees that provide habitat for animals.
- Ij - breeding or roosting sites used by a significant number of individuals.
- Ik - climate change refuge.

The following table identifies the value and extent area of the Other Essential Criteria H and I within the AOI.

Table 13: Relative importance of expert panel criteria (H and I) used to access overall biodiversity significance with respect to the AOI

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
H: Core Habitat Priority Taxa			1,918.52	0.9	5,519.02	2.6		
Ia: Centres of Endemism	1,964.73	0.9						
Ib: Wildlife Refugia	4,774.43	2.2	4,182.38	2.0				
Ic: Disjunct Populations	2,226.48	1.0						
Id: Limits of Geographic Ranges			1,964.73	0.9				
Ie: High Species Richness	4,774.43	2.2	4,182.38	2.0				
If: Relictual Populations								
Ig: Variation in Species Composition	2,468.13	1.2	6,118.55	2.9				
Ih: Artificial Wetland								
Ii: Hollow Bearing Trees	2,547.95	1.2	290.31	0.1				
Ij: Breeding or Roosting Site	2,547.95	1.2	1,993.29	0.9				

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
Ik: Climate Refugia	341.57	0.2						

NB. Whilst biodiversity values associated with Criteria I may be present within the site (refer to tables 12 and 15), for the New England Tableland and Central Queensland Coast BPAs, area and % area figures associated with Criteria Ia through to Ij cannot be listed in the table above (due to slight variations in data formats between BPAs).

Criteria J. Corridors: areas identified under this criterion qualify either because they are existing vegetated corridors important for contiguity, or cleared areas that could serve this purpose if revegetated. Some examples of corridors include riparian habitats, transport corridors and "stepping stones".

Bioregional and subregional conservation corridors have been identified in the more developed bioregions of Queensland through the BPAs, using an intensive process involving expert panels. Map 3 displays the location of corridors as identified under the Statewide Corridor network. The Statewide Corridor network incorporates BPA derived corridors and for bioregions where no BPA has been assessed yet, corridors derived under other planning processes. Note: as a result of updating and developing a statewide network, the alignment of corridors may differ slightly in some instances when compared to those used in individual BPAs.

The functions of these corridors are:

- **Terrestrial** Bioregional corridors, in conjunction with large tracts of remnant vegetation, maintain ecological and evolutionary processes at a landscape scale, by:

  • Maintaining long term evolutionary/genetic processes that allow the natural change in distributions of species and connectivity between populations of species over long periods of time;

  • Maintaining landscape/ecosystems processes associated with geological, altitudinal and climatic gradients, to allow for ecological responses to climate change;

  • Maintaining large scale seasonal/migratory species processes and movement of fauna;

  • Maximising connectivity between large tracts/patches of remnant vegetation;

  • Identifying key areas for rehabilitation and offsets; and

- **Riparian** Bioregional Corridors also maintain and encourage connectivity of riparian and associated ecosystems.

The location of the corridors is determined by the following principles:

- Terrestrial

  • Complement riparian landscape corridors (i.e. minimise overlap and maximise connectivity);

  • Follow major watershed/catchment and/or coastal boundaries;

  • Incorporate major altitudinal/geological/climatic gradients;

  • Include and maximise connectivity between large tracts/patches of remnant vegetation;

  • Include and maximise connectivity between remnant vegetation in good condition; and

- Riparian

  • Located on the major river or creek systems within the bioregion in question.

The total extent of remnant vegetation triggered as being of "State", "Regional" or "Local" significance due to the presence of an overlying BPA derived terrestrial or riparian corridor within the AOI, is provided in the following table. For further information on how remnant vegetation is triggered due to the presence of an overlying BPA derived corridor, refer to the relevant landscape BPA expert panel report(s).

Table 14: Extent of triggered remnant vegetation due to the presence of BPA derived corridors with respect to the AOI

Biodiversity Significance	Area (Ha)	% of AOI
State	4,103.03	1.92
Regional	5,871.26	2.74
Local	0.0	0.0

NB: area figures associated with the extent of corridor triggered remnant vegetation are only available for those bioregions where a BPA has been undertaken.

Refer to **Map 3** for further information.

Threatening process/condition (Criteria K) - areas identified by experts under this criterion may be used to amend (upgrade or downgrade) biodiversity significance arising from the "first-cut" analysis. The condition of remnant vegetation is affected by threatening processes such as weeds, ferals, grazing and burning regime, selective timber harvesting/removal, salinity, soil erosion, and climate change.

Assessment of Criteria K with respect to the AOI is not currently included in the "Biodiversity and Conservation Values" report, as it has not been applied to the majority of Queensland due to data/information limitations and availability.

Special Area Decisions

Expert panel derived "Special Area Decisions" are used to assign values to Other Essential Criteria. The specific decisions which relate to the AOI in question are listed in the table below.

Table 15: Expert panel decisions for assigning levels of biodiversity significance with respect to the AOI

Decision Number	Description	Panel Recommended Significance	Criteria Values
gup_fa_05	Bauhinia woodlands	Regional	Ib (wildlife refugia): HIGH Ie (high species diversity): HIGH Ig (REs show distinct variation in species composition): HIGH
gup_fa_17	High precision records for priority taxa of Regional significance are contained within the remnant.	Regional	Criteria H: HIGH
gup_fl_20	High precision records for priority taxa of Regional significance are contained within the remnant.	Regional	Criteria H: HIGH
gup_l_41	Riparian ecosystems and associated areas	State	Ib (wildlife refugia): VERY HIGH Ie (high species diversity): VERY HIGH Ig (REs show distinct variation in species composition): VERY HIGH Ii (high density of hollow-bearing habitat trees):VERY HIGH Ij (significant breeding or roosting sites): VERY HIGH
gup_l_45	Wetlands	Regional	Ib (wildlife refugia): HIGH Ie (high species diversity):HIGH Ii (high density of hollow-bearing habitat trees): HIGH Ij (significant breeding or roosting sites): HIGH
gup_l_47	Riparian corridors	State	Criterion J (corridors): State
nwh_l_04	Permanent and semi-permanent instream waterholes - drought refugia	State	Ib (wildlife refugia): VH Ie (high species richness): VH Ii (habitat shelters): VH Ij (Breeding/roosting sites used by sig. no. of individuals): VH Ik (climate refugia): VH
nwh_l_07	Coarse Granites and Tor Fields	State	Ia (centre of endemism): VH Ib (wildlife refugia): VH Ic (disjunct populations): VH Id (geographic range limits): H Ie (high species richness): VH Ig (REs with distinct variation in species composition): H Ij (Breeding/roosting sites used by sig. no. of individuals): H

Decision Number	Description	Panel Recommended Significance	Criteria Values
nwh_l_11	Softwood Thickets on Metamorphic Screes	State	Ib (wildlife refugia): VH Ic (disjunct populations): VH Ie (high species richness): VH Ii (habitat shelters): H Ik (Climate refugia): VH
nwh_l_17a	Riparian bioregional corridors (landscape connections)	State)	Criterion J (riparian corridor): State
nwh_l_17b	Riparian bioregional corridors (landscape connections)	Regional	Criterion J (riparian corridor): Regional

Expert panel decision descriptions:

gup_fa_05

Seasonally important for nectarivores (honeyeaters, white-browed woodswallows Artamus supercilious, white-winged trillers Lalage sueurii and varied lorikeets Psitteuteles versicolor) (Richard Johnson in lit). Important for honeyeater diversity given relatively high fertility and productivity with shallow sands over shales.

Bauhinia woodland on alluvium may be at risk given possible future development of agriculture in the region (Richard Johnson in lit).

gup_fa_17

Remnant contains habitat for priority taxa with high precision records.

gup_fl_20

Remnant contains habitat for priority taxa with high precision records.

gup_l_41

Riparian ecosystems in the Gulf Plains provide a refuge in otherwise seasonally droughty and sparsely vegetated landscapes that dominate non-riparian areas.

See also gup_fa_08 for specific values of western riparian systems.

gup_l_45

Wetlands have a range of biodiversity values, both in their own right, and for the role they play in maintaining water quality, protecting downstream aquatic ecosystems, and as part of the wetland ecosystem continuum where they are periodically connected with other aquatic ecosystems. Wetlands act as refugia for many species, and play a vital role in the life cycle of others. Wetlands are a defining characteristic of the bioregion, in their extent, diversity, and condition.

Wetlands were given a 200m buffer with the same significance rating to ensure that all areas adjacent to them, and the areas most likely to have higher values, were also included.

Numerous decisions in southern Gulf of Carpentaria ACA relate to wetlands within the Flinders, Norman and Gilbert river catchments (Rollason and Howell 2010).

gup_l_47

Riparian corridors in the Gulf Plains are particularly significant for biodiversity, both as a climatic refuge and as a major element of habitat continuity. This decision is based on the bioregional corridor values of major riparian areas. The refugial and other values of riparian areas are covered by decision gup_l_41.

nwh_l_04

Within the Mount Isa and Southwestern Plateaus and Floodouts subregions, permanent waterholes and surrounding riparian vegetation support aquatic and terrestrial flora and fauna in an otherwise arid environment. Systems, such as Gunpowder Creek and its tributary Eastern Creek, retreat to become isolated waterholes which persist during long dry periods and provide drought refugia. The more permanent and deeper waterholes may act as important climate refugia.

The waterholes are important for common species within the region and often encompass a high species richness relative to the surrounding landscape. The large deep permanent pools provide habitat for aquatic species like freshwater crocodiles (**Crocodylus johnsoni**), diamond head turtle (**Emydura subglobosa worrelli**) and blue catfish (**Neoarius graeffei**), whilst the adjoining riparian vegetation (1.3.7) provides a diverse habitat structure with numerous hollows and habitat shelters along the terraces and supports species such as **Ipomoea antonschmidii**, purple-necked rock-wallaby (**Petrogale purpureicollis**), Cloncurry parrot (**Barnardius zonarius macgillivrayi**), **Brachychiton collinus**, **Cyperus cunninghamii** ssp**. cheradicus**, **Eucalyptus leucophylla** and pictorella mannikin (**Heteromunia pectoralis**). This special area type is a critical dry season refugia for fauna that require regular access to drinking water.

nwh_l_07

Regional ecosystems 1.12.2 and 1.12.7, occur on ancient weathered skeletal and relatively infertile soils. Deeply fractured coarse grained granite tors which house caves and crevices, characterise the landscape. The unique habitat created by the coarse nature of the soils and fractured rock allow water to be absorbed and retained in the soil profile. These unique habitat niches and characteristics support high flora and fauna species richness and provide a fire refugia, however, are potentially at risk from more intense and frequent climate induced fires (Low, 2011).

Whilst likely to house a wide range of currently unidentified taxa, notable fauna values include the presence of the purple-necked rock-wallabies (**Petrogale purpureicollis**), Carpentarian pseudantechinus (**Pseudantechinus mimulus**) and it's likely that micro bat colonies occupy crevices. Priority taxa such as the Kalkadoon grasswren (**Amytornis ballarae**), Cloncurry parrot (**Barnardius zonarius macgillivrayi**), ten-lined ctenotus (**Ctenotus decaneurus**), stripe-headed finesnout ctenotus (**Ctenotus striaticeps**), gulf fat-tailed gecko (**Diplodactylus barraganae**), Hosmer's skink (**Egernia hosmeri**), robust dtella (**Gehyra robusta**), spectacled hare-wallaby (**Lagorchestes conspicillatus**), white-striped gecko (**Strophurus taeniatus**), **Eucalyptus leucophylla** and **Heliotropium frohlichii** have been recorded. There is a probable night parrot (**Pezoporus occidentalis**) sighting in this habitat from the vicinity of Galah Creek, south of Mt Isa. Also the western range limit of **E. melanophloia** ssp. nana

n.b. Relates to an adjoining bioregional decision eiu_l_23.

nwh_l_11

Regional ecosystem 1.11.8 occurs on rock outcrops on hills and ranges on strongly folded siliceous sedimentary and metamorphic pre-Cambrian rocks (Queensland Herbarium, 2019). Some occurrences of this community are dominated by **Terminalia aridicola** and **Brachychiton collinus** softwood thickets.

The softwood thickets are characterised by large crown trees with >30% foliage projection cover. The dense canopy and hill shade results in cooler conditions allowing species to survive in an otherwise dry hot environment. Small areas of surface water can be present and along with deeper organic matter accumulation and higher soil moisture, provide a cooler microclimate. In comparison to surrounding ecosystems, the thickets have high species richness and support significant habitat for birds (e.g., bower birds). Due to their topographic position, they represent a refuge from grazing, whilst instances of this community situated on steep rock dominated slopes, also provide a refuge from fire.

Threatened species recorded include **Eucalyptus nudicaulis** and purple-necked rock-wallaby (**Petrogale purpureicollis**) and priority species Kalkadoon grasswren (**Amytornis ballarae**), sandstone frog (**Litoria coplandi**), giant rocketfrog (**Litoria watjulumensis**) and Carpentarian pseudantechinus (**Pseudantechinus mimulus**).

nwh_l_17a

Riparian corridors encompass some of the most diverse, dynamic and complex habitats incorporating both environmental and topographic gradients. Comparatively, such areas tend to exhibit high species richness with respect to both flora and fauna, provide important resources in terms of water, food, shelter, nesting and nursery sites and act as a refugia during periods of drought, or in response to longer terms impacts associated with climatic change.

At the landscape scale, networks of major and minor riparian linkages are a significant element of habitat continuity and provide important migratory and dispersal pathways for a substantial number of species (especially birds, insects and flora, but also for many arboreal mammals and reptiles).

Within the NWH, remnant vegetation within 200m and 100m of selected major and minor waterways was designated as being of State and Regional significance respectively. The significance of selected riverine systems was also modified in some instances. For further information regarding the broad principles and intent, as well as more specific information relating to the Northwest Highlands riparian corridor network, refer to Section 3.3.2.2and Table 15.

nwh_l_17b

Riparian corridors encompass some of the most diverse, dynamic and complex habitats incorporating both environmental and topographic gradients. Comparatively, such areas tend to exhibit high species richness with respect to both flora and fauna, provide important resources in terms of water, food, shelter, nesting and nursery sites and act as a refugia during periods of drought, or in response to longer terms impacts associated with climatic change.

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Aquatic Conservation Assessments

Introduction

The Aquatic Biodiversity Assessment and Mapping Method or AquaBAMM (Clayton et al. 2006), was developed to assess conservation values of wetlands in queensland, and may also have application in broader geographical contexts. It is a comprehensive method that uses available data, including data resulting from expert opinion, to identify relative wetland conservation/ecological values within a specified study area (usually a catchment). The product of applying this method is an Aquatic Conservation Assessment (ACA) for the study area.

An ACA using AquaBAMM is non-social, non-economic and identifies the conservation/ecological values of wetlands at a user-defined scale. It provides a robust and objective conservation assessment using criteria, indicators and measures that are founded upon a large body of national and international literature. The criteria, each of which may have variable numbers of indicators and measures, are naturalness (aquatic), naturalness (catchment), diversity and richness, threatened species and ecosystems, priority species and ecosystems, special features, connectivity and representativeness. An ACA using AquaBAMM is a powerful decision support tool that is easily updated and simply interrogated through a geographic information system (GIS).

Where they have been conducted, ACAs can provide a source of baseline wetland conservation/ecological information to support natural resource management and planning processes. They are useful as an independent product or as an important foundation upon which a variety of additional environmental and socio-economic elements can be added and considered (i.e. an early input to broader 'triple-bottom-line' decision-making processes). An ACA can have application in:

- determining priorities for protection, regulation or rehabilitation of wetlands and other aquatic ecosystems
- on-ground investment in wetlands and other aquatic ecosystems
- contributing to impact assessment of large-scale development (e.g. dams)
- water resource and strategic regional planning prcesses

For a detailed explanation of the methodology please refer to the summary and expert panel reports relevant to the ACA utilised in this assessment. These reports can be accessed at Wetland Info:

http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

Explanation of Criteria

Under the AquaBAMM, eight criteria are assessed to derive an overall conservation value. Similar to the Biodiversity Assessment and Mapping Methodology, the criteria may be primarily diagnostic (quantitative) or primarily expert opinion (qualitative) in nature. The following sections provide a brief description of each of the 8 criteria.

Criteria 1. Naturalness - Aquatic: This attribute reflects the extent to which a wetland's (riverine, non-riverine, estuarine) aquatic state of naturalness is affected through relevant influencing indicators which include: presence of exotic flora and fauna; presence of aquatic communities; degree of habitat modification and degree of hydrological modification.

Criteria 2. Naturalness - Catchment: The naturalness of the terrestrial systems of a catchment can have an influence on many wetland characteristics including: natural ecological processes e.g. nutrient cycling, riparian vegetation, water chemistry, and flow. The indicators utilised to assess this criterion include: presence of exotic flora and/or fauna; riparian, catchment and flow modification.

Criteria 3. Naturalness - Diversity and Richness: This criterion is common to many ecological assessment methods and can include both physical and biological features. It includes such indicators as species richness, riparian ecosystem richness and geomorphological diversity.

Criteria 4. Threatened Species and Ecosystems: This criterion evaluates ecological rarity characteristics of a wetland. This includes both species rarity and rarity of communities / assemblages. The communities and assemblages are best represented by regional ecosystems. Species rarity is determined by NCA and EPBC status with Endangered, Vulnerable or Near-threatened species being included in the evaluation. Ecosystem rarity is determined by regional ecosystem biodiversity status i.e. Endangered, Of Concern, or Not of Concern.

Criteria 5. Priority Species and Ecosystems: Priority flora and fauna species lists are expert panel derived. These are aquatic, semi-aquatic and riparian species which exhibit at least 1 particular trait in order to be eligible for consideration. For

flora species the traits included:

- It forms significant macrophyte beds (in shallow or deep water).
- It is an important food source.
- It is important/critical habitat.
- It is implicated in spawning or reproduction for other fauna and/or flora species.
- It is at its distributional limit or is a disjunct population.
- It provides stream bank or bed stabilisation or has soil binding properties.
- It is a small population and subject to threatening processes.

Fauna species are included if they meet at least one of the following traits:

- It is endemic to the study area (>75 per cent of its distribution is in the study area/catchment).
- It has experienced, or is suspected of experiencing, a serious population decline.
- It has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area/catchment.
- It is currently a small population and threatened by loss of habitat.
- It is a significant disjunct population.
- It is a migratory species (other than birds).
- A significant proportion of the breeding population (>one per cent for waterbirds, >75 per cent other species) occurs in the waterbody (see Ramsar criterion 6 for waterbirds).
- Limit of species range.

See the individual expert panel reports for the priority species traits specific to an ACA.

Criteria 6. Special Features: Special features are areas identified by flora, fauna and ecology expert panels which exhibit characteristics beyond those identified in other criteria and which the expert panels consider to be of the highest ecological importance. Special feature traits can relate to, but are not solely restricted to geomorphic features, unique ecological processes, presence of unique or distinct habitat, presence of unique or special hydrological regimes e.g. spring-fed streams. Special features are rated on a 1 - 4 scale (4 being the highest).

Criteria 7. Connectivity: This criterion is based on the concept that appropriately connected aquatic ecosystems are healthy and resilient, with maximum potential biodiversity and delivery of ecosystem services.

Criteria 8. Representativeness: This criterion applies primarily to non-riverine assessments, evaluates the rarity and uniqueness of a wetland type in relation to specific geographic areas. Rarity is determined by the degree of wetland protection within "protected Areas" estate or within an area subject to the Fisheries Act 1994, Coastal Protection and Management Act 1995, or Marine Parks Act 2004. Wetland uniqueness evaluates the relative abundance and size of a wetland or wetland management group within geographic areas such as catchment and subcatchment.

Riverine Wetlands

Riverine wetlands are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water. AquaBAMM, when applied to riverine wetlands uses a discrete spatial unit termed subsections. A subsection can be considered as an area which encompasses discrete homogeneous stream sections in terms of their natural attributes (i.e. physical, chemical, biological and utilitarian values) and natural resources. Thus in an ACA, an aquatic conservation significance score is calculated for each subsection and applies to all streams within a subsection, rather than individual streams as such.

Please note, the area figures provided in Tables 16 and 17, are derived using the extent of riverine subsections within the AOI. Refer to **Map 5** for further information. A summary of the conservation significance of riverine wetlands within the AOI is provided in the following table.

Table 16: Overall level/s of riverine aquatic conservation significance

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	2,419.71	1.13

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
High	123,195.32	57.59
Medium	88,301.26	41.28
Low	0.0	0.0
Very Low	0.0	0.0

The individual aquatic conservation criteria ratings for riverine wetlands within the AOI are listed below.

Table 17: Level/s of riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic	172,930.11	80.8	39,387.53	18.4	1,598.65	0.7		
2. Naturalness catchment			209,523.13	97.9	4,393.16	2.1		
3. Diversity and richness	16,227.86	7.6	124,432.64	58.2	73,255.79	34.2		
4. Threatened species and ecosystems	57,930.31	27.1	4,864.60	2.3	151,121.38	70.6		
5. Priority species and ecosystems	58,073.02	27.1	72,414.13	33.9	56,651.51	26.5		
6. Special features	2,419.71	1.1	67,262.23	31.4				
7. Connectivity	2,419.71	1.1						
8. Representative-ness	2,419.71	1.1						

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to riverine wetlands within the AOI.

Table 18: Expert panel decisions for assigning overall levels of riverine aquatic conservation significance

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
lr_r_ec_31	Perennial waterholes in central southern headwaters of the Leichhardt Basin	Leichhardt	6.1.1, 6.2.1, 6.3.1, 6.3.4, 6.4.1, 7.1.1, 7.1.2, 7.2.1, 7.3.2, 7.4.1, 8.2.5	4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4
lr_r_fl_16	Riverine systems containing Terminalia bursarina	Leichhardt Nicholson Settlement	5.2.1, 6.3.1	4, 3
lr_r_fl_17	Low woodlands fringing major or minor watercourses	Leichhardt Mornington Inlet Nicholson Settlement Wellesley Islands	5.2.1	4

4 is the highest rating/value

Expert panel decision descriptions:

lr_r_ec_31

Two main subcatchments, Mistake and Surprise Creeks, of the central southern headwaters of the Leichhardt River basin contain significant numbers of perennial waterholes. This part of the basin is extremely arid and few of the surrounding subcatchments contain few natural perennial waterholes. Both creeks drain to the main Leichhardt channel, Mistake Creek via a confluence with the Gunpowder Creek main channel immediately upstream of its confluence with the Leichhardt River, and Surprise Creek via a confluence with Ewen Creek to the reach below Lake Julius. Mistake Creek has significantly more exposed bedrock and this creates greater lengths of rocky waterhole reaches with associated gorges, scarps and seasonal races. Major waterholes within Surprise Creek are sand bed channel hosted and restricted to its lowermost reach above the Leichhardt River main channel confluence with which it shares analogous habitat types but retains a hydrological regime unmodified by upstream impoundments.

Pools within these subcatchments have an important function as refugia for obligate freshwater biota and other dependent terrestrial fauna that seasonally occupy the more extensive seasonal riverine habitats within these systems. Ecological values and the geomorphic setting are very similar to those described for upper Gunpowder Creek. This special feature is subject to invasion by rubber vine (Cryptostegia grandiflora) and grazing pressure that can lead to habitat loss and erosion.

For a more detailed explanation of this special feature, please refer to Appendix III of the Southern Gulf Catchment Aquatic Conservation Assessment Expert Panel Report.

lr_r_fl_16

Terminalia bursarina is a rare species occurring within-channel deposits and levees of major watercourses or on the fringes of minor watercourses. Vegetation communities in the Gulf which contain Terminalia bursarina are important because this is the only area in Queensland where it is found. This includes woodland including river red gum (Eucalyptus camaldulensis), swamp box (Lophostemon grandiflorus), Melaleuca argentea, Terminalia bursarina, Lysiphyllum cunninghamii and Acacia holosericea (regional ecosystem 1.3.7f), and river red gum (Eucalyptus camaldulensis) woodland commonly with Terminalia bursarina, swamp box (Lophostemon grandiflorus) and paperbarks (Melaleuca spp.) in the canopy (regional ecosystem 2.3.26f).

lr_r_fl_17

This special feature consists of low open woodland to woodland coolabah (Eucalyptus microtheca) communities occurring along major watercourses or minor channels in landscapes (i.e. Wondoola and Armraynald Plains subregions) where they represent the only or most significant riparian communities. For example, they form the key riparian corridors across the large clay plains of the western Gulf Plains, whilst in the Armraynald Plain subregion they form the main (or only) source of water and shade. This decision includes vegetation communities dominated by coolabah (Eucalyptus microtheca) low open woodland to woodland, commonly with Excoecaria parvifolia, Lysiphyllum cunninghamii and Atalaya hemiglauca (regional ecosystem 2.3.17), coolabah low open woodland to woodland, commonly with Excoecaria parvifolia and Lysiphyllum cunninghamii (regional ecosystem 2.3.17a), coolabah woodland (regional ecosystem 2.3.17b), and coolabah woodland to open forest, commonly with Terminalia platyphylla (regional ecosystem 2.3.17d). These communities are diverse and ecologically complex especially in areas with braided watercourses. They are known to provide refuge for fauna, including macropods, and are the only permanent coolabah regional ecosystems in the Gulf Plains. All are generally subject to grazing pressure, widespread erosion and habitat loss. Regional ecosystems 2.3.17 and 2.3.17a are also known to be subject to extensive invasion by buffel grass (Cenchrus ciliaris) on sandier soils, whilst regional ecosystem 2.3.17d is commonly heavily invaded by Cryptostegia grandiflora (rubber vine).

Non-riverine Wetlands

Non-riverine wetlands include both lacustrine and palustrine wetlands, however, do not currently incorporate estuarine, marine or subterranean wetland types. A summary of the conservation significance of non-riverine wetlands within the AOI is provided in the following table. Refer to **Map 6** for further information.

Table 19: Overall level/s of non-riverine aquatic conservation significance

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0
High	8.27	0.0
Medium	0.0	0.0
Low	0.0	0.0
Very Low	0.0	0.0

The following table provides an assessment of non-riverine wetlands within the AOI and associated aquatic conservation criteria values.

Table 20: Level/s of non-riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic	8.27							
2. Naturalness catchment			8.27					
3. Diversity and richness			8.27					
4. Threatened species and ecosystems			8.27					
5. Priority species and ecosystems								
6. Special features								
7. Connectivity								
8. Representative-ness			8.27					

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to non-riverine wetlands within the AOI.

Table 21: Expert panel decisions for assigning overall levels of non-riverine aquatic conservation significance.

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
(No Records)				

4 is the highest rating/value

Expert panel decision descriptions:

(No Records)

Threatened and Priority Species

Introduction

This chapter contains a list of threatened and priority flora and/or fauna species that have been recorded on, or within 4km of the Assessment Area.

The information presented in this chapter with respect to species presence is derived from compiled databases developed primarily for the purpose of BPAs and ACAs. Data is collated from a number of sources and is updated periodically.

It is important to note that the list of species provided in this report, may differ when compared to other reports generated from other sources such as the State government's WildNet, Herbrecs or the federal government's EPBC database for a number of reasons.

Records for threatened and priority species are filtered and checked based on a number of rules including:

- Taxonomic nomenclature - current scientific names and status,
- Location - cross-check co-ordinates with location description,
- Taxon by location - requires good knowledge of the taxon and history of the record,
- Duplicate records - identify and remove,
- Expert panels - check records and provide new records,
- Flora cultivated records excluded,
- Use precise records less than or equal to 2000m,
- Use recent records greater than or equal to 1975 animals, greater than or equal to 1950 plants.

Threatened Species

Threatened species are those species classified as "Endangered" or "Vulnerable" under the Environment Protection and Biodiversity Conservation Act 1999 or "Endangered", "Vulnerable" or "Near threatened" under the Nature Conservation Act 1992.

The following threatened species have been recorded on, or within approximately 4km of the AOI.

Table 22: Threatened species recorded on, or within 4km of the AOI

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Amytornis dorotheae	Carpentarian grasswren	E	E	High			FA
Dichanthium setosum		C	V				FL
Falco hypoleucos	grey falcon	V	V	Data Deficient			FA
Grantiella picta	painted honeyeater	V	V	High			FA
Petrogale purpureicollis	purple-necked rock-wallaby	V		Low			FA

NB. Please note that the threatened species listed in this section are based upon the most recently compiled DES internal state-wide threatened species dataset. This dataset may contain additional records that were not originally available for inclusion in the relevant individual BPAs and ACAs.

*JAMBA - Japan-Australia Migratory Bird Agreement; CAMBA - China-Australia Migratory Bird Agreement; ROKAMBA - Republic of Korea-Australia Migratory Bird Agreement; CMS - Convention on the Conservation of Migratory Species.

**I - wetland indicator species; D - wetland dependent species.

BPA Priority Species

A list of BPA priority species that have been recorded on, or within approximately 4km of the AOI is contained in the following table.

Table 23: Priority species recorded on, or within 4km of the AOI

Species	Common name	Back on Track rank	Identified flora/fauna
Amytornis ballarae	Kalkadoon grasswren	H	FA
Artamus cinereus	black-faced woodswallow	None	FA
Barnardius zonarius macgillivrayi	Cloncurry parrot	L	FA
Brachychiton collinus	None	L	FL
Corymbia bella	None	None	FL
Ctenotus decaneurus	ten-lined ctenotus	L	FA
Ctenotus striaticeps	stripe-headed finesnout ctenotus	L	FA
Cyperus cunninghamii subsp. cheradicus	None	None	FL
Diplodactylus barraganae	Gulf fat-tailed gecko	None	FA
Egernia hosmeri	Hosmer's skink	DD	FA
Eucalyptus leucophylla	None	None	FL
Gehyra robusta	robust dtella	L	FA
Heteromunia pectoralis	pictorella mannikin	L	FA
Livistona rigida	None	None	FL
Onychogalea unguifera	northern nailtail wallaby	L	FA
Planigale ingrami	long-tailed planigale	L	FA
Polygala barklyensis	None	None	FL
Tephrosia sp. (Barkly Downs S.L.Everist 3384)	None	None	FL
Tephrosia sp. (Mt Isa P.L.Harris 277)	None	None	FL
Triumfetta rupestris	None	None	FL
Varanus mertensi	Mertens' water monitor	L	FA

NB. Please note that the list of priority species is based on those species identified in the BPAs, however records for these species may be more recent than the originals used. furthermore, the BPA priority species databases are updated from time to time. At each update, the taxonomic details for all species are amended as necessary to reflect current taxonomic name and/or status changes.

ACA Priority Species

A list of ACA priority species used in riverine and non-riverine ACAs that have been recorded on, or within approximately 4km of the AOI are contained in the following tables.

Table 24: Priority species recorded on, or within 4 km of the AOI - riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Cyperus exaltatus	tall flatsedge	None	FL
Eucalyptus camaldulensis	None	None	FL
Ficus racemosa var. racemosa	None	None	FL
Hephaestus fuliginosus	sooty grunter	Low	FA
Lates calcarifer	barramundi	Low	FA
Leiopotherapon unicolor	spangled perch	Low	FA
Leiopotherapon unicolor	Spangled Perch	None	FA
Livistona rigida	None	None	FL

Species	Common name	Back on Track rank	Identified flora/fauna
Melaleuca bracteata	None	None	FL
Melaleuca fluviatilis	None	None	FL
Pseudoraphis spinescens	spiny mudgrass	None	FL
Scortum ogilbyi	Gulf grunter	Low	FA
Strongylura krefftii	freshwater longtom	Low	FA
Varanus mertensi	Mertens' Water Monitor	None	FA

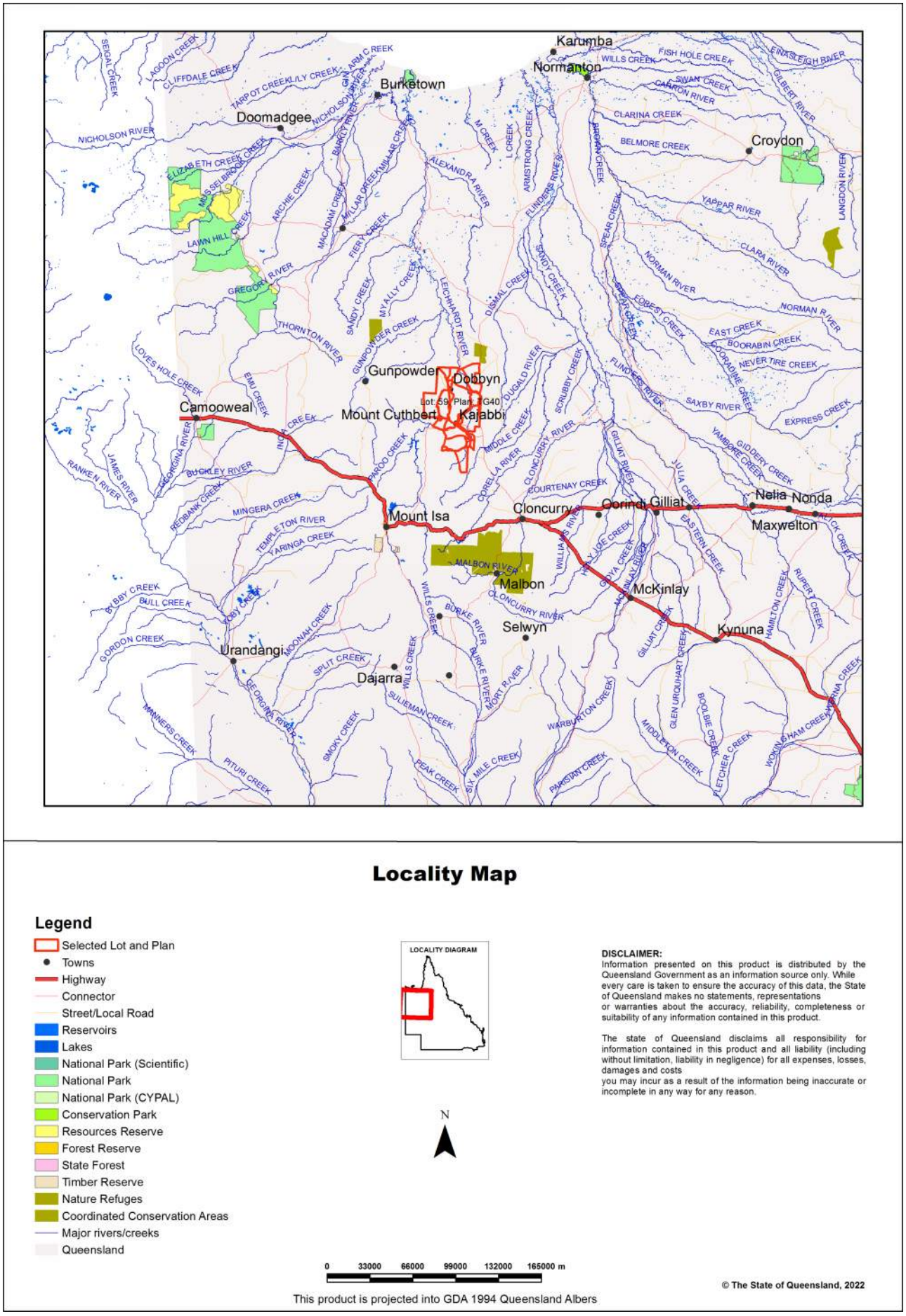
Table 25: Priority species recorded on, or within 4 km of the AOI - non-riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Cyperus exaltatus	tall flatsedge	None	FL
Eucalyptus camaldulensis	None	None	FL
Hephaestus fuliginosus	sooty grunter	Low	FA
Lates calcarifer	barramundi	Low	FA
Leiopotherapon unicolor	spangled perch	Low	FA
Leiopotherapon unicolor	Spangled Perch	None	FA
Melaleuca bracteata	None	None	FL
Pseudoraphis spinescens	spiny mudgrass	None	FL
Scortum ogilbyi	Gulf grunter	Low	FA
Strongylura krefftii	freshwater longtom	Low	FA
Varanus mertensi	Mertens' Water Monitor	None	FA

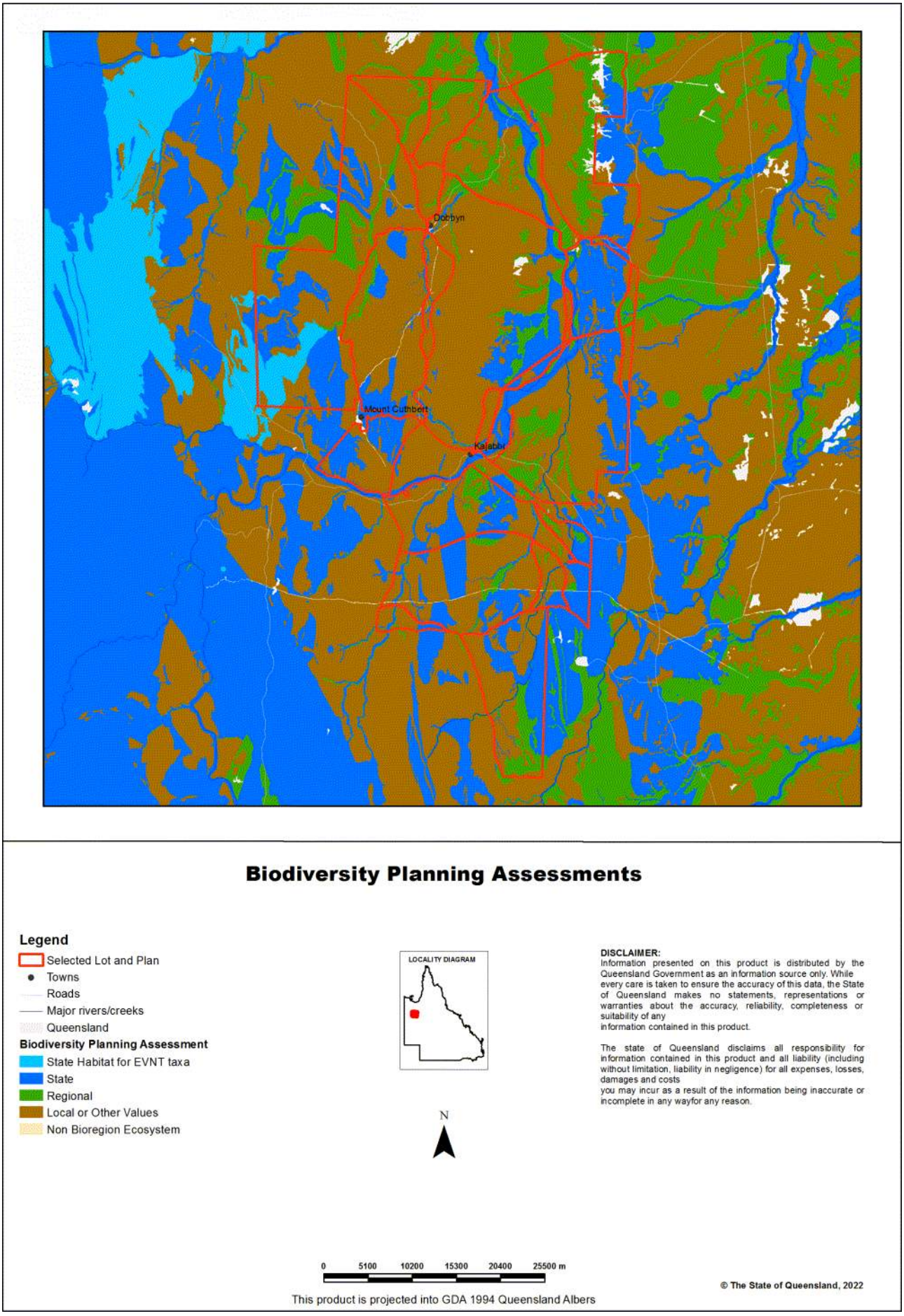
NB. Please note that the priority species records used in the above two tables are comprised of those adopted for the released individual ACAs. The ACA riverine and non-riverine priority species databases are updated from time to time to reflect new release of ACAs. At each update, the taxonomic details for all ACAs records are amended as necessary to reflect current taxonomic name and/or status changes.

Maps

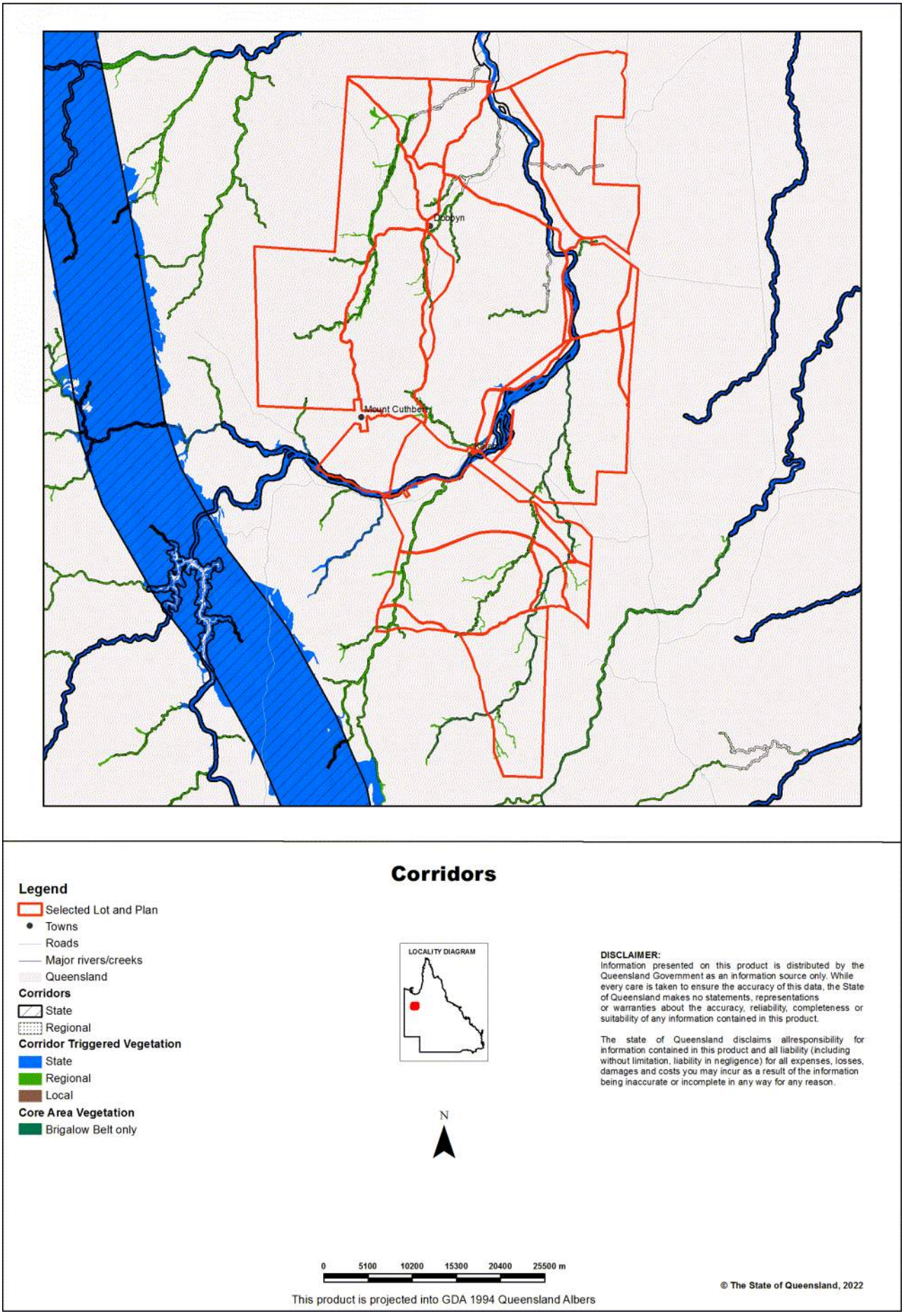
Map 1 - Locality Map



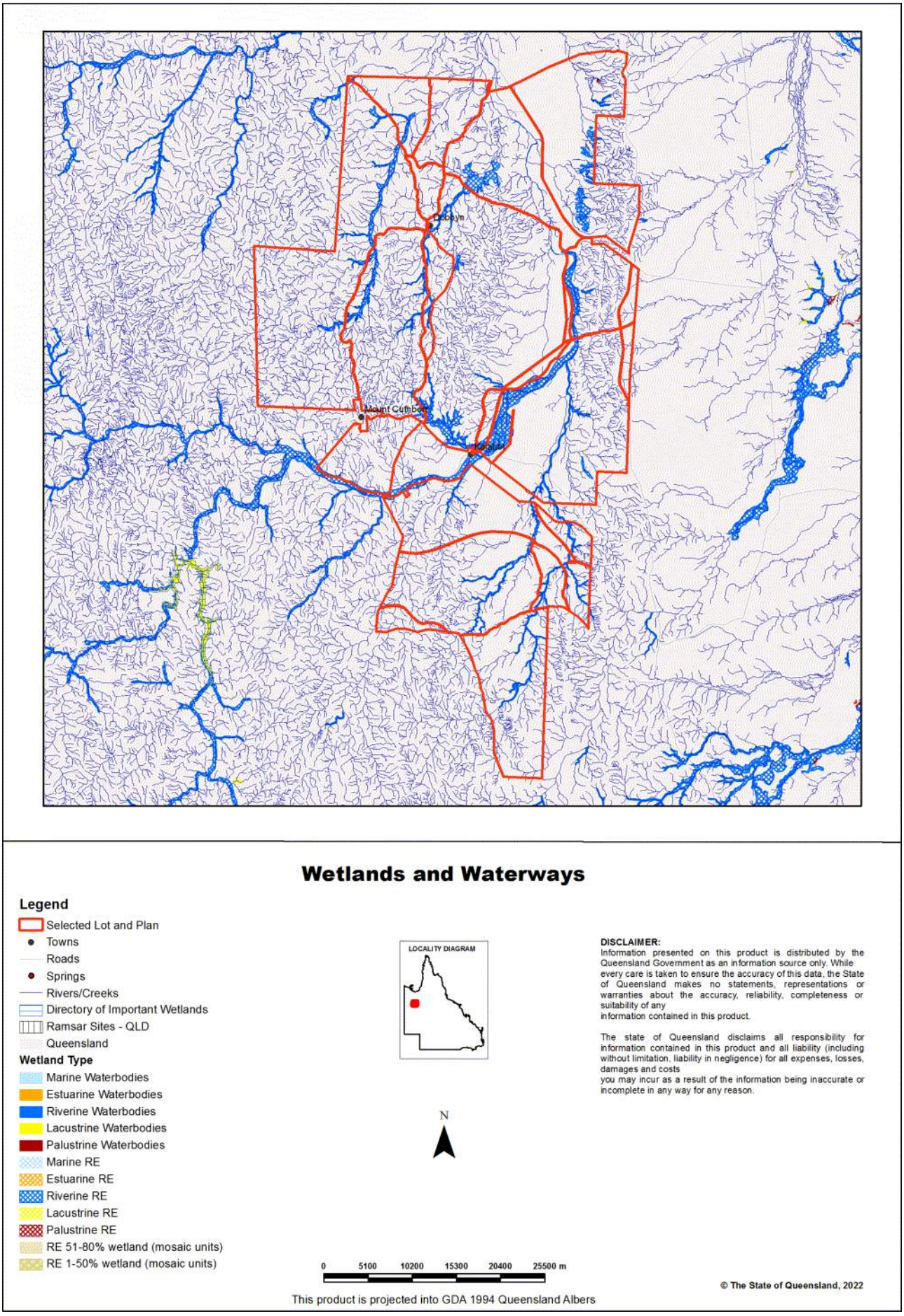
Map 2 - Biodiversity Planning Assessment (BPA)



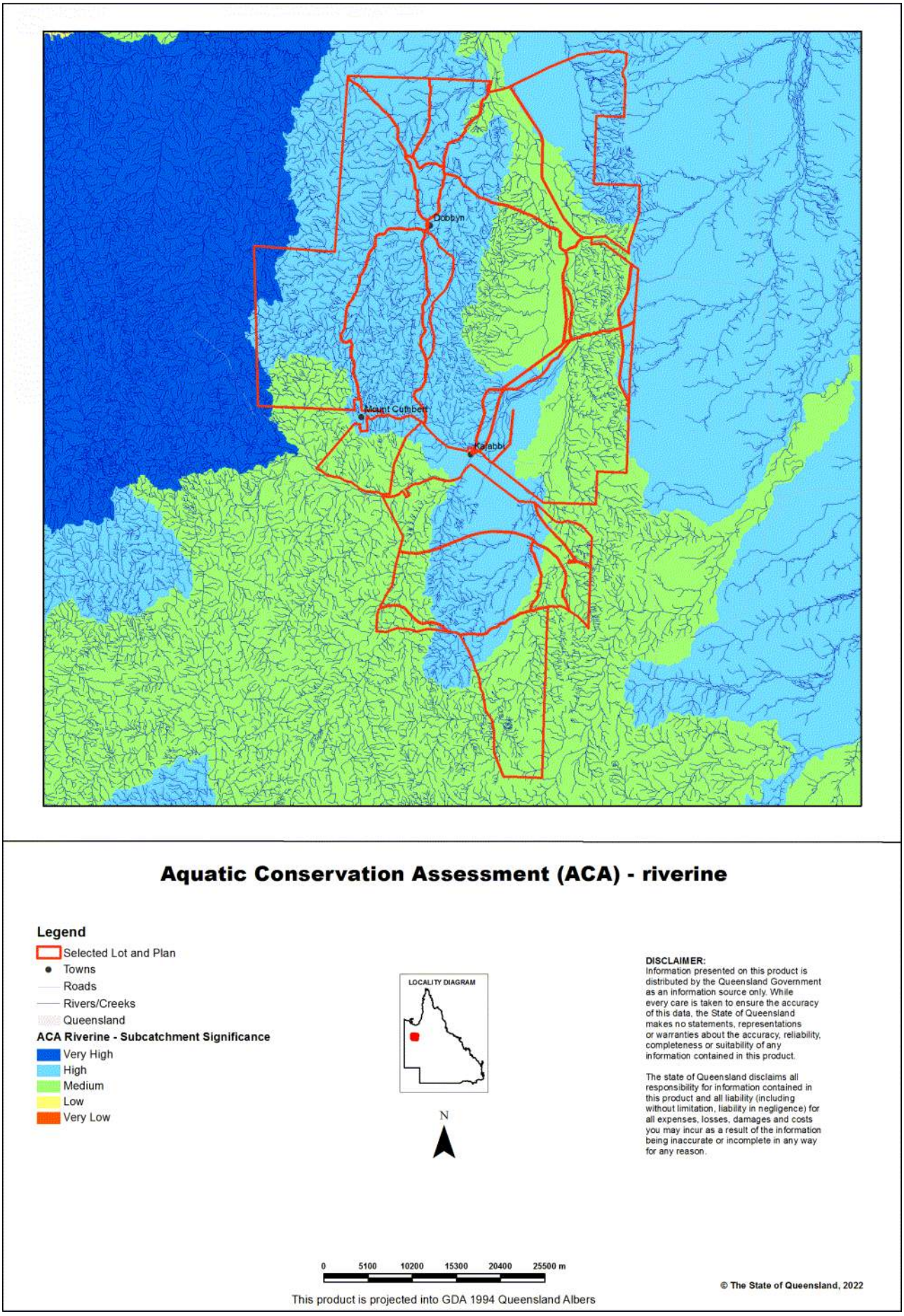
Map 3 - Corridors



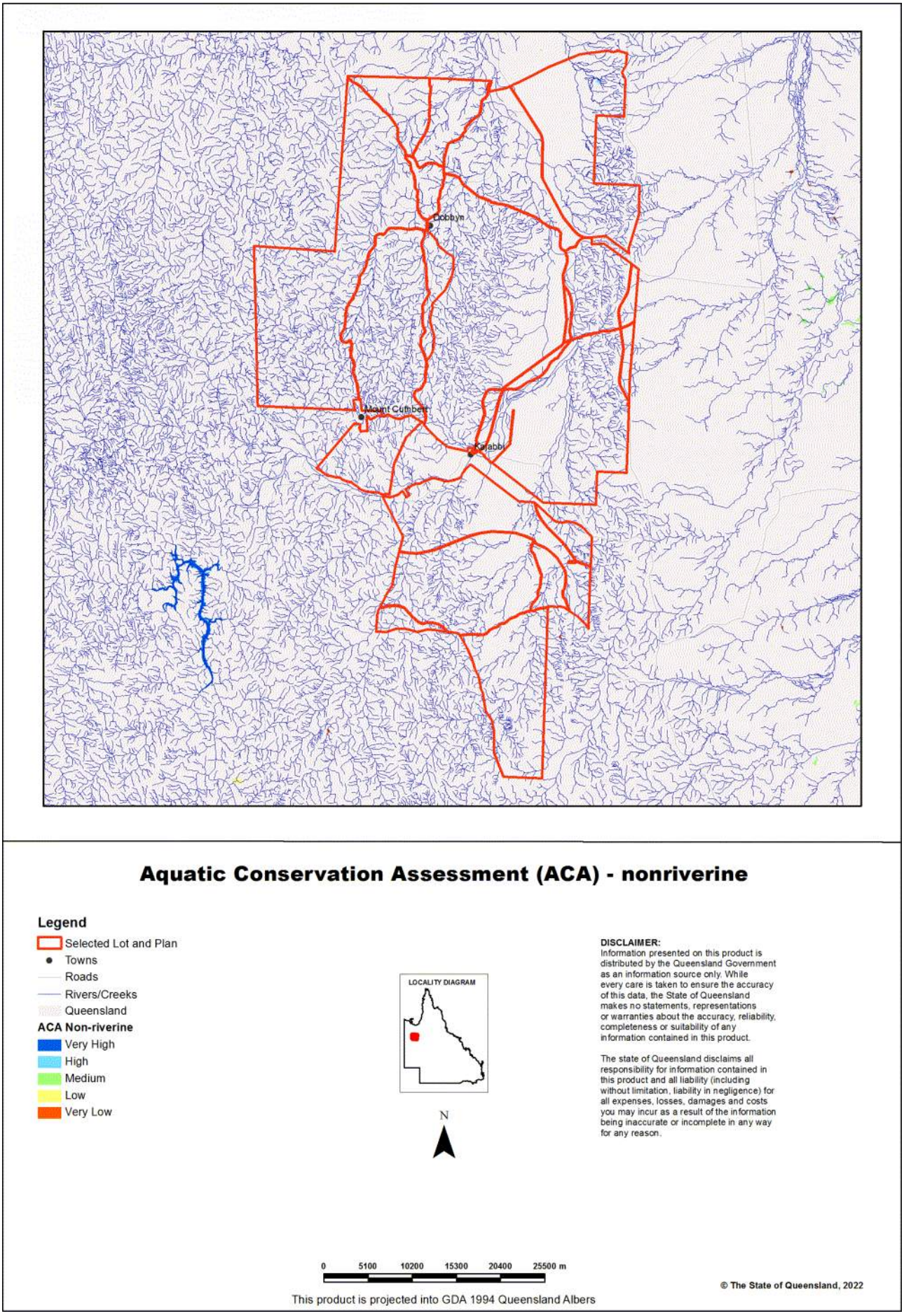
Map 4 - Wetlands and waterways



Map 5 - Aquatic Conservation Assessment (ACA) - riverine



Map 6 - Aquatic Conservation Assessment (ACA) - non-riverine



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http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca/

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Appendices

Appendix 1 - Source Data

Theme	Datasets
Aquatic Conservation Assessments Non-riverine*	Combination of the following datasets: Cape York Peninsula Non-riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Non-riverine v1.3 Lake Eyre and Bulloo Basins v1.1 QMDB Non-riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Non-riverine ACA v1.1 Southern Gulf Catchments Non-riverine ACA v1.1
Aquatic Conservation Assessments Riverine*	Combination of the following datasets: Cape York Peninsula Riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Riverine v1.1 Lake Eyre and Bulloo Basins v1.1 QMDB Riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Riverine ACA v1.1 Southern Gulf Catchments Riverine ACA v1.1
Biodiversity Planning Assessments*	Combination of the following datasets: Brigalow Belt BPA v2.1 Cape York Peninsula BPA v1.1 Central Queensland Coast BPA v1.3 Channel Country BPA v1.1 Desert Uplands BPA v1.3 Einasleigh Uplands BPA v1.1 Gulf Plains BPA v1.1 Mitchell Grass Downs BPA v1.1 Mulga Lands BPA v1.4 New England Tableland v2.3 Northwest Highlands v1.1 Southeast Queensland v4.1 Wet Tropics v1.1
Statewide BPA Corridors*	Statewide corridors v1.6
Threatened Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
BPA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
ACA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.

***These datasets are available at:**

http://dds.information.qld.gov.au/DDS

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
ACA	- Aquatic Conservation Assessment
AQUABAMM	- Aquatic Biodiversity Assessment and Mapping Methodology
BAMM	- Biodiversity Assessment and Mapping Methodology
BoT	- Back on Track
BPA	- Biodiversity Planning Assessment
CAMBA	- China-Australia Migratory Bird Agreement
DES	- Department of Environment and Science
EPBC	- Environment Protection and Biodiversity Conservation Act 1999
EVNT	- Endangered, Vulnerable, Near Threatened
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
JAMBA	- Japan-Australia Migratory Bird Agreement
NCA	- Nature Conservation Act 1992
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
ROKAMBA	- Republic of Korea-Australia Migratory Bird Agreement

APPENDIX E – ENVIRONMENTAL REPORTS – REGIONAL ECOSYSTEMS – BIODIVERSITY STATUS

TAILINGS.WATER.WASTE.

Queensland Government

Department of Environment and Science

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
Lot: 59 Plan: TG40

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the Vegetation Management Act 1999 (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Resources website https://www.resources.qld.gov.au/

Please direct queries about these reports to: Queensland.Herbarium@qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.

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Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Area of interest details: Lot: 59 Plan: TG40

Size (ha)	213,915.93
Local Government(s)	Cloncurry Shire
Bioregion(s)	Northwest Highlands, Gulf Plains
Subregion(s)	Armraynald Plains, Donors Plateau, Mount Isa Inlier
Catchment(s)	Flinders, Leichhardt

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	4,053.28	1.89
Of concern	13,681.21	6.4
No concern at present	195,826.07	91.54
Total remnant vegetation	213,560.56	99.83

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and are usually distinguished by differences in dominant species, frequently in the shrub or ground layers and are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2020) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the Vegetation Management Act 1999 (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Resources website.

https://www.resources.qld.gov.au/

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent of its pre-clearing extent across the bioregion; or 10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

*Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.

**Rare regional ecosystem: pre-clearing extent (1000 ha); or patch size (100 ha and of limited total extent across its range).

***Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.

****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
1.10.4a	Eucalyptus leucophloia low open woodland on sandstone plateaus	No concern at present	576.21	0.27
1.11.2a	Eucalyptus leucophloia low open woodland	No concern at present	52,820.66	24.69
1.11.3a	Corymbia terminalis and/or Eucalyptus leucophylla low open woodland on metamorphics	No concern at present	34,067.09	15.93
1.11.3b	Corymbia terminalis and/or Eucalyptus leucophylla low open woodland on metamorphics	No concern at present	4,562.79	2.13
1.11.7	Acacia cambagei low woodland on metamorphic hills	Of concern	72.96	0.03
1.11.8	Terminalia aridicola and/or Corymbia aspera low open woodland to low woodland, usually with vine-scrub species, on rock outcrops	No concern at present	1,525.20	0.71
1.12.1	Eucalyptus leucophloia low open woodland on granites	No concern at present	2,638.12	1.23
1.12.3a	Eucalyptus leucophylla and/or Corymbia terminalis +/- C. aparrerinja low open woodland on igneous rocks	No concern at present	2,834.63	1.33
1.12.7	Terminalia aridicola and Brachychiton collinus low open woodland on torfields	No concern at present	294.7	0.14
1.3.13a	Eucalyptus leucophylla woodland on levees and minor drainage lines	No concern at present	3,980.82	1.86
1.3.15	Eucalyptus pruinosa low woodland on recent alluvium	No concern at present	117.91	0.06
1.3.4a	Acacia cambagei low open woodland to woodland on alluvium, sometimes with Eucalyptus leucophylla	No concern at present	355.58	0.17
1.3.6a	Corymbia aparrerinja, Corymbia terminalis woodland on sandy levees	No concern at present	5,339.32	2.5
1.3.7a	Eucalyptus camaldulensis woodland on channels and levees	Endangered	2,863.81	1.34
1.3.7b	Eucalyptus camaldulensis woodland on channels and levees	Endangered	1,189.46	0.56
1.5.13	Eucalyptus pruinosa low open woodland on older alluvial and residual soils	No concern at present	19,115.62	8.94
1.5.15	Aristida contorta annual grasslands on hard setting red soils	No concern at present	23.78	0.01

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
1.5.16	Acacia cambagei low woodlands on red earths	No concern at present	4,861.36	2.27
1.5.3	Eucalyptus leucophloia low open woodland to woodland on sandy and gravelly red soils	No concern at present	2,936.81	1.37
1.5.4a	Eucalyptus leucophylla and/or Corymbia terminalis low open woodland on red earths	No concern at present	2,279.83	1.07
1.5.4d	Eucalyptus leucophylla and/or Corymbia terminalis low open woodland on red earths	No concern at present	17,295.73	8.09
1.7.1a	Eucalyptus leucophloia low open woodland on silcrete and lateritic surfaces	No concern at present	894.87	0.42
1.7.5a	Acacia shirleyi low woodland on lateritic scarps and hills	No concern at present	166.13	0.08
1.7.7a	Corymbia capricornia +/- Eucalyptus leucophloia or E. miniata low open woodland on silcrete	No concern at present	9,171.29	4.29
1.9.11c	Corymbia terminalis and/or Eucalyptus leucophylla and/or Lysiphyllum cunninghamii low open woodland on limestone	No concern at present	138.78	0.06
2.3.11	Eucalyptus microtheca +/- Excoecaria parvifolia, Atalaya hemiglauca, Grevillea striata low woodland on active Quaternary alluvial plains with cracking clay soils	No concern at present	437.15	0.2
2.3.17a	Eucalyptus microtheca +/- Excoecaria parvifolia, Lysiphyllum cunninghamii, Atalaya hemiglauca woodland fringing channels in fine-textured alluvial systems	Of concern	52.64	0.02
2.3.17b	Eucalyptus microtheca +/- Excoecaria parvifolia, Lysiphyllum cunninghamii, Atalaya hemiglauca woodland fringing channels in fine-textured alluvial systems	Of concern	4.33	less than 0.01
2.3.20a	Corymbia bella, Eucalyptus pruinosa, C. terminalis, Lysiphyllum cunninghamii in mixed woodlands on active levees and alluvial plains in the west	Of concern	473.6	0.22
2.3.20b	Corymbia bella, Eucalyptus pruinosa, C. terminalis, Lysiphyllum cunninghamii in mixed woodlands on active levees and alluvial plains in the west	Of concern	4,667.86	2.18
2.3.26d	Eucalyptus camaldulensis +/- Melaleuca spp. woodland fringing sandy, seasonal channels	Of concern	691.47	0.32
2.3.26f	Eucalyptus camaldulensis +/- Melaleuca spp. woodland fringing sandy, seasonal channels	Of concern	54.16	0.03
2.3.3	Astrebla squarrosa and/or A. elymoides and/or Iseilema spp. tussock grassland on active Quaternary alluvial plains	No concern at present	2,537.04	1.19
2.3.42c	Eucalyptus microtheca +/- Excoecaria parvifolia, Lysiphyllum cunninghamii, Melaleuca spp. open woodland on Quaternary alluvial plains with coarse-grained parent material	Of concern	140.78	0.07
2.3.46	Corymbia terminalis, C. aparrerinja +/- Lysiphyllum cunninghamii woodland on river levees in dry, southern parts of the bioregion	Of concern	1,275.35	0.6

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
2.3.49	Seasonal swamps. Mixed herblands and/or low shrublands with a fringe of Eucalyptus microtheca in closed depressions on silty, active Quaternary alluvial plains in the west of the bioregion	Of concern	8.27	less than 0.01
2.3.50a	Waterholes, bare sand and rock in the channels of major watercourses	Of concern	116.15	0.05
2.3.50b	Waterholes, bare sand and rock in the channels of major watercourses	Of concern	58.4	0.03
2.3.69b	Dichanthium spp., Iseilema spp., Aristida spp. and Brachyachne convergens in mixed tussock grasslands on active Quaternary alluvial deposits derived from coarse-grained parent material in the west	Of concern	148.64	0.07
2.3.7a	Acacia cambagei +/- Eucalyptus microtheca low woodland on fine-textured Quaternary alluvial plains	No concern at present	201.06	0.09
2.4.1a	Dichanthium spp., Eulalia aurea, Chrysopogon fallax and Themeda avenacea in mixed tussock grasslands on Tertiary clay plains	No concern at present	8,034.78	3.76
2.4.2a	Astrebla spp., Iseilema spp. +/- Aristida latifolia, Eulalia aurea tussock grassland on Tertiary clay deposits	No concern at present	697.42	0.33
2.4.2b	Astrebla spp., Iseilema spp. +/- Aristida latifolia, Eulalia aurea tussock grassland on Tertiary clay deposits	No concern at present	2,379.58	1.11
2.4.3a	Acacia cambagei low woodland on Tertiary clay deposits and shallow clay depressions on plateau surfaces	Of concern	2,971.72	1.39
2.4.5	Atalaya hemiglauca, Grevillea striata, Acacia victoriae and Vachellia sutherlandii in mixed low open woodlands on Tertiary clay plains	Of concern	2,763.75	1.29
2.5.11a	Eucalyptus leucophloia low open woodland on plains on lateritic podsolic soils	No concern at present	1,750.85	0.82
2.5.12a	Eucalyptus pruinosa subsp. pruinosa low woodland on plains and low rises on red and yellow earths	No concern at present	8,360.55	3.91
2.5.12b	Eucalyptus pruinosa subsp. pruinosa low woodland on plains and low rises on red and yellow earths	No concern at present	918.2	0.43
2.5.34a	Acacia cambagei low woodland on gravelly deposits and deeply weathered surfaces	No concern at present	697.16	0.33
2.7.14	Corymbia capricornia and/or Eucalyptus miniata low open woodland on margins of broad, Tertiary lateritic surfaces.	No concern at present	897.44	0.42
2.7.4	Eucalyptus leucophloia and/or Eucalyptus pruinosa subsp. pruinosa and/or Corymbia setosa low open woodland on surfaces, margins and residuals of Tertiary lateritic plateaus.	No concern at present	826.15	0.39
2.7.5a	Terminalia canescens and Corymbia setosa subsp. pedicellaris woodland on dissected plateau margins on skeletal soils	No concern at present	1,342.44	0.63
2.9.2a	Aristida spp., Eulalia aurea, Dichanthium spp. and Heteropogon contortus in mixed tussock grasslands on undulating plains on fine-grained Cretaceous sediments.	No concern at present	749.0	0.35

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
2.9.4	Acacia cambagei low woodland on undulating plains and hillslopes of Cretaceous mudstones.	Of concern	181.14	0.08
non-remnant	None	None	354.59	0.17
water	None	None	1.61	less than 0.01

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the AOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
1.10.4a	Pre-clearing 55000 ha; Remnant 2019 54000 ha	19a	Not a Wetland	High
1.11.2a	Pre-clearing 1245000 ha; Remnant 2019 1239000 ha	19a	Not a Wetland	Low
1.11.3a	Pre-clearing 662000 ha; Remnant 2019 658000 ha	19b	Not a Wetland	No representation
1.11.3b	Pre-clearing 662000 ha; Remnant 2019 658000 ha	19b	Not a Wetland	No representation
1.11.7	Pre-clearing 9000 ha; Remnant 2019 8000 ha	26a	Not a Wetland	No representation
1.11.8	Pre-clearing 30000 ha; Remnant 2019 30000 ha	27c	Not a Wetland	No representation
1.12.1	Pre-clearing 169000 ha; Remnant 2019 169000 ha	19a	Not a Wetland	No representation
1.12.3a	Pre-clearing 307000 ha; Remnant 2019 307000 ha	19b	Not a Wetland	Low
1.12.7	Pre-clearing 31000 ha; Remnant 2019 31000 ha	27c	Not a Wetland	No representation
1.3.13a	Pre-clearing 151000 ha; Remnant 2019 150000 ha	19b	Not a Wetland	Low
1.3.15	Pre-clearing 45000 ha; Remnant 2019 45000 ha	19c	Riverine	Low
1.3.4a	Pre-clearing 55000 ha; Remnant 2019 54000 ha	26a	Not a Wetland	No representation
1.3.6a	Pre-clearing 76000 ha; Remnant 2019 76000 ha	19b	Riverine	Low
1.3.7a	Pre-clearing 163000 ha; Remnant 2019 162000 ha	16a	Riverine	Medium
1.3.7b	Pre-clearing 163000 ha; Remnant 2019 162000 ha	16a	Riverine	Medium
1.5.13	Pre-clearing 320000 ha; Remnant 2019 319000 ha	19c	Not a Wetland	Low

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
1.5.15	Pre-clearing 14000 ha; Remnant 2019 14000 ha	31b	Not a Wetland	No representation
1.5.16	Pre-clearing 180000 ha; Remnant 2019 177000 ha	26a	Not a Wetland	No representation
1.5.3	Pre-clearing 290000 ha; Remnant 2019 289000 ha	19a	Not a Wetland	Low
1.5.4a	Pre-clearing 356000 ha; Remnant 2019 352000 ha	19b	Not a Wetland	Low
1.5.4d	Pre-clearing 356000 ha; Remnant 2019 352000 ha	19b	Not a Wetland	Low
1.7.1a	Pre-clearing 421000 ha; Remnant 2019 420000 ha	19a	Not a Wetland	High
1.7.5a	Pre-clearing 111000 ha; Remnant 2019 110000 ha	24a	Not a Wetland	Low
1.7.7a	Pre-clearing 575000 ha; Remnant 2019 575000 ha	19a	Not a Wetland	High
1.9.11c	Pre-clearing 81000 ha; Remnant 2019 80000 ha	19b	Not a Wetland	Low
2.3.11	Pre-clearing 661000 ha; Remnant 2019 658000 ha	16c	Not a Wetland	Low
2.3.17a	Pre-clearing 352000 ha; Remnant 2019 349000 ha	16a	Riverine	Low
2.3.17b	Pre-clearing 352000 ha; Remnant 2019 349000 ha	16a	Riverine	Low
2.3.20a	Pre-clearing 310000 ha; Remnant 2019 309000 ha	16b	Contains Riverine	Low
2.3.20b	Pre-clearing 310000 ha; Remnant 2019 309000 ha	16b	Contains Riverine	Low
2.3.26d	Pre-clearing 236000 ha; Remnant 2019 235000 ha	16a	Riverine	Low
2.3.26f	Pre-clearing 236000 ha; Remnant 2019 235000 ha	16a	Riverine	Low
2.3.3	Pre-clearing 791000 ha; Remnant 2019 786000 ha	30a	Not a Wetland	No representation
2.3.42c	Pre-clearing 498000 ha; Remnant 2019 497000 ha	16c	Not a Wetland	Low
2.3.46	Pre-clearing 49000 ha; Remnant 2019 48000 ha	16b	Riverine	No representation
2.3.49	Pre-clearing 9000 ha; Remnant 2019 9000 ha	34d	Palustrine	No representation
2.3.50a	Pre-clearing 81000 ha; Remnant 2019 81000 ha	16d	Riverine	Low
2.3.50b	Pre-clearing 81000 ha; Remnant 2019 81000 ha	16d	Riverine	Low
2.3.69b	Pre-clearing 145000 ha; Remnant 2019 144000 ha	31a	Not a Wetland	Low
2.3.7a	Pre-clearing 105000 ha; Remnant 2019 99000 ha	26a	Not a Wetland	No representation

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
2.4.1a	Pre-clearing 918000 ha; Remnant 2019 916000 ha	30b	Not a Wetland	Low
2.4.2a	Pre-clearing 1333000 ha; Remnant 2019 1317000 ha	30b	Not a Wetland	No representation
2.4.2b	Pre-clearing 1333000 ha; Remnant 2019 1317000 ha	30b	Not a Wetland	No representation
2.4.3a	Pre-clearing 139000 ha; Remnant 2019 113000 ha	26a	Not a Wetland	No representation
2.4.5	Pre-clearing 67000 ha; Remnant 2019 67000 ha	27a	Not a Wetland	No representation
2.5.11a	Pre-clearing 83000 ha; Remnant 2019 83000 ha	19b	Not a Wetland	No representation
2.5.12a	Pre-clearing 352000 ha; Remnant 2019 349000 ha	19b	Not a Wetland	Low
2.5.12b	Pre-clearing 352000 ha; Remnant 2019 349000 ha	19c	Not a Wetland	Low
2.5.34a	Pre-clearing 115000 ha; Remnant 2019 110000 ha	26a	Not a Wetland	No representation
2.7.14	Pre-clearing 15000 ha; Remnant 2019 15000 ha	19a	Not a Wetland	No representation
2.7.4	Pre-clearing 190000 ha; Remnant 2019 189000 ha	19a	Not a Wetland	No representation
2.7.5a	Pre-clearing 107000 ha; Remnant 2019 107000 ha	19c	Not a Wetland	No representation
2.9.2a	Pre-clearing 148000 ha; Remnant 2019 146000 ha	30b	Not a Wetland	No representation
2.9.4	Pre-clearing 39000 ha; Remnant 2019 31000 ha	26a	Not a Wetland	No representation
non-remnant	None	None	None	None
water	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
1.10.4a	Potential habitat for NCA listed species: Trachymene glandulosa
1.11.2a	Potential habitat for NCA listed species: Eucalyptus nudicaulis, Ipomoea antonschmidii, Solanum carduiforme, Trachymene glandulosa
1.11.3a	Potential habitat for NCA listed species: Eucalyptus nudicaulis
1.11.3b	Potential habitat for NCA listed species: Eucalyptus nudicaulis
1.11.7	None
1.11.8	Potential habitat for NCA listed species: Eucalyptus nudicaulis

Regional Ecosystem	Special Values
1.12.1	None
1.12.3a	None
1.12.7	None
1.3.13a	Potential habitat for NCA listed species: Ipomoea antonschmidii, Ptilotus maconochiei
1.3.15	None
1.3.4a	None
1.3.6a	Significant sub-regional fauna habitat due to the number and size of trees with hollows. 1.3.6b: Significant sub-regional fauna habitat due to the number and size of trees with hollows. 1.3.6e: Significant sub-regional fauna habitat due to the number and size of trees with hollows.
1.3.7a	Important seasonal water bird habitat; regional corridor for fauna.
1.3.7b	Important seasonal water bird habitat; regional corridor for fauna.
1.5.13	None
1.5.15	None
1.5.16	None
1.5.3	None
1.5.4a	Potential habitat for NCA listed species: Ipomoea antonschmidii
1.5.4d	Potential habitat for NCA listed species: Ipomoea antonschmidii
1.7.1a	Potential habitat for NCA listed species: Solanum carduiforme, Trachymene glandulosa
1.7.5a	None
1.7.7a	Potential habitat for NCA listed species: Ipomoea antonschmidii
1.9.11c	None
2.3.11	Seasonal wetland. Important feeding and moulting sites for water birds. 2.3.11x2a: Seasonal wetland. Important feeding and moulting sites for water birds. 2.3.11x2b: Seasonal wetland. Important feeding and moulting sites for water birds. 2.3.11x2c: Seasonal wetland. Important feeding and moulting sites for water birds. 2.3.11x2d: Seasonal wetland. Important feeding and moulting sites for water birds. 2.3.11x3: Seasonal wetland. Important feeding and moulting sites for water birds.
2.3.17a	Bioregional refuge for fauna, including macropods. 2.3.17a: Bioregional refuge for fauna, including macropods.
2.3.17b	Bioregional refuge for fauna, including macropods. 2.3.17a: Bioregional refuge for fauna, including macropods.
2.3.20a	Provincial refuge for some woodland flora and fauna. 2.3.20a: Provincial refuge for some woodland flora and fauna. 2.3.20b: Provincial refuge for some woodland flora and fauna. 2.3.20d: Provincial refuge for some woodland flora and fauna. 2.3.20f: Provincial refuge for some woodland flora and fauna. 2.3.20p: Provincial refuge for some woodland flora and fauna. 2.3.20x1d: Supports plant growth well into the dry season. Provincial refuge for flora and fauna. 2.3.20x4: Provincial refuge for some woodland flora and fauna. A restricted geomorphic surface.

Regional Ecosystem	Special Values
2.3.20b	Provincial refuge for some woodland flora and fauna. 2.3.20a: Provincial refuge for some woodland flora and fauna. 2.3.20b: Provincial refuge for some woodland flora and fauna. 2.3.20d: Provincial refuge for some woodland flora and fauna. 2.3.20f: Provincial refuge for some woodland flora and fauna. 2.3.20p: Provincial refuge for some woodland flora and fauna. 2.3.20x1d: Supports plant growth well into the dry season. Provincial refuge for flora and fauna. 2.3.20x4: Provincial refuge for some woodland flora and fauna. A restricted geomorphic surface.
2.3.26d	Significant provincial refuges for fauna. Includes areas of permanent water with high habitat values for aquatic and other species. 2.3.26a: Significant provincial refuges for fauna. Includes areas of permanent water with high habitat values for aquatic and other species. 2.3.26b: Provincial refuge for flora and fauna. 2.3.26d: Significant provincial refuges for fauna. Includes permanent, spring-fed water with high habitat values for aquatic and other species. 2.3.26e: Provincial refuge for flora and fauna. 2.3.26f: Provincial refuge for flora and fauna. 2.3.26x1a: Significant provincial refuges for fauna. Includes permanent, spring-fed water with high habitat values for aquatic and other species. 2.3.26x1b: Significant provincial refuges for fauna. Includes permanent, spring-fed water with high habitat values for aquatic and other species. 2.3.26x1c: Provincial refuge for flora and fauna. 2.3.26x1d: Provincial refuge for flora and fauna. 2.3.26x2: Supports plant growth well into the dry season. Provincial refuge for flora and fauna.
2.3.26f	Significant provincial refuges for fauna. Includes areas of permanent water with high habitat values for aquatic and other species. 2.3.26a: Significant provincial refuges for fauna. Includes areas of permanent water with high habitat values for aquatic and other species. 2.3.26b: Provincial refuge for flora and fauna. 2.3.26d: Significant provincial refuges for fauna. Includes permanent, spring-fed water with high habitat values for aquatic and other species. 2.3.26e: Provincial refuge for flora and fauna. 2.3.26f: Provincial refuge for flora and fauna. 2.3.26x1a: Significant provincial refuges for fauna. Includes permanent, spring-fed water with high habitat values for aquatic and other species. 2.3.26x1b: Significant provincial refuges for fauna. Includes permanent, spring-fed water with high habitat values for aquatic and other species. 2.3.26x1c: Provincial refuge for flora and fauna. 2.3.26x1d: Provincial refuge for flora and fauna. 2.3.26x2: Supports plant growth well into the dry season. Provincial refuge for flora and fauna.
2.3.3	Potential habitat for Sminthopsis douglasi (Julia Creek dunnart).
2.3.42c	None
2.3.46	None
2.3.49	Seasonal wetland. Important feeding and moulting sites for water birds.
2.3.50a	Important sites for feeding and movement of birds, fish and reptiles. Potential habitat for Pristis pristis (freshwater sawfish), Elseya lavarackorum (Gulf snapping turtle) and Malurus coronatus (purple-crowned fairy wren).
2.3.50b	Important sites for feeding and movement of birds, fish and reptiles. Potential habitat for Pristis pristis (freshwater sawfish), Elseya lavarackorum (Gulf snapping turtle) and Malurus coronatus (purple-crowned fairy wren).
2.3.69b	None
2.3.7a	None

Regional Ecosystem	Special Values
2.4.1a	A proven impact structure in Geology of Queensland, 2013. (Ed: Peter A. Jell)
2.4.2a	Potential habitat for Sminthopsis douglasi (Julia Creek dunnart).
2.4.2b	Potential habitat for Sminthopsis douglasi (Julia Creek dunnart).
2.4.3a	None
2.4.5	None
2.5.11a	None
2.5.12a	None
2.5.12b	None
2.5.34a	None
2.7.14	None
2.7.4	Provincial refuge for flora and fauna.
2.7.5a	Supports locally uncommon plant species in the bioregion, including Corymbia aspera.
2.9.2a	None
2.9.4	None
non-remnant	None
water	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at:

https://publications.qld.gov.au/dataset/redd/resource/

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	356.2	0.17
16a	Open forest and woodlands dominated by Eucalyptus camaldulensis (river red gum) (or E. tereticornis (blue gum)) and/or E. coolabah (coolabah) (or E. microtheca (coolabah)) fringing drainage lines. Associated species may include Melaleuca spp., Corymbia tessellaris (carbeen), Angophora spp., Casuarina cunninghamiana (riveroak). Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (MGD, BRB, GUP, CHC, MUL, DEU, EIU, NWH, SEQ, [NET, WET]) (All bioregions except CYP and CQC)	4,855.87	2.27
16b	Woodlands dominated by Eucalyptus leptophleba (Molloy red box), with Corymbia tessellaris (carbeen) or C. clarksoniana (grey bloodwood) or C. dallachiana. On sandy levees. (land zones 3, 5) (GUP, EIU, CYP)	6,416.81	3.0

BVG (1 Million)	Description	Area (Ha)	% of AOI
16c	Woodlands and open woodlands dominated by Eucalyptus coolabah (coolabah) or E. microtheca (coolabah) or E. largiflorens (black box) or E. tereticornis (blue gum) or E. chlorophylla on floodplains. Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (All bioregions except WET, principally GUP, BRB, MUL).	577.94	0.27
16d	River beds, open water or sand, or rock, frequently unvegetated. (land zone 3) (GUP, EIU, BRB, CYP, DEU, [CQC, MUL])	174.55	0.08
19a	Low open woodlands dominated by Eucalyptus leucophloia (snappy gum) with Triodia spp. dominated ground layer, mainly on hills and ranges. (land zones 11, 7, 5, 12, 9, 10) (NWH, GUP, MGD)	70,761.56	33.08
19b	Low open woodlands dominated by Eucalyptus leucophylla (Cloncurry box) or less extensively Corymbia terminalis (long-fruited bloodwood) low open woodlands and related associations, mainly lower slopes and valleys. (land zones 5, 11, 9, 7, 12, 3) (NWH, MGD, GUP, CHC)	80,610.39	37.68
19c	Low open woodlands dominated by Eucalyptus pruinosa low open woodlands on sandplains and outwash areas. (land zones 5, 7, 9, 11) (GUP, NWH)	21,494.17	10.05
24a	Low woodlands to tall shrublands dominated by Acacia spp. on residuals. Species include A. shirleyi (lancewood), A. catenulata (bendee), A. microsperma (bowyakka), A. clivicola, A. sibirica, A. rhodoxylon (rosewood) and A. leptostachya (Townsville wattle). (land zones 7, 10, 5, 12, 11, [9, 3]) (MUL, CHC, BRB, GUP, EIU, MGD, DEU, NWH, [CYP])	166.13	0.08
26a	Open forests to tall shrublands dominated by Acacia cambagei (gidgee) or A. georginae (Georgina gidgee) or A. argyrodendron (blackwood). (land zones 9, 3, 4, 6, 5, 7, [8, 11]) (MGD, MUL, CHC, BRB, DEU, GUP, NWH, [EIU])	9,340.98	4.37
27a	Low open woodlands dominated by a variety of species including Acacia tephrina (boree), Atalaya hemiglauca (whitewood), Ventilago viminalis (supplejack) and Lysiphyllum spp. (land zones 9, 3, 4, [5]) (MGD, GUP, BRB, NWH, DEU, [CYP, EIU])	2,763.75	1.29
27c	Low open woodlands dominated by a variety of species including Grevillea striata (beefwood), Acacia spp., Terminalia spp. or Cochlospermum spp. (land zones 9, 12, 3, 11, 5) (NWH, EIU, DEU, GUP, [BRB])	1,819.90	0.85
30a	Tussock grasslands dominated by Astrebla spp. (mitchell grass) or Dichanthium spp. (bluegrass) often with Eulalia aurea (silky browntop) on alluvia. (land zones 3, 4) (MGD, GUP, BRB, MUL, [DEU])	2,537.04	1.19
30b	Tussock grasslands dominated by Astrebla spp. (mitchell grass) or Dichanthium spp. (bluegrass) often with Iseilema spp. on undulating downs or clay plains. (land zones 9, 3, 4, 8, [5]) (MGD, CHC, GUP, BRB, [EIU, DEU, NWH])	11,860.79	5.54
31a	Open forblands to open tussock grasslands which may be composed of Atriplex spp. (saltbush), Sclerolaena spp. (burr), Asteraceae spp. and/or short grasses on alluvial plains. (land zone 3) (CHC, MGD, MUL, GUP, [BRB, DEU])	148.64	0.07
31b	Short grass / forb associations on stony downs. (land zones 9, 7, [5]) (CHC, DEU, [NWH])	23.78	0.01

BVG (1 Million)	Description	Area (Ha)	% of AOI
34d	Palustrine wetlands. Freshwater swamps/springs/billabongs on floodplains ranging from permanent and semi-permanent to ephemeral. (land zone 3) (GUP, EIU, BRB, CYP, CHC, [MGD])	8.27	less than 0.01

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

The descriptions are compiled using site survey data from the Queensland Herbarium's CORVEG database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the Vegetation Management Act 1999. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2020 (PDF)* section 3.3 of:

https://publications.qld.gov.au/dataset/redd/resource/

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community.

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

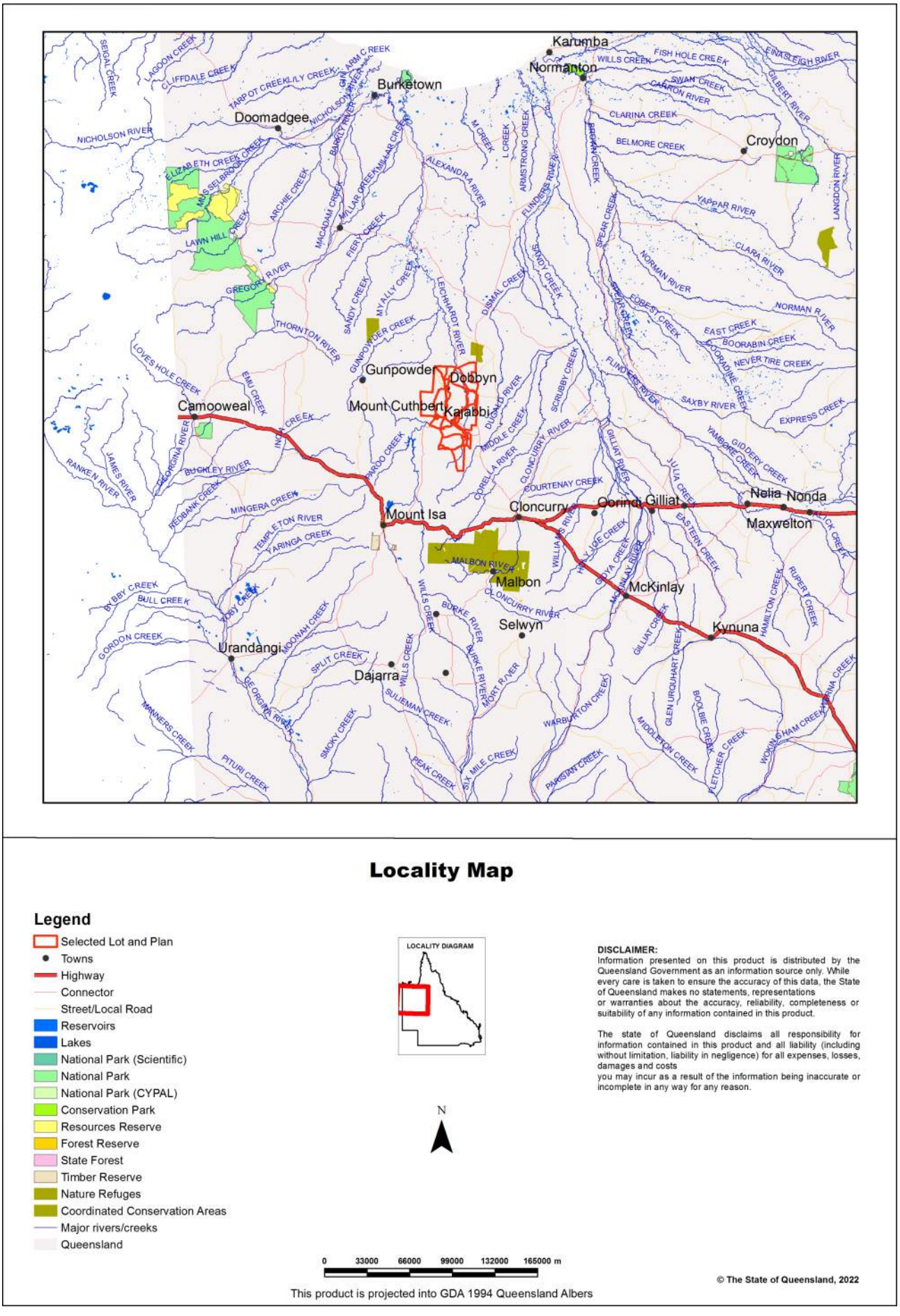
Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
1.10.4a	Available	Not currently available
1.11.2a	Available	Not currently available
1.11.3a	Available	Not currently available
1.11.3b	Available	Not currently available
1.11.7	Available	Not currently available
1.11.8	Available	Not currently available
1.12.1	Available	Not currently available
1.12.3a	Available	Not currently available
1.12.7	Available	Not currently available
1.3.13a	Available	Not currently available
1.3.15	Available	Not currently available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
1.3.4a	Available	Not currently available
1.3.6a	Available	Not currently available
1.3.7a	Available	Not currently available
1.3.7b	Available	Not currently available
1.5.13	Available	Not currently available
1.5.15	Available	Not currently available
1.5.16	Available	Not currently available
1.5.3	Available	Not currently available
1.5.4a	Available	Not currently available
1.5.4d	Available	Not currently available
1.7.1a	Available	Not currently available
1.7.5a	Available	Not currently available
1.7.7a	Available	Not currently available
1.9.11c	Available	Not currently available
2.3.11	Not currently available	Not currently available
2.3.17a	Not currently available	Not currently available
2.3.17b	Not currently available	Not currently available
2.3.20a	Not currently available	Not currently available
2.3.20b	Not currently available	Not currently available
2.3.26d	Not currently available	Not currently available
2.3.26f	Not currently available	Not currently available
2.3.3	Not currently available	Available
2.3.42c	Not currently available	Not currently available
2.3.46	Not currently available	Not currently available
2.3.49	Not currently available	Not currently available
2.3.50a	Not currently available	Not currently available
2.3.50b	Not currently available	Not currently available
2.3.69b	Not currently available	Not currently available
2.3.7a	Not currently available	Available
2.4.1a	Not currently available	Not currently available
2.4.2a	Not currently available	Available
2.4.2b	Not currently available	Available
2.4.3a	Not currently available	Not currently available
2.4.5	Not currently available	Not currently available
2.5.11a	Not currently available	Not currently available
2.5.12a	Not currently available	Not currently available
2.5.12b	Not currently available	Not currently available
2.5.34a	Not currently available	Not currently available
2.7.14	Not currently available	Not currently available
2.7.4	Not currently available	Not currently available
2.7.5a	Not currently available	Not currently available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
2.9.2a	Not currently available	Not currently available
2.9.4	Not currently available	Not currently available
non-remnant	Not currently available	Not currently available
water	Not currently available	Not currently available

Maps

Map 1 - Location



Locality Map

Legend

- Selected Lot and Plan
- Towns
- Highway
- Connector
- Street/Local Road
- Reservoirs
- Lakes
- National Park (Scientific)
- National Park
- National Park (CYPAL)
- Conservation Park
- Resources Reserve
- Forest Reserve
- State Forest
- Timber Reserve
- Nature Refuges
- Coordinated Conservation Areas
- Major rivers/creeks
- Queensland

LOCALITY DIAGRAM

N

0 33000 66000 99000 132000 165000 m

This product is projected into GDA 1994 Queensland Albers

DISCLAIMER:
Information presented on this product is distributed by the Queensland Government as an information source only. While every care is taken to ensure the accuracy of this data, the State of Queensland makes no statements, representations or warranties about the accuracy, reliability, completeness or suitability of any information contained in this product.

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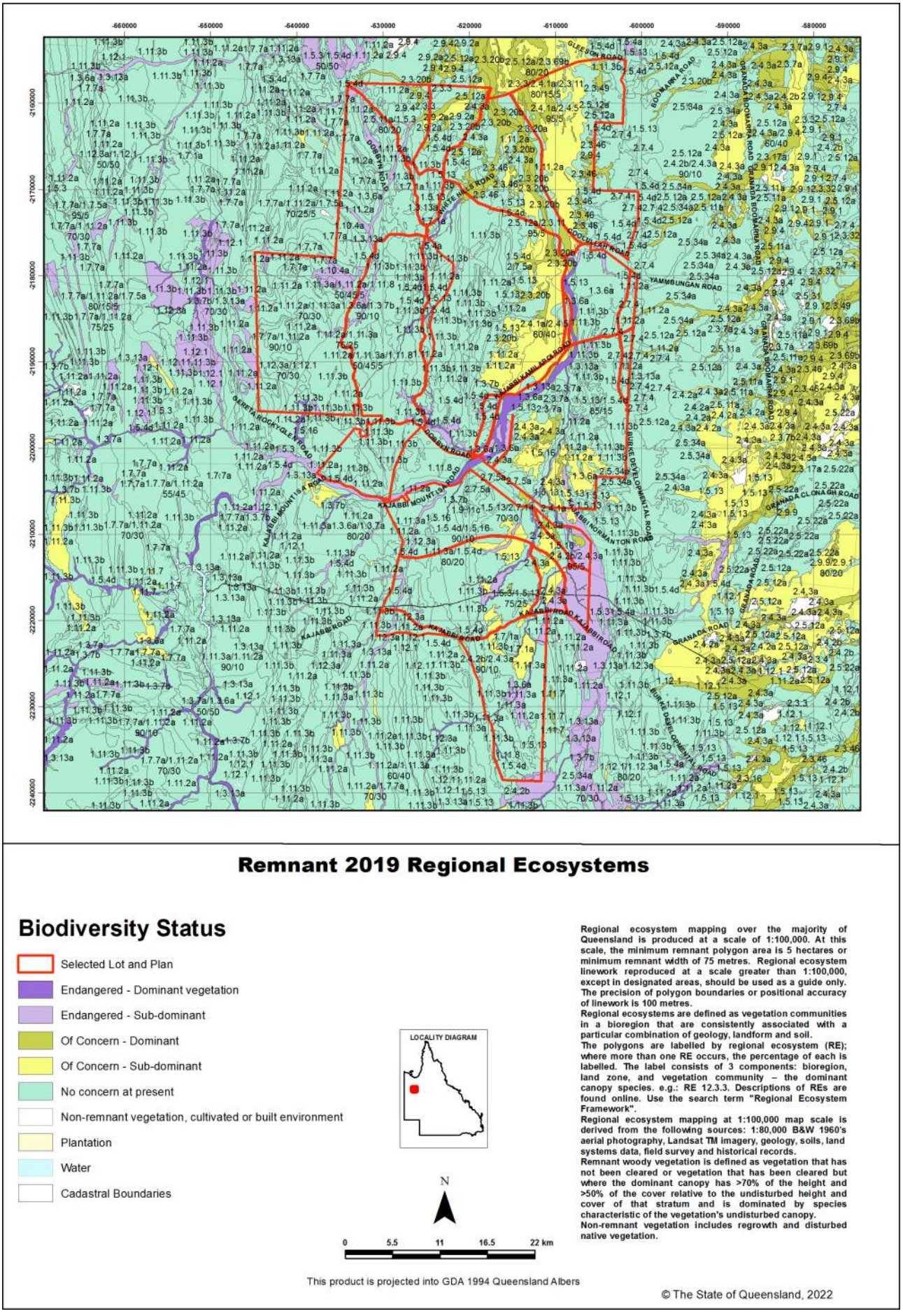
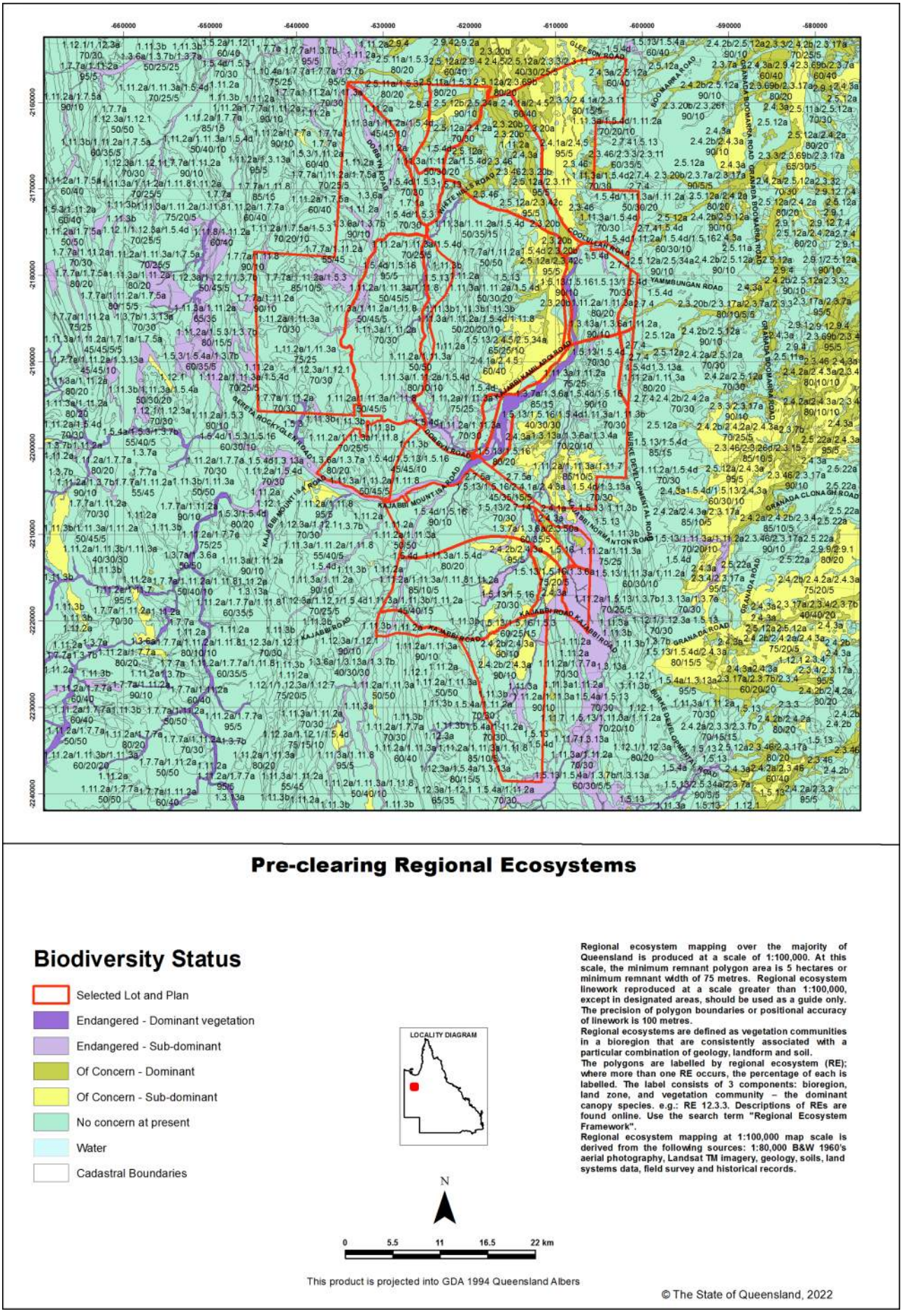
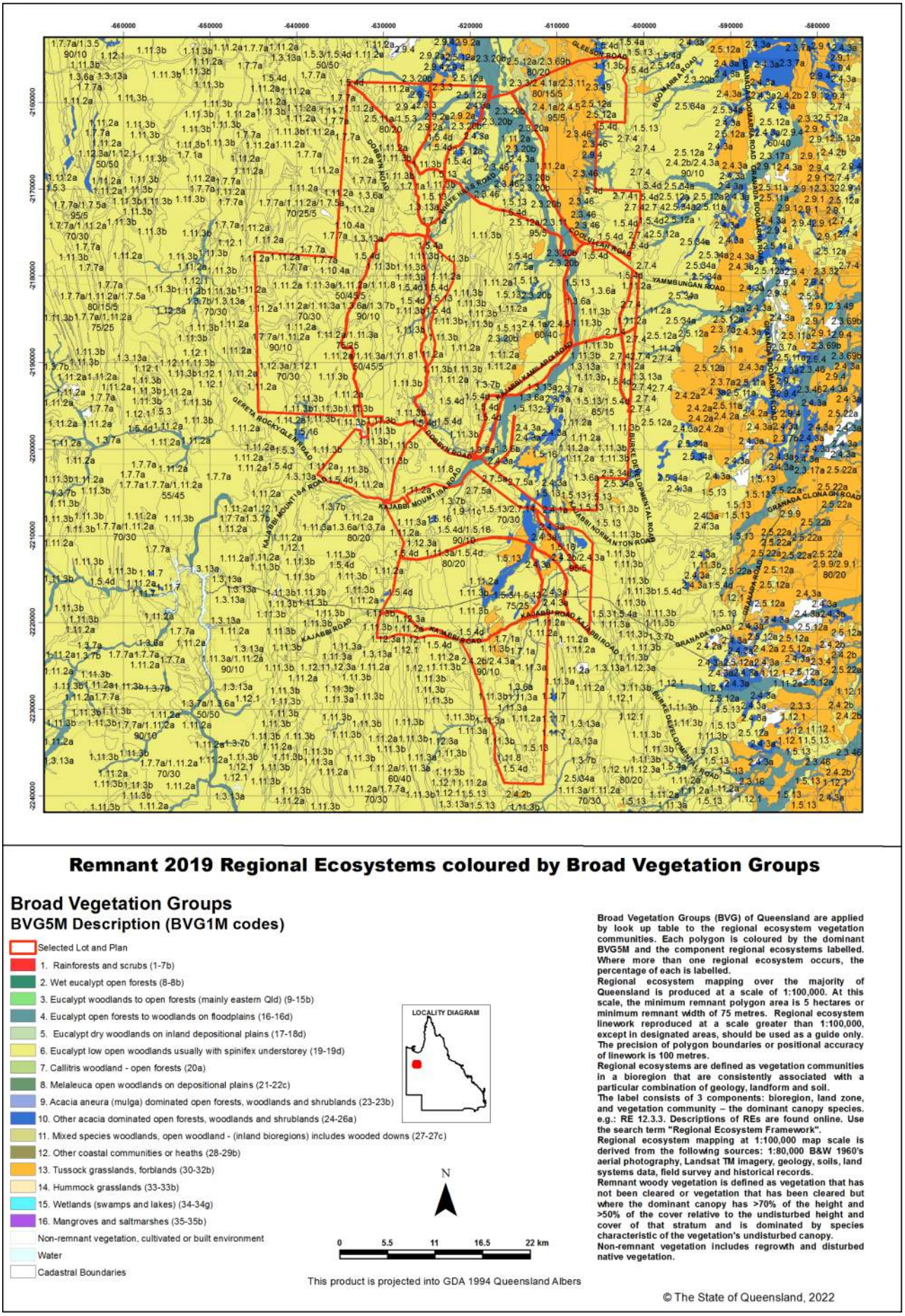
Map 2 - Remnant 2019 regional ecosystems



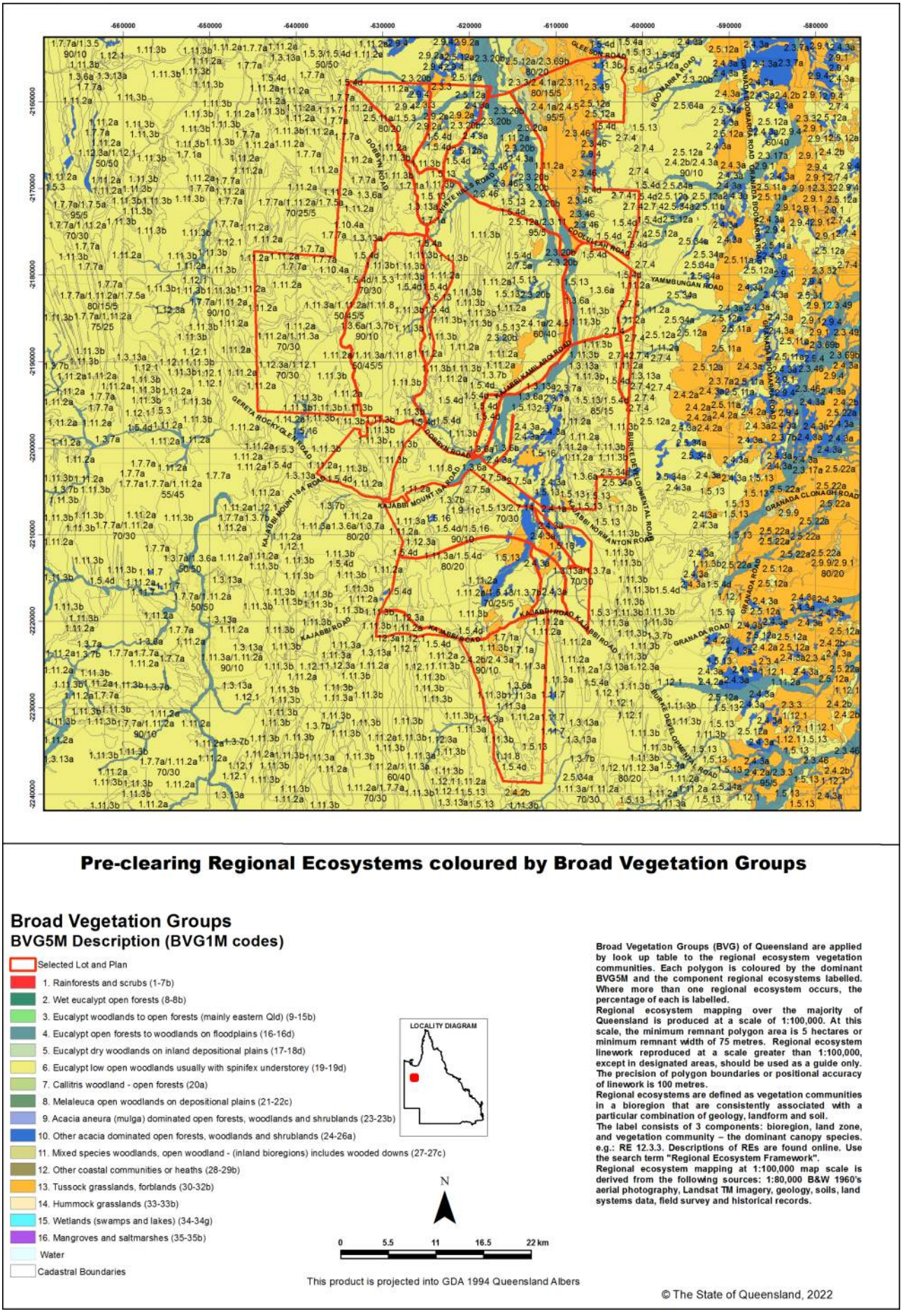
Map 3 - Pre-clearing regional ecosystems



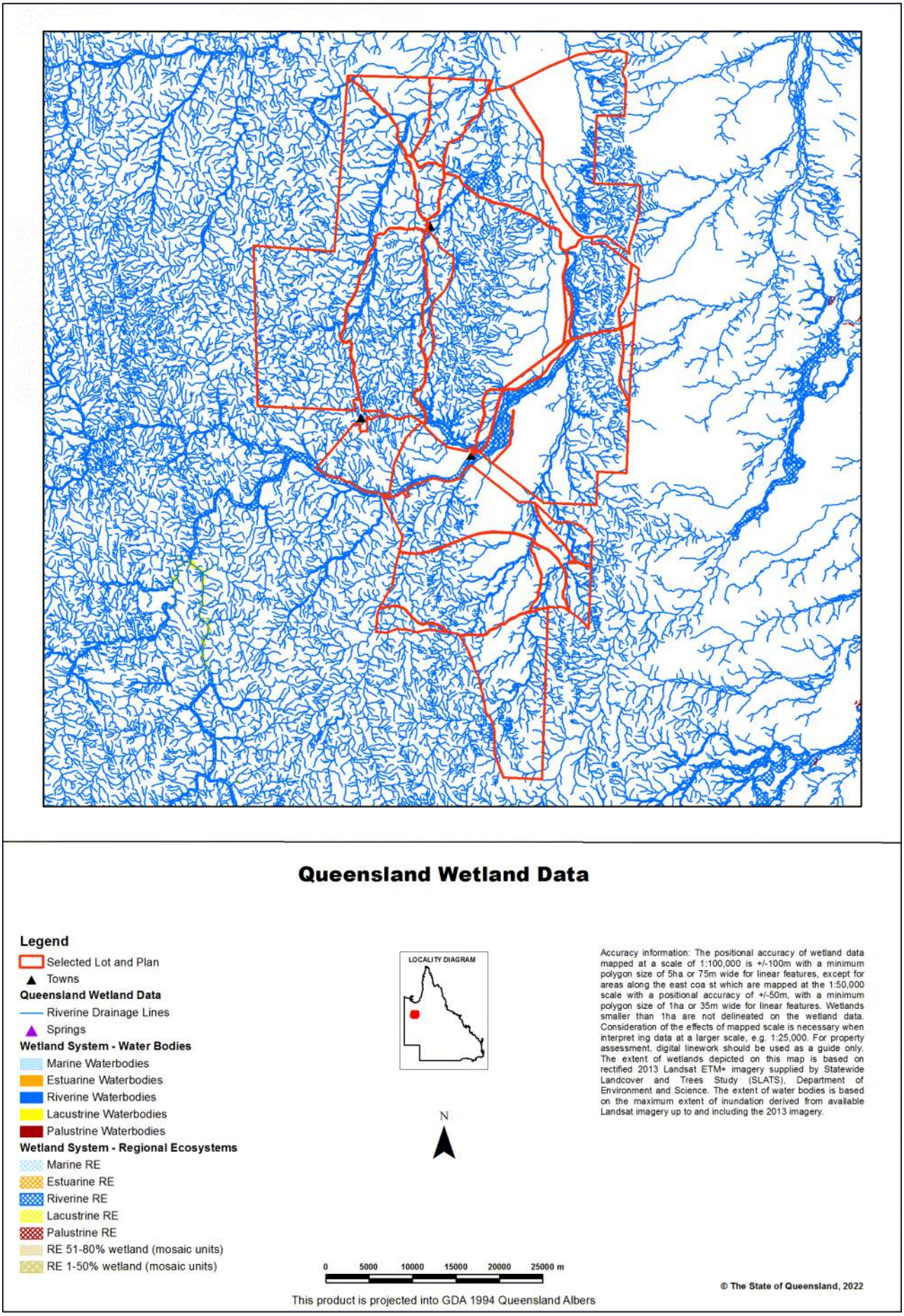
Map 4 - Remnant 2019 regional ecosystems by BVG (5M)



Map 5 - Pre-clearing regional ecosystems by BVG (5M)



Map 6 - Wetlands and waterways



Links and Other Information Sources

The Department of Environment and Science's Website -

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/

provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

The methodology for mapping regional ecosystems can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

Technical descriptions for regional ecosystems can be obtained from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

Benchmarks can be obtained from:

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Government Information System portal,

http://dds.information.qld.gov.au/dds/

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link:

https://qldglobe.information.qld.gov.au/

References

Neldner, V.J., Niehus, R.E., Wilson, B.A., McDonald, W.J.F., Ford, A.J. and Accad, A. (2019). The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 4.0. Queensland Herbarium, Department of Environment and Science.

(https://publications.qld.gov.au/dataset/redd/resource/78209e74-c7f2-4589-90c1-c33188359086)

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S., Butler, D.W., McDonald, W.J.F, Addicott, E.P. and Appelman, C.N. (2020). Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland. Version 5.1. Updated March 2020. Queensland Herbarium, Queensland Department of Environment and Science, Brisbane.

(https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4)

Sattler, P.S. and Williams, R.D. (eds) (1999). The Conservation Status of Queensland's Bioregional Ecosystems. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/

- Regional Ecosystem Description Database

The datasets listed below are available for download from:

http://dds.information.qld.gov.au/dds/

- Biodiversity status of pre-clearing and 2019 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
VMA	- Vegetation Management Act 1999

APPENDIX C – WATER BALANCE MEMORANDUM

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MEMORANDUM

TO	Jack Hollingsworth	**COMPANY**	MMG Limited
FROM	ATC Williams	**OFFICE**	Melbourne
EMAIL	JasonL@atcwilliams.com.au DaleR@atcwilliams.com.au	**PHONE**	+613 8587 0900
PROJECT TITLE	Dugald River – TSF Stage 3 Detailed Design		
SUBJECT	Water Balance Memorandum		
DATE	6 February 2026	**OUR REF**	250542-M02 Rev0

1 INTRODUCTION

1.1 Overview

MMG Limited (MMG) owns and operates the Dugald River Mine (DRM), located approximately 65 kilometres north-west of Cloncurry and 85 kilometres north-east of Mt Isa in Queensland, Australia.

MMG have engaged ATC Williams (ATCW) to produce a detailed design for a 9.25 m raise to the existing Dugald River Mine (DRM) Tailings Storage Facility (TSF) to an embankment crest level of RL 253.5 m, hereafter referred to as 'Stage 3'.

This Memorandum documents the outcomes of the water balance modelling undertaken as part of the Stage 3 detailed design works.

1.2 Scope of Works

The Stage 3 water balance model has been developed by updating the existing site water balance model used for annual Water Accounting Assessments **[1]**. The water balance model has been updated to incorporate the following:

- Latest bathymetric survey;
- Stage 3 storage characteristics;
- Recent rainfall records;
- Adoption of synthetic rainfall datasets;
- Latest process throughput rates;
- Revised production forecasts;
- Influences of climate change; and
- Influences of evaporator fans.

2 MODEL STRUCTURE AND INPUTS

2.1 Overview

The water balance model has been developed using Goldsim 15. GoldSim enables the water balance model to incorporate deterministic and probabilistic framework modules. Processes in the water balance are modelled using a deterministic approach while the inherent variability of some of the inputs, i.e., climate, are characterised in probabilistic terms to capture the range of potential outcomes.

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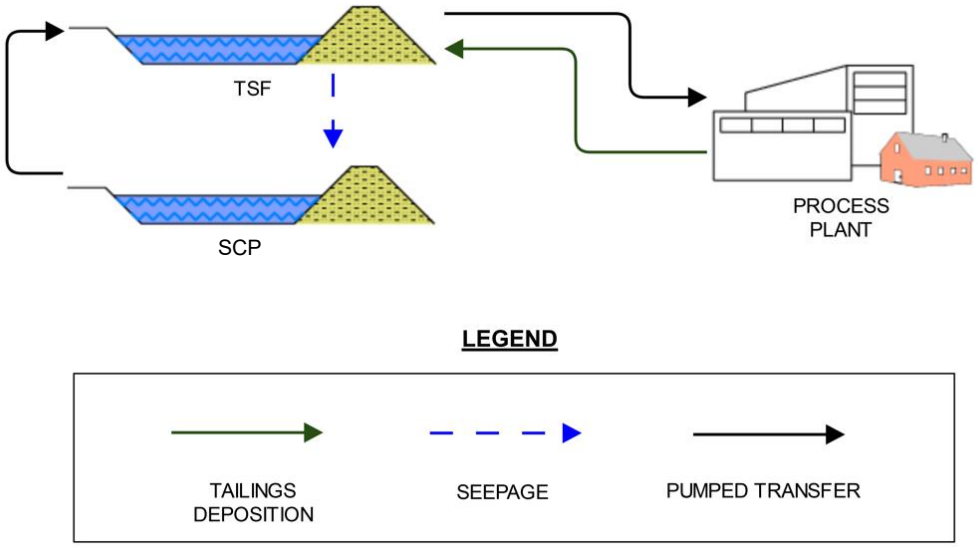
2.2 Model Structure

The process flow chart for the TSF circuit at the Dugald River Mine is depicted in **Diagram 1**. Primary water balance inputs applicable to the TSF are described in the following sections.

DIAGRAM 1 – TSF WATER BALANCE MODEL



2.3 Existing Conditions

Bathymetric survey data for the TSF decant pond was provided by MMG for January 2025. The bathymetric survey indicated a decant pond level of RL 235.02 m and a decant pond volume of 3,373 ML as of 21 January 2025.

2.4 Stage 3 Configuration

The Stage 3 tailings beach has been modelled at various stages to facilitate interpolation of the decant pond volumes. As the TSF fills with tailings, the decant pond moves in position and elevation. In the water balance model, the decant pond volumes versus RL versus surface area relationships are interpolated from the modelled tailings beach stages.

The general configuration of the Stage 3 TSF is summarised in **Table 1**.

TABLE 1 – STAGE 3 TSF CONFIGURATION

Parameter	Value
Crest Level	RL 253.5 m
Maximum Embankment Height	47.5 m
Full Supply Level (Emergency Spillway Invert)	RL 251.35 m
Surface Area at Full Supply Level	97.8 ha
Pond Volume at Full Supply Level	7,250 ML

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2.5 Production Forecast

The latest process throughput data and production forecast (dated February 2026) have been in incorporated in the model as summarised in **Table 2.**

TABLE 2 – TAILINGS PRODUCTION FORECAST (FEBRUARY 2026)

Source	Year	Tailings to TSF (Mt)	
		Annual	Cumulative
Actuals	**2017**	0.231	0.231
	2018	1.243	1.474
	2019	1.066	2.540
	2020	0.807	3.347
	2021	0.819	4.166
	2022	0.827	4.993
	2023	0.835	5.828
	2024	0.854	6.681
Forecast	**2025**	0.928	7.609
	2026	0.858	8.467
	2027	0.861	9.329
	2028	0.784	10.113
	2029	0.893	11.006
	2030	1.002	12.008
	2031	0.786	12.794
	2032	0.806	13.600
	2033	0.791	14.391
	2034	0.773	15.165
	2035	0.781	15.946
	2036	0.775	16.721
	2037	0.772	17.493
	2038	0.779	18.272
	2039	0.824	19.096
	2040	0.827	19.923
	2041	0.891	20.814
	2042	0.820	21.634
	2043	0.709	22.343

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2.6 Process and Tailings Parameters

Process water usage forms a key component of site water management. Key processing parameters relevant to water balance modelling are outlined in **Table 3**.

TABLE 3 – PROCESS AND TAILINGS PARAMETERS

Parameter	Value
Ore Moisture Content	1.0%
Slurry Solids Content	48.1%
Ore Specific Gravity	2.9 t/m³
Initial Settling Density	1.1 t/m³
Final Density*	1.38 t/m³

* Overall In-situ Density as of October 2024

2.7 Rainfall and Evaporation

The water balance model incorporates a combination of daily site rainfall data (during periods of available data), SILO data drill data **[2]** (during periods in which site data is unavailable), and synthetic rainfall data (for future forecasting).

The synthetic rainfall data has been generated as part of the Dugald River Mine Climate Change study **[3]**, in which long-term SILO data has been used to generate 100 realisations of synthetic rainfall using the Stochastic Climate Library **[4]**. Each generated realisation of data is a unique set of rainfall that is statistically similar to the historical data. A 119-year period of SILO data has been used to generate the 100 realisations.

A summary of the climatic data parameters utilised in the water balance model is provided in **Table 4**.

TABLE 4 – RAINFALL AND EVAPORATION INPUT DATA

Climate Data	Model Period	Data Source	Comments
Daily Rainfall Rate (mm/day)	1889 – 2015	Rainfall data obtained from the SILO Data Drill Program for the Site Location	Applied over dam surface areas, and as an input parameter for the estimation of surface runoff (AWBM).
	2015 – 2024	Site weather station data	
	2024 – 2040	Synthetic rainfall data	
Daily Evaporation Rate (mm/day)	1990 – 2024	Morton Lake data obtained from the SILO Data Drill Program for the Site Location	Data is scaled by evaporation factors for each site storage to reflect water storage conditions and expected water quality.
	2024 – 2040	Morton Lake data monthly average	
Daily Evapo-Transpiration	1990 – 2024	Morton wet environment areal evapotranspiration over land data obtained	PET is calculated based on temperature, vapour pressure

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Climate Data	Model Period	Data Source	Comments
Rate (mm/day)		from the SILO Data Drill Program for the Site Location	and solar global exposure parameters derived from climatic data and is adopted as a reasonable estimate of potential evapotranspiration losses from ground surfaces within the model.
	2024 – 2040	Morton wet environment areal evapotranspiration over land data monthly average	

2.8 Catchment Runoff Estimation

The Australian Water Balance Model (AWBM) has been utilised to simulate daily runoff from rainfall generated within the various sub-catchment types that are present on the project site. Catchment areas reporting to each storage have been assessed using survey data obtained from site.

Diagram 2 represents a schematic of the AWBM model, reproduced from Boughton (2009) **[5]**.

The catchment types and AWBM model parameters used to simulate these different catchment types, and the average yields from these catchments are summarised in **Table 5**. AWBM model parameters have been selected based on experience with similar WBM studies and have been adjusted through calibration exercises based on historic data.

The catchment types and catchment areas contributing to the TSF have been designated using aerial imagery and site survey. The designated catchment areas are presented in **Table 6**.

The TSF catchment area of 338 ha is shown in **Diagram 3**.

It is noted that the inputs provided below represent the initial model conditions; the surface water area and tailings surface area are dynamically calculated over time based on interpolation of the filling stages as described in **Section 2.4**.

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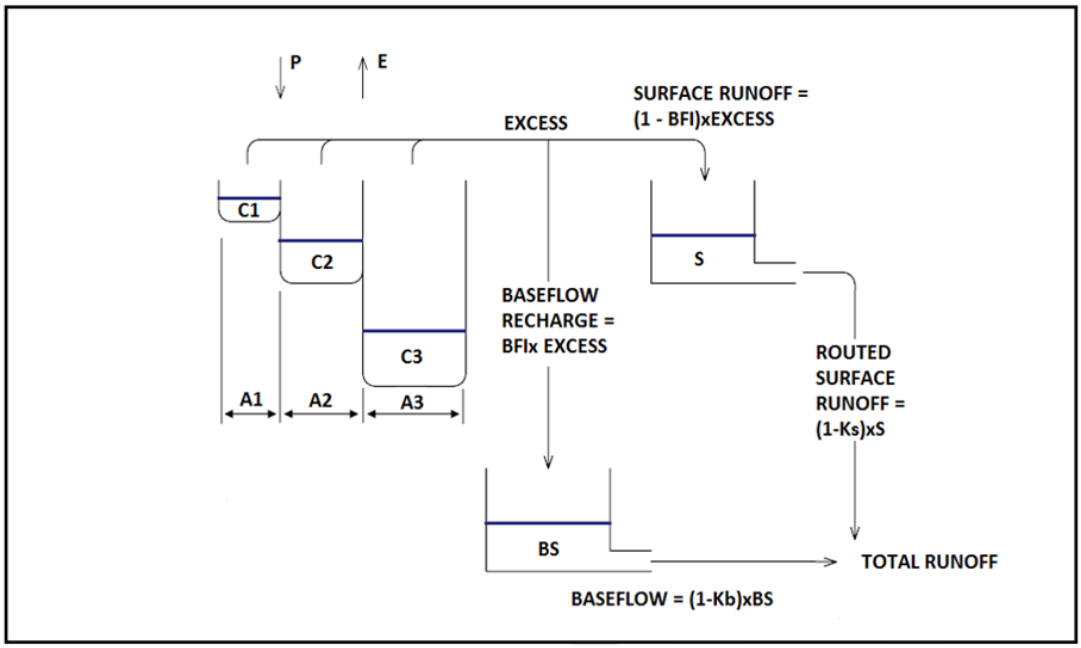
DIAGRAM 2 – SCHEMATIC OF AWBM MODEL STRUCTURE



Where:

C1 - C3	= Surface Storage Capacities
A1 - A3	= Partial Areas Represented by Surface Storages
BFI	= Baseflow Index
K_b	= Daily Baseflow Recession Constant
BS	= Current Volume in Baseflow Store
K_S	= Daily Surface Flow Recession Constant
S	= Current Volume in Surface Store Routing

TABLE 5 – AWBM MODEL PARAMETERS

Catchment Type	Split Areas (sum=1.0)			Storage Capacities (mm)			Average Surface Stores	Ks (day-1)	BFI	Kb (day-1)
	A1	A2	A3	C1	C2	C3				
Natural	0.134	0.433	0.433	6	60	120	79 mm	0.05	0.1	0.1
Hardstand	1	0	0	15	10	10	15 mm	0	0.1	0.1
Stockpile	0.134	0.433	0.433	12	80	200	123 mm	0.2	0.5	0.9

TABLE 6 – TSF CATCHMENT DETAILS AT BEGINNING OF SIMULATION

Surface Runoff Type	Area (ha)
Natural (Undisturbed)	275.0
Tailings Surface	20.7
Surface Water Area	42.3
Total Catchment Area	338.0

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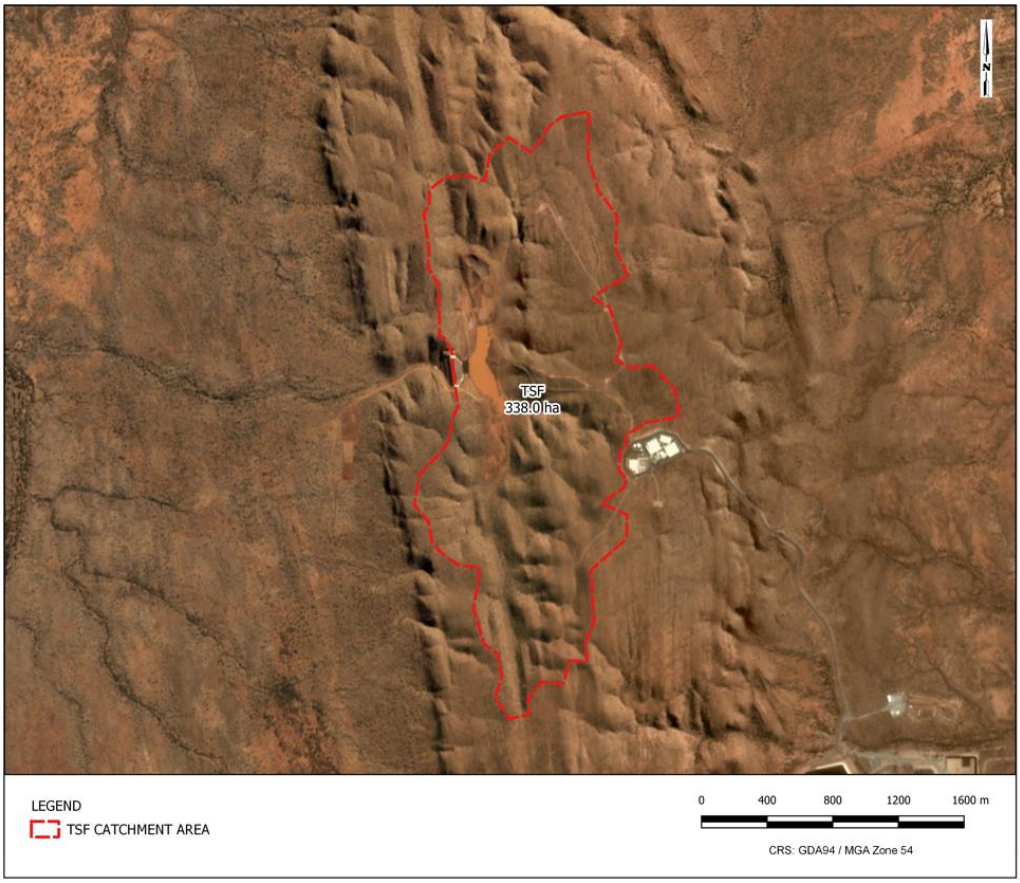
DIAGRAM 3 – TSF CATCHMENT AREA



2.9 Climate Change

Climate change impacts have been incorporated into the model based on the outcomes from the Dugald River Mine Climate Change study **[3]**. Climate projection data has been obtained from the Queensland Government Future Climate Dashboard **[6]**, which utilises 11 Global Climate Models to produce a comprehensive suite of downscaled, high-resolution climate projection data that can be used in climate risk assessments. The output is in the form of % change in daily precipitation and daily evaporation relative to the reference period (1995 – 2014).

The science of climate change is evolving, and as such the climate projections are highly variable and uncertain in nature. Hence, the median outcomes from the climate projections have been adopted for the purpose of the water balance modelling. The adopted climate change factors are summarised in **Table 7** and **Table 8**. Further discussion is provided in the Dugald River Mine Climate Change study **[3]**.

TABLE 7 – PRECIPITATION CLIMATE CHANGE FACTORS

Period	Median % Change Relative to Reference Period			
	Summer	Autumn	Winter	Spring
2020 – 2039	-0.10%	-11.75%	-8.20%	5.35%
2040 – 2059	-2.20%	-18.45%	-6.05%	-9.80%
2060 – 2079	-0.10%	-22.05%	-13.60%	4.25%

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Period	Median % Change Relative to Reference Period			
	Summer	Autumn	Winter	Spring
2080 – 2099	-0.40%	-23.85%	-22.90%	13.35%

TABLE 8 – PAN EVAPORATION CLIMATE CHANGE FACTORS

Period	Median % Change Relative to Reference Period			
	Summer	Autumn	Winter	Spring
2020 – 2039	3.50%	9.60%	6.55%	4.00%
2040 – 2059	12.55%	16.50%	12.20%	9.95%
2060 – 2079	14.45%	22.20%	15.60%	12.05%
2080 – 2099	17.95%	25.80%	21.55%	15.55%

2.10 Pumping Schedule

Pump routing and typical transfer rates have been derived from site logs, in conjunction with discussion with site personnel. Site transfers, specific to the TSF, are shown in **Table 9**.

TABLE 9 – SITE TRANSFERS

Source	Destination	Max. Rate	Activation Condition	Deactivation Condition
TSF	Process Plant	40 m^3/hr	Transfer is active whilst process plant is online	
Seepage Collection Pond	TSF	60 m^3/hr	Occurs when the water level in SCP exceeds RL 204.15 m	Deactivated when the water level in SCP is below RL 204.05 m

2.11 Evaporator Fans

The proposed evaporator fans have been included in the model based on advice from site personnel. The evaporator fans have been assumed to operate at a conservative capacity of 300 ML per year (combined capacity between two evaporator fans), with an assumed commissioning date of 21st May 2025.

2.12 TSF Seepage Losses

The seepage loss rate from the TSF has been estimated to be 3 mm/day on average, applied over the modelled pond water surface area. This loss rate represents the total seepage losses from the TSF, with a proportion reporting to the seepage collection system, and a proportion lost to the environment. The loss rates have been adopted based on calibration of the model against observed pond volumes.

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3 WATER BALANCE RESULTS

3.1 Model Objectives

The water balance has been used to investigate specific design parameters for the TSF. The following are the key objectives of the water balance study:

1. Assess the water level fluctuation and hence the statistical range of expected water levels in the TSF due to seasonal impacts of the Dugald River regional climate;
2. Estimate the Design Storage Allowance (DSA) using the method of operational simulation; and
3. Assess the influence of evaporator fans on the stored water volumes.

3.2 Model Scenarios

The water balance modelling has been carried out for the following three scenarios:

1. Scenario 1: Baseline climate data
2. Scenario 2: Climate change adjusted climate data
3. Scenario 3: Climate change adjusted climate data plus operational evaporator fans

3.3 Design Storage Allowance

3.3.1 Method of Operational Simulation

The DSA for the Stage 3 TSF has been calculated using the Method of Operational Simulation, as follows:

- The maximum increase in stored water inventory for the TSF over the last year of operation wet season was sampled from 100 simulated wet seasons. Each wet season represents a single realisation of the synthetic climate data (refer **Section 2.7**) for the period 1 November to 31 May;
- Pearson Type III distributions were fitted to the sampled data and trend lines were derived;
- The fitted trend lines were interpolated to determine the 1:20 Annual Exceedance Probability (AEP) relevant to Significant consequence categories (as per the Manual **[7]**), to calculate the required wet season DSA volume; and
- The DSA volume was calculated as the addition of the wet season storage volume and the Design Simulation Margin (DSM).

Graph 1 presents the modelled storage volume probabilities for the 100 simulated wet seasons based on Scenario 1. The maximum increase in storage volume within the Stage 3 TSF is in the order of 1,500 ML for the 1:20 AEP wet season. Similar assessments were carried out for Scenario 2 and Scenario 3, yielding comparable results.

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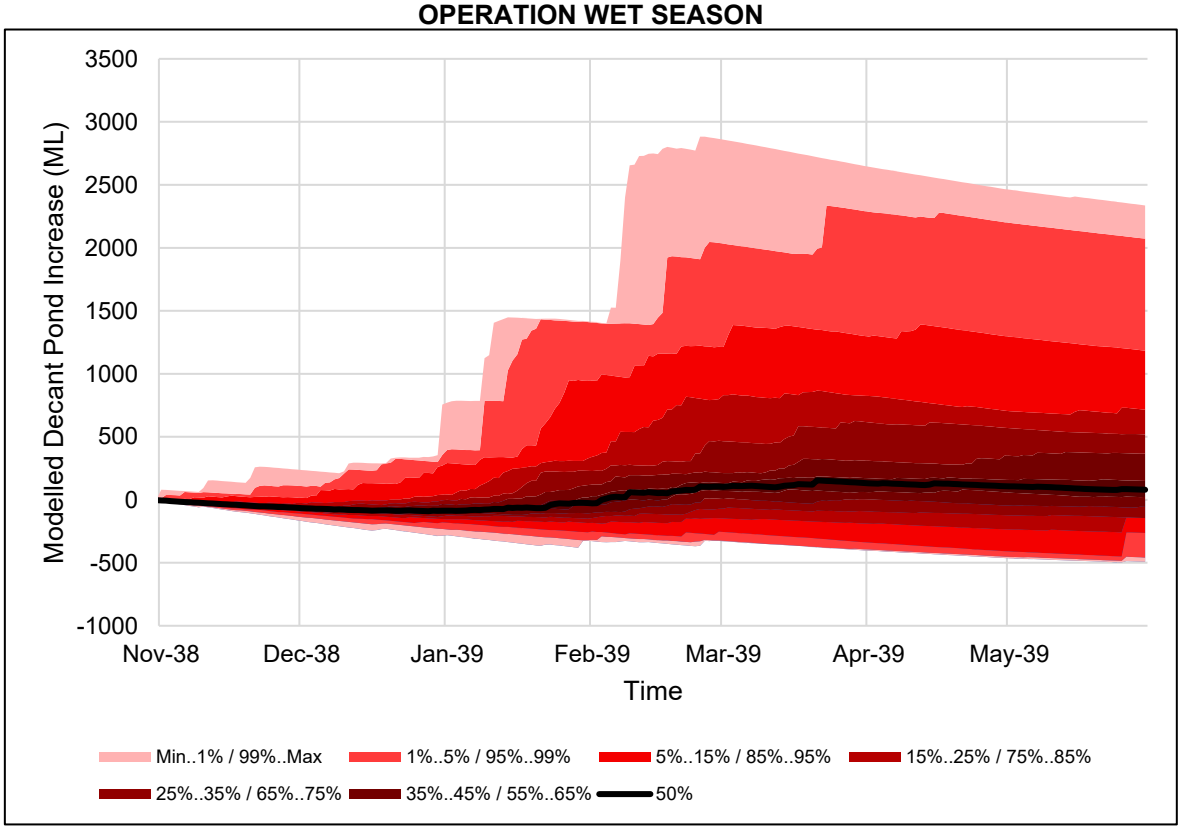
GRAPH 1 – SIMULATED INCREASE IN STORED WATER INVENTORY FOR LAST YEAR OF OPERATION WET SEASON



3.3.2 Review of Design Simulation Margin

A review of the Design Simulation Margin (DSM) has been undertaken as part of the TSF Operational Simulation assessment. The review process involved analysing results of previous WBM calibration efforts. The monitored water inventories within the TSF, generated from bathymetric survey, were compared against the modelled output from the WBM since the beginning of 2024. Comparison of measured water inventories prior to 2024 was not appropriate due to updates to the water balance model throughout the course of 2024. The outcomes of this comparison are presented in **Table 10** and **Graph 2**.

TABLE 10 – REVIEW OF WBM CALIBRATION DATA FOR TSF

Date	TSF Water Inventory		Percentage Difference
	Monitored	Modelled	
23 January 2024	3,331 ML	3,479 ML	4.4%
25 April 2024	3,958 ML	3,982 ML	0.6%
31 July 2024	3,593 ML	3,712 ML	3.3%
15 October 2024	3,536 ML	3,508 ML	-0.8%
21 January 2025	3,372 ML	3,359 ML	-0.4%

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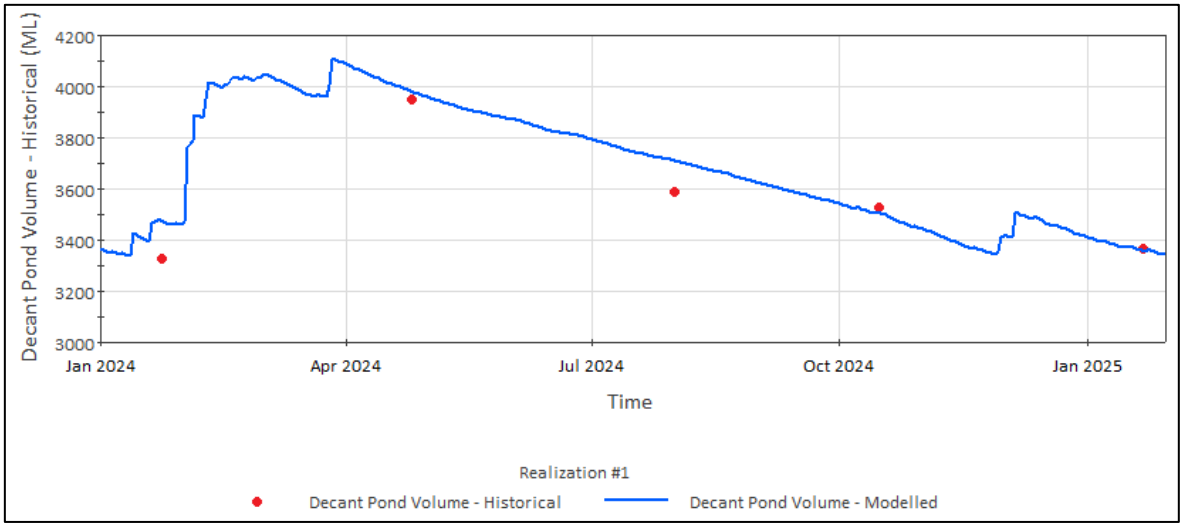
GRAPH 2 – MODELLED STORAGE VOLUME VS MONITORED



Overall, the calibration is assessed to be very good, with a maximum of 4.4% difference between monitored and modelled storage volumes. Based on the above, the DSM for the Operation Simulation DSA assessment has been taken to be 5.0%. This value is deemed to be conservative based on the previous calibration exercises undertaken for the Water Balance Model.

3.3.3 Design Storage Allowance Outcome

Table 11 summarises the estimated DSA volumes for the TSF based on the proposed Stage 3 configuration.

TABLE 11 – TSF OPERATIONAL SIMULATION DSA

Parameter	Scenario 1	Scenario 2	Scenario 3
Consequence Category (Failure to contain – Overtopping)	Significant	Significant	Significant
Wet Season Containment	1:20 AEP	1:20 AEP	1:20 AEP
Wet Season Inflow	1533 ML	1448 ML	1429 ML
DSM	5%	5%	5%
DSM Volume	77 ML	72 ML	71 ML
DSA Volume	1610 ML	1520 ML	1500 ML
Fully Supply Level (FSL)	251.35	251.35	251.35
Capacity at FSL	7248 ML	7256 ML	7242 ML
Maximum Allowable Storage	5639 ML	5736 ML	5742 ML
DSA level	RL 249.7 m	RL 249.8 m	RL 249.8 m

3.4 Decant Pond Volume

Water balance results for the Stage 3 TSF capacity assessment are presented in **Graph 3** to **Graph 5**, which are provided in the form of probability plots for the TSF. These plots depict percentile outcomes for water stored in the TSF (excluding tailings solids), of which the 99th

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percentile result represents water storage accumulation equivalent to a 1% probability of occurrence.

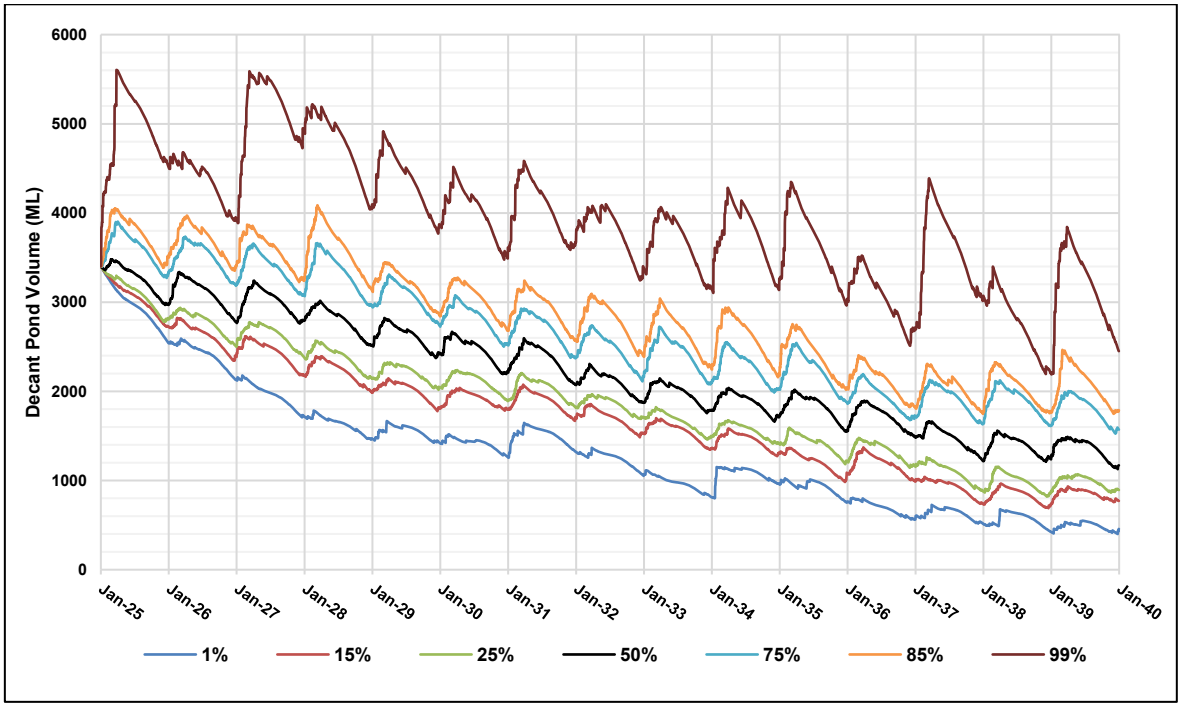
A comparison of the modelled decant pond volumes at the end of the simulation is summarised in **Table 12**.

The results indicate that the TSF decant pond generally reduces over time as a result of climatic effects (i.e., evaporation rates exceeding precipitation).

A comparison between Scenario 2 and Scenario 1 indicates that the influences of climate change (i.e., increasing evaporation rates over time and moderate decline in precipitation rates over time) impose a negative effect on decant pond volumes.

The results from Scenario 3 indicate that the role of the evaporator fans in drawing down the decant pond volumes is significant.

GRAPH 3 – SCENARIO 1 (BASELINE) DECANT POND VOLUME



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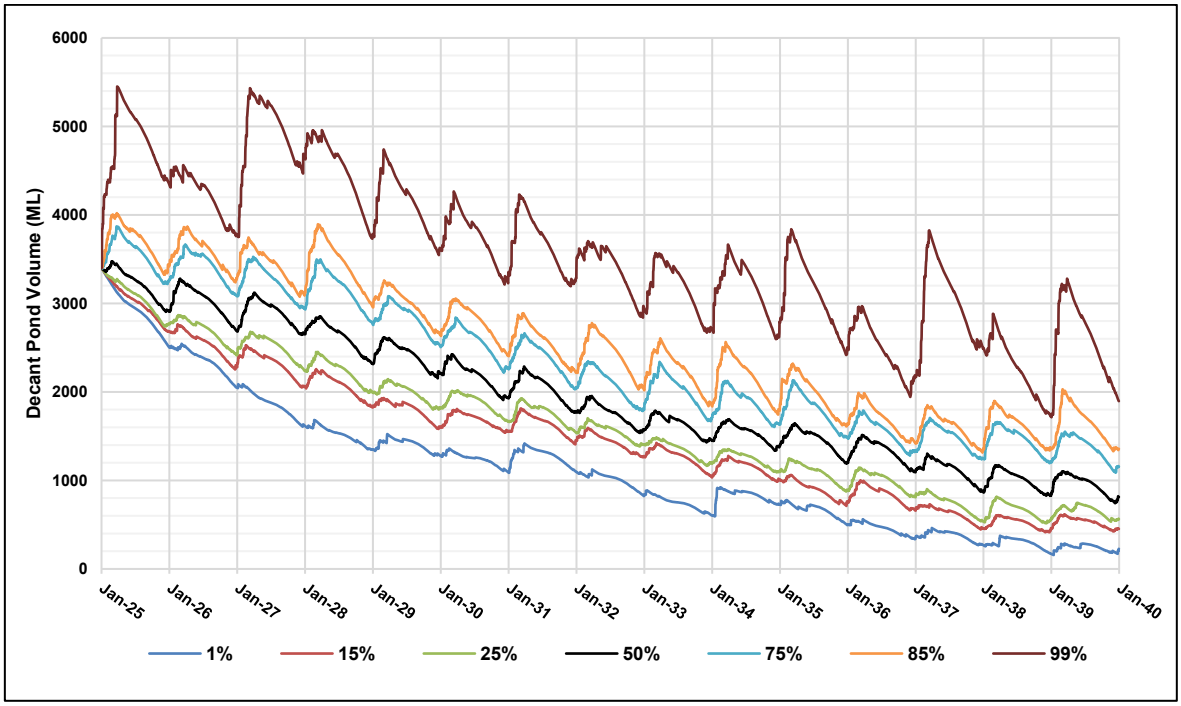
GRAPH 4 – SCENARIO 2 (CLIMATE CHANGE) DECANT POND VOLUME



GRAPH 5 – SCENARIO 3 (CLIMATE CHANGE & EVAPORATORS) DECANT POND VOLUME

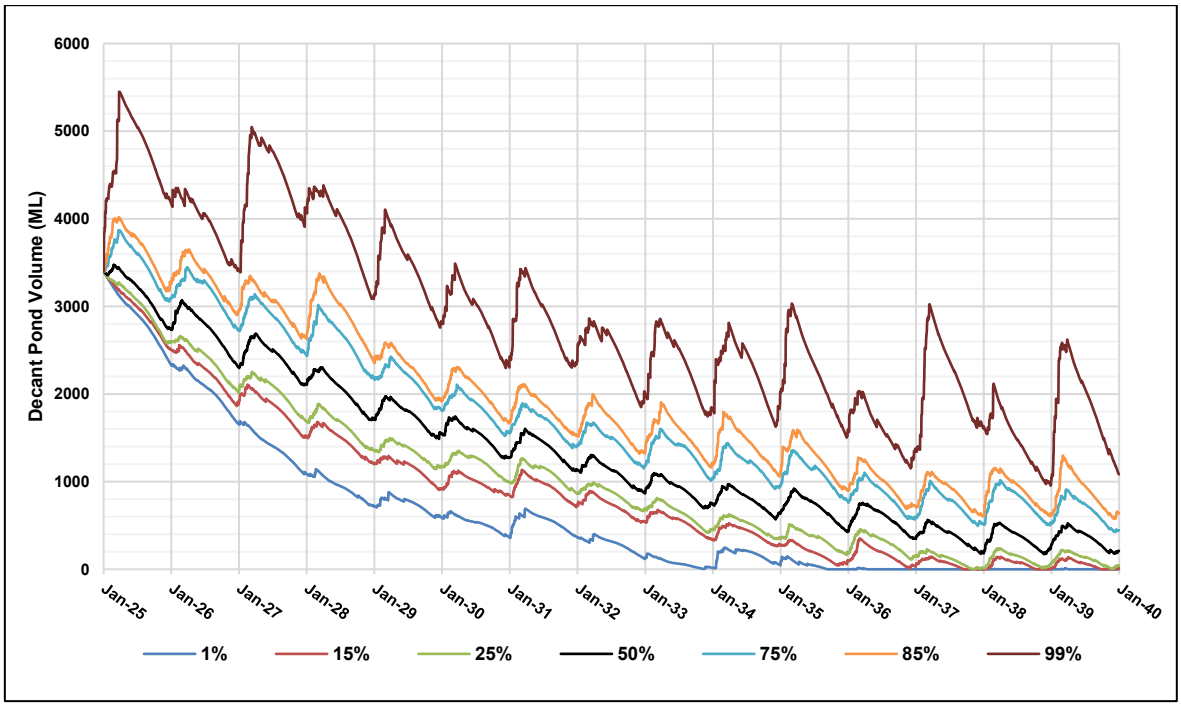


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TABLE 12 – DECANT POND VOLUME SUMMARY

	Decant Pond Volume (ML) – End of Model Period		
Probability	**Scenario 1**	**Scenario 2**	**Scenario 3**
1%	457	228	0
15%	771	453	18
25%	894	565	44
50%	1170	812	210
75%	1571	1156	444
85%	1787	1356	641
99%	2451	1896	1083

3.5 Decant Pond Level

Water balance results for the Stage 3 TSF decant pond level assessment are presented in **Graph 6** to **Graph 8**, which are provided in the form of probability plots for the TSF. These plots depict percentile outcomes for decant pond levels, of which the 99th percentile result represents water storage levels equivalent to a 1% probability of occurrence.

A comparison of the modelled decant pond levels at the start of the last year of operation wet season is summarised in **Table 13**.

The results indicate that for Scenario 1 and 2, there is a 15% probability that the Stage 2 DSA Reporting Level is exceeded by March 2028.

The results from Scenario 3 indicate that the evaporators play a significant role in reducing the decant pond level. Hence, the 15% probability of the Stage 2 DSA Reporting Level being exceeded is extended to February 2031 under Scenario 3.

The results from all Scenarios indicate that the Stage 3 DSA Reporting Level is not exceeded for any of the water balance realisations (maximum probability plots not shown for clarity). It is thus unlikely that the Stage 3 DSA Reporting Level will be exceeded during the operational life of the facility.

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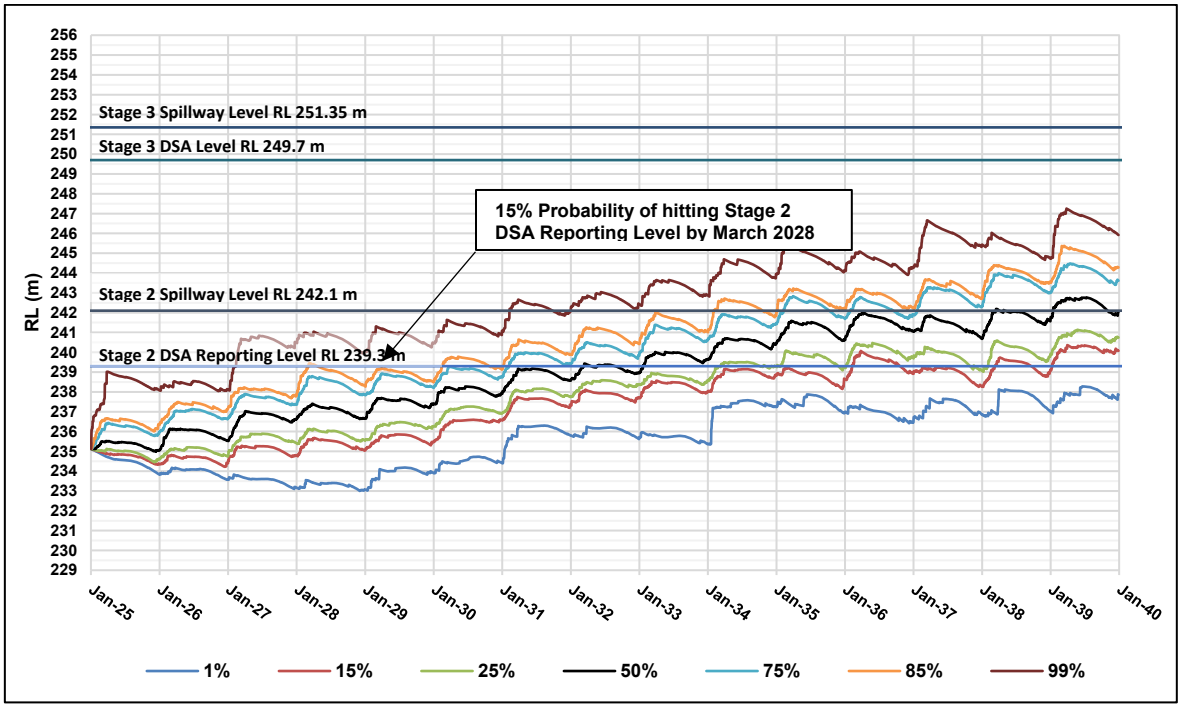
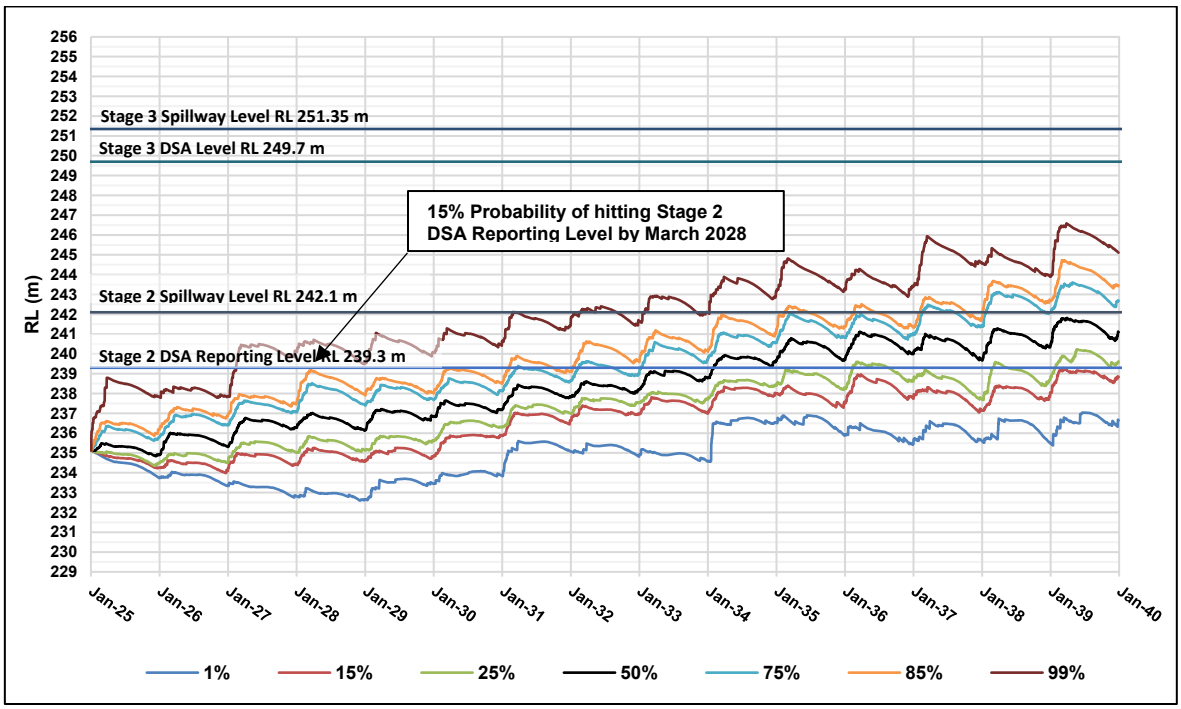
GRAPH 6 – SCENARIO 1 (BASELINE) DECANT POND LEVEL



GRAPH 7 – SCENARIO 2 (CLIMATE CHANGE) DECANT POND LEVEL



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GRAPH 8 – SCENARIO 3 (CLIMATE CHANGE & EVAPORATORS) DECANT POND LEVEL

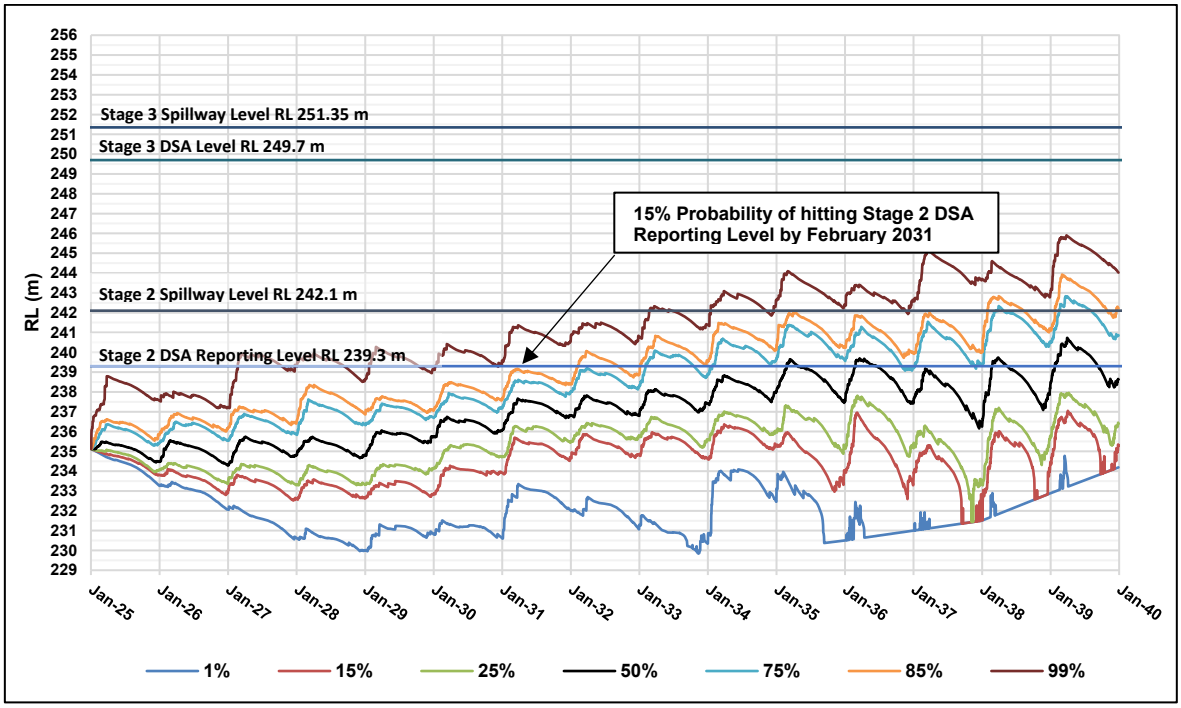

TABLE 13 – DECANT POND LEVEL SUMMARY

Decant Pond Level (RL m) – Last Year of Operation (Start of Wet Season)			
Probability	**Scenario 1**	**Scenario 2**	**Scenario 3**
1%	237.8	236.5	234.0
15%	240.1	238.7	234.0
25%	240.6	239.5	236.0
50%	242.1	240.9	238.4
75%	243.6	242.7	241.0
85%	244.4	243.6	242.1
99%	246.2	245.4	244.5

4 SUMMARY AND CONCLUSIONS

The outcomes of the water balance modelling are summarised as follows:

- The stored water volume is estimated to decrease over the operational life of the Stage 3 TSF owing to climatic effects (i.e., evaporation rates exceeding precipitation rates);
- The reservoir level is estimated to increase over the operational life of the Stage 3 TSF as a result of tailings deposition and rising tailings beach levels;

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- The addition of the evaporator fans is estimated to have a significant influence on the ability to draw down the stored water volumes in the TSF;
- The water balance modelling indicates that there is a 15% probability of the Stage 2 DSA Reporting level being exceeded by March 2028 under the existing operational arrangements (i.e., without the influence of the evaporator fans);
- The water balance modelling indicates that there is a 15% probability of the Stage 2 DSA Reporting level being exceeded by February 2031 when considering the influences of the evaporator fans;
- The water balance modelling indicates that the Stage 3 DSA Reporting Level will not be exceeded during the operational life of the facility, for any of the modelled scenarios (based on the current production rates); and
- It is recommended that the water balance is reviewed on an annual basis or more frequently.

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REFERENCES

[1] ATC Williams (2025), “Dugald River Mine – 2024 Annual Water Account”, Ref: 240475R01-rev0, February 2025.

[2] The Long Paddock (2025), “SILO Data Drill”, Queensland Government [Online]. Accessed via: https://www.longpaddock.qld.gov.au/silo/gridded-data/.

[3] ATC Williams (2025), “Dugald River Mine – Design Rainfall & Climate Change Data Generation”, Ref: 240473_R01_RevA, To Be Published.

[4] CRCCH (2004), “Stochastic Climate Library (SCL)”, developed by the CRC for Catchment Hydrology, Australia. Accessed via: https://toolkit.ewater.org.au/Tools/SCL

[5] Boughton (2009), “Selecting Parameters for the AWBM Daily Rainfall-Runoff Model for Use on Ungauged Catchments”, Journal of Hydrologic Engineering, Volume 14, Issue 12, December 2009.

[6] Queensland Government (2025), “Queensland Future Climate Dashboard – CMIP6”. Accessed via: https://longpaddock.qld.gov.au/qld-future-climate/dashboard-cmip6/, 3 January 2025.

[7] Queensland Government Department of Environment, Tourism, Science and Innovation (2024), “Manual for Assessing Consequence Categories and Hydrualic Performance of Dams”, ESR/2016/1933 Version 5.03, Feburary 2024.

APPENDIX D – SEEPAGE COLLECTION SYSTEM INVESTIGATIONS

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ABN 64 005 931 288

Our Ref: 250542-L01

12 May 2025

MMG Dugald River
Burke Development Road
CLONCURRY Queensland 4824

ATTENTION: JACK HOLLINGSWORTH

Dear Jack,

DUGALD RIVER TSF STAGE 3 RAISE – SEEPAGE COLLECTION SYSTEM INVESTIGATION

1 INTRODUCTION

ATC Williams (ATCW) have been engaged by MMG Limited (MMG) to produce a detailed design for the Stage 3 raise of the Tailings Storage Facility (TSF) located at the Dugald River Mine.

This letter presents the outcomes of a test pitting investigation to identify a suitable cut-off trench location required as part of the Stage 3 seepage collection system.

2 BACKGROUND

The existing (Stage 2) seepage collection system comprises a rockfill seepage collection drain constructed within the embankment foundation, which reports to a small, lined Seepage Collection Pond (SCP) located downstream of the TSF embankment. The pond is lined with a waterproofing geocomposite called “concrete canvas” and is fitted with an electric pump to maintain the water level within the SCP by returning water into the TSF impoundment.

The existing SCP is located within the footprint of the Stage 3 embankment raise, and as such, is required to be decommissioned and removed. The proposed Stage 3 seepage collection system will involve the extension of the existing rockfill seepage collection drain to beyond the downstream toe of the Stage 3 embankment, to discharge into a seepage monitoring sump and rock-lined interception trench.

3 INVESTIGATION OVERVIEW

The purpose of the investigation was to identify an alignment for the interception trench, as well as to estimate the excavation depth to bedrock for the trench.

The investigation was undertaken on the 16th and 17th of April 2025. The weather on both days was sunny and approximately 31 degrees Celsius and no significant rainfall had occurred in the period preceding the works.

The investigation was focussed within the immediate downstream extents of the TSF, with a specific focus along the embankment streamline (i.e., unnamed tributary of Cabbage Tree Creek).

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Test pitting was performed using a CAT 330F excavator, operated by MMG contractors. At the time of the investigations, only a toothed bucket was available.

The investigation was supervised by Jason Leung (ATCW Senior Engineer) and Jack Hollingsworth (MMG Senior Engineer). A total of 11 test pits were excavated. Test pits were excavated to refusal. No soil samples were specified or taken for laboratory testing.

A photo of the excavator used is presented in **Photo 1**. A photo of the general site conditions prior to the investigation is presented in **Photo 2**.

Test pit locations are presented in **Attachment 1**.

PHOTO 1 – CAT 330F EXCAVATOR

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PHOTO 2 – GENERAL SITE CONDITIONS (EMBANKMENT STREAMLINE)

4 RESULTS OF INVESTIGATION

In general, the test pits uncovered thin surficial soil layers underlain by fractured Knapdale Quartzite. Test pits were generally terminated between 1 to 2 m depth following virtual refusal (i.e., once minimal progress was observed).

Visual inspection of the test pit floor was difficult due to the unavailability of an excavator mud bucket and hence there was difficulty in achieving a clean pit floor surface. Notwithstanding, the base of the test pits were generally observed to be highly fractured and/or heavily jointed and did not appear to represent a clean cut-off surface.

Water infiltration was observed in some test pits at approximately 1.5 to 2 m depth, particularly within those test pits located towards the existing SCP and within the embankment streamline. The water infiltration appeared to emanate from the pit sidewalls rather than through the base of the test pit. It is estimated that the rate of infiltration was between 1 to 2L per hour. The source of the water requires further investigation. A sample of the infiltrated water was collected for water quality testing.

There was minimal variability observed in the inferred bedrock level (i.e. virtual refusal depth) across all test pits, and hence the trench excavation volumes are therefore not sensitive to the chosen interception trench alignment. As such, it is recommended that the interception trench alignment be located along the SCP-TP09 to SCP-TP12 alignment to minimise the extents of the rockfill drain extension.

A summary of the test pitting is provided in **Table 1**. Geotechnical logs and photos of each test pit are provided in **Attachment 2**.

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TABLE 1 – TEST PITTING SUMMARY

Test Pit	Easting	Northing	Elevation[1]	Depth to Refusal	Comments
SCP-TP01	408818	7763527	RL 205.7 m	0.5 m	
SCP-TP02	408818	7763519	RL 205.3 m	0.7 m	
SCP-TP03	-	-	-	-	Cancelled due to poor access
SCP-TP04	408823	7763499	RL 209.0 m	1.9 m	
SCP-TP05	408850	7763530	RL 206.1 m	1.5 m	Water infiltration observed
SCP-TP06	408848	7763520	RL 205.7 m	1.1 m	Water infiltration observed
SCP-TP07	-	-	-	-	Cancelled due to poor access
SCP-TP08	408847	7763501	RL 209.2 m	1.7 m	
SCP-TP09	408881	7763528	RL 207.2 m	2.5 m	Water infiltration observed
SCP-TP10	408879	7763521	RL 206.8 m	1.8 m	Water infiltration observed
SCP-TP11	408879	7763514	RL 207.5 m	2.0 m	Water infiltration observed
SCP-TP12	408877	7763500	RL 208.3 m	1.1 m	
SCP-TP13	408865	7763519	RL 206.5 m	1.4 m	Water infiltration observed

Note 1: Discrepancies in surface elevations have been noted between the handheld Trimble measurements and site LiDAR surveys.

5 CLOSURE

This letter has provided a summary of the test pitting investigations carried out for the Stage 3 seepage collection system works.

Please contact the undersigned for any further queries.

Yours sincerely,

Jason Leung

Senior Engineer

JasonL@atcwilliams.com.au

ATC Williams Pty Ltd

Attachments:

1. Attachment 1: Test Pitting Locations
2. Attachment 2: Test Pitting Logs & Photographs

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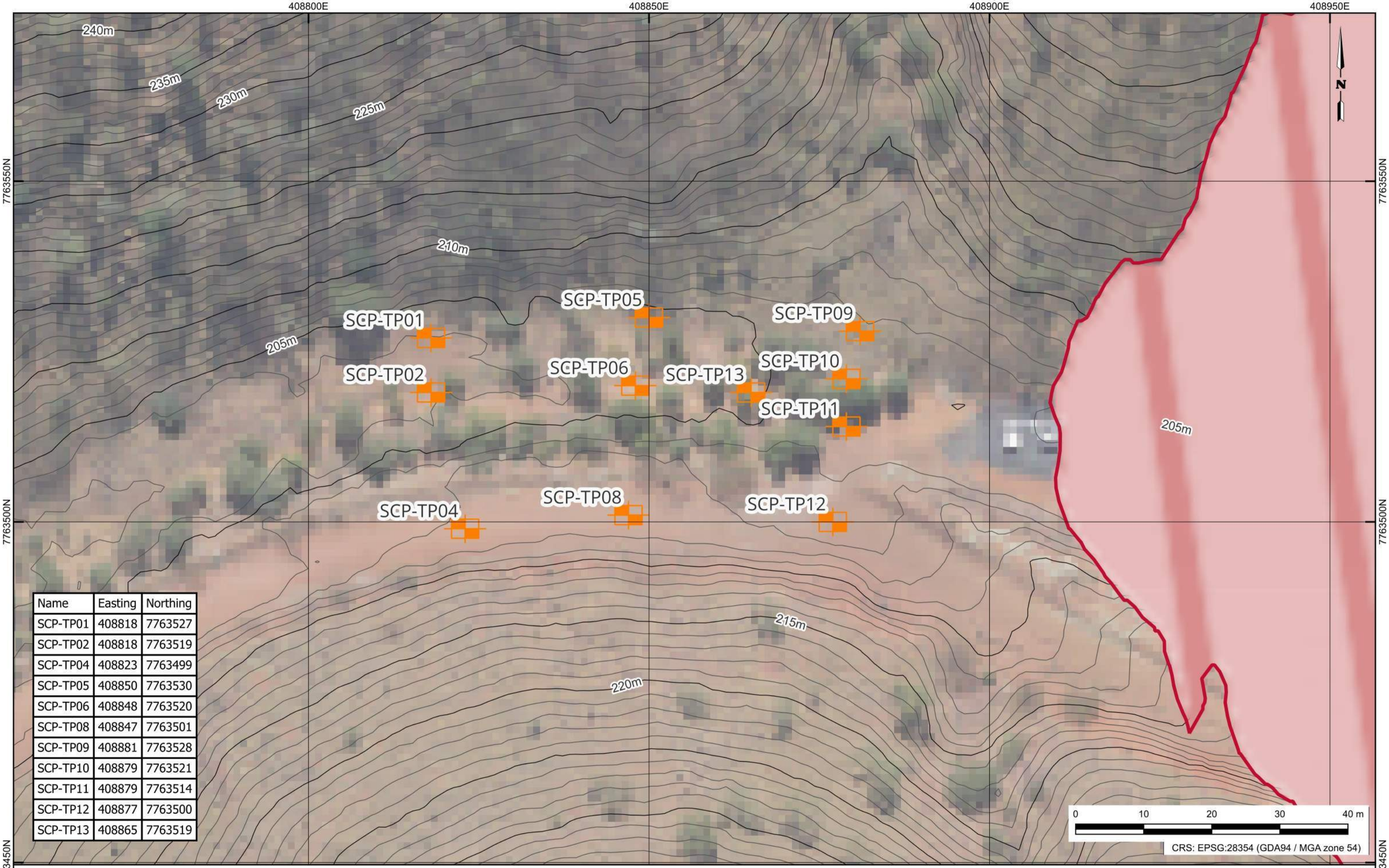
TAILINGS.WATER.WASTE.

ATTACHMENTS

TAILINGS.WATER.WASTE.

ATTACHMENT 1 – TEST PITTING LOCATIONS

TAILINGS.WATER.WASTE.



Name	Easting	Northing
SCP-TP01	408818	7763527
SCP-TP02	408818	7763519
SCP-TP04	408823	7763499
SCP-TP05	408850	7763530
SCP-TP06	408848	7763520
SCP-TP08	408847	7763501
SCP-TP09	408881	7763528
SCP-TP10	408879	7763521
SCP-TP11	408879	7763514
SCP-TP12	408877	7763500
SCP-TP13	408865	7763519

LEGEND
- Major Contours (5m)
- Minor Contours (1m)
- Stage 3 Embankment Footprint

MMG DUGALD RIVER
TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION
TEST PITTING LOCATIONS

ATC WILLIAMS

FIGURE A1

JOB NO. 250542
DATE: 24/04/2025
REVISION: A
SCALE: 1:500 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

ATTACHMENT 2 – TEST PITTING LOGS & PHOTOGRAPHS

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REPORT OF TESTPIT: SCP-TP01

Job No	: 250542	Easting	: 408818.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763527.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 24/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
									SM	COLLUVIAL; silty SAND (SM): loose, poorly graded, medium grained, brown, dry, with cobbles and boulders, very coarse grained, grey and brown, MW.	D	L	Base of pit highly fractured. Clean cut-off surface not achieved	
										SCP-TP01 refusal at 0.5m (Virtual refusal due to minimal progress)				

MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP01

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP02

Job No	: 250542	Easting	: 408818.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763519.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 24/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						205			SP	COLLUVIAL; gravelly SAND (SP): medium dense, poorly graded, medium grained, coarse sized gravel, orange - brown, trace silt, moist.	M	MD	Base of pit highly fractured. Clean cut-off surface not achieved	
										SCP-TP02 refusal at 0.7m (Virtual refusal due to minimal progress)				

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SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP02

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP04

Job No	: 250542	Easting	: 408823.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763499.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 22/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						209			GP	FILL MATERIAL; sandy GRAVEL (GP): dense, poorly graded, angular, coarse sized, medium grained sand, orange - brown, dry, with cobbles.	D	D		
							0.2							
									GP	COLLUVIAL; sandy GRAVEL (GP): medium dense, poorly graded, angular, coarse sized, medium grained sand, orange - brown, dry, with cobbles and boulders, MW.	D	MD		
						208	1							
													Base of pit highly fractured. Clean cut-off surface not achieved	
										SCP-TP04 refusal at 1.9m (Virtual refusal due to minimal progress)				

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TEST PIT SCP-TP04

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP05

Job No	: 250542	Easting	: 408850.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763530.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 24/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						206			ML	COLLUVIAL; sandy SILT (ML): firm, low plasticity, medium grained sand, light brown, with gravel, w < pl.	w < PL	F		
							0.7		ML	Becoming: stiff, grey and brown, with cobbles and boulders.	w < PL	St		
		r infiltration a				205	1						50 - 100 mm band of sandy CLAY, grey-brown, medium plasticity	
										SCP-TP05 refusal at 1.5m (Virtual refusal due to minimal progress)			Base of pit highly fractured. Clean cut-off surface not achieved	

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TEST PIT SCP-TP05

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP06

Job No	: 250542	Easting	: 408848.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763520.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 24/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						205	1		SP	COLLUVIAL; gravelly SAND (SP): medium dense, poorly graded, medium grained, coarse sized gravel, light brown, trace clay, moist, with cobbles and boulders.	M	MD	Base of pit highly fractured. Clean cut-off surface not achieved	
		ating at base								**SCP-TP06 refusal at 1.1m (Virtual refusal due to minimal progress)**				

MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP06

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP08

Job No	: 250542	Easting	: 408847.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763501.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 22/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						209	0.3		GP	FILL MATERIAL; sandy GRAVEL (GP): dense, poorly graded, angular, coarse sized, medium grained sand, orange - brown, dry, with cobbles.	D	D		
							1		SP	COLLUVIAL; gravelly SAND dense, medium grained, coarse sized gravel, orange - brown, dry, with cobbles and boulders.	D	D	Base of pit highly fractured. Clean cut-off surface not achieved	
						208				**SCP-TP08 refusal at 1.7m (Virtual refusal due to minimal progress)**				

MMG DUGALD RIVER

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SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP08

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Seepage Collection Pond\Test Pit Photos

REPORT OF TESTPIT: SCP-TP09

Job No	: 250542	Easting	: 408881.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763528.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 22/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						207	1		GC	COLLUVIAL; clayey GRAVEL (GC): medium dense, poorly graded, angular, coarse sized, low plasticity clay, brown, moist, with cobbles and boulders, tree roots.	M	MD		
						206	1.5		GC	COLLUVIAL; clayey GRAVEL (GC): dense, angular, coarse sized, medium plasticity clay, grey - brown, moist, with cobbles and boulders.	M	D	Base of pit highly fractured. Clean cut-off surface not achieved	
						205	2			**SCP-TP09 refusal at 2.5m (Virtual refusal due to minimal progress)**				

MMG DUGALD RIVER

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TEST PIT SCP-TP09

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP10

Job No	: 250542	Easting	: 408879.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763521.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 22/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
									SP	COLLUVIAL; gravelly SAND (SP): medium dense, poorly graded, medium grained, coarse sized gravel, red - brown, moist. Tree roots	M	MD		
							0.6		SP	Becoming: grey - brown, with large cobbles and boulders and bands of sandy clay.	M	MD		
						206	1							
		ng via pit side				205				**SCP-TP10 refusal at 1.8m (Virtual refusal due to minimal progress)**			Base of pit highly fractured. Clean cut-off surface not achieved	

MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP10

ATC WILLIAMS

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP11

Job No	: 250542	Easting	: 408879.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763514.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 22/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
									GP	FILL MATERIAL; sandy GRAVEL (GP): dense, poorly graded, angular, coarse sized, medium grained sand, orange - brown, moist, with cobbles.	M	D		
						207	0.3 1		SP	COLLUVIAL; gravelly SAND (SP): dense, poorly graded, medium grained, coarse sized gravel, brown, moist, with cobbles and boulders.	M	D	Trace tree roots	
						206							Base of pit highly fractured. Clean cut-off surface not achieved	
		emanating at								**SCP-TP11 refusal at 2m (Virtual refusal due to minimal progress)**				

MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP11

ATC WILLIAMS

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Job No: 250542

Date: 16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP12

Job No	: 250542	Easting	: 408877.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763500.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 16/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 22/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						208	0.3		ML	FILL MATERIAL; gravelly SILT (ML): firm, low plasticity, light brown, with sand, w < PL, with cobbles.	w < PL	F		
							1		ML	COLLUVIAL; sandy SILT (ML): firm, low plasticity, medium grained sand, orange - brown, with gravel, w < pl.	w < PL	F	Base of pit highly fractured. Clean cut-off surface not achieved	
										SCP-TP12 refusal at 1.1m (Virtual refusal due to minimal progress)				

MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP12

ATC WILLIAMS

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Job No:	250542
Date:	16/04/2025

ATTACHMENT B

REPORT OF TESTPIT: SCP-TP13

Job No	: 250542	Easting	: 408865.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7763519.00	Logged	: JL
Project	: Dugald River Stage 3 Seepage Collection Pond Investigation	UTM	: 54K	Logged Date	: 17/04/2025
Location	: 5RF2Q4GG+CW	Excavator	: CAT 330F	Checked	: DMR
Contractor	: MMG	Inclination	:	Checked Date	: 24/04/2025

General comments: Only bucket with teeth available - clean finish not possible

Excavation								Soil Description					Observations	
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Structure and Additional Observations	PSP
						206	0.5		SP	COLLUVIAL; gravelly SAND medium dense, medium grained, coarse sized gravel, brown, moist, with cobbles, angular.	M	MD		
							1		SP	Becoming: With large boulders, blue - grey, MW. 100 - 200 mm sandy clay band, grey-brown.	M	MD	Base of pit highly fractured. Clean cut-off surface not achieved	
		Ifration of wa								**SCP-TP13 refusal at 1.4m (Virtual refusal due to minimal progress)**				

MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP13

ATC WILLIAMS

www.atcwilliams.com.au

Job No: 250542

Date: 16/04/2025

ATTACHMENT B

APPENDIX E – ZONE 2 BORROW INVESTIGATIONS

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ABN 64 005 931 288

Our Ref: 108003.67-L01

19 July 2024

MMG Dugald River
Burke Development Road
CLONCURRY Queensland 4824

ATTENTION: JACK HOLLINGSWORTH

Dear Jack,

DUGALD RIVER TSF STAGE 3 RAISE – ZONE 2 BORROW INVESTIGATION

1 INTRODUCTION

ATC Williams (ATCW) have been engaged by MMG Limited (MMG) to produce a concept design for the Stage 3 raise of the Tailings Storage Facility (TSF) located at the Dugald River Mine.

This letter report presents the results of a test pitting investigation to identify suitable borrow areas for Zone 2B and Zone 2C materials, which are proposed to be used as 'liner support layer material' and 'granular filter material' respectively.

2 BACKGROUND

For the Stage 1 & 2 embankment, the majority of Zone 2B & 2C materials were sourced from borrow areas within the Knapdale Valley (TSF impoundment area).

The Zone 2B material was sourced from the following areas:

1. Designated borrow area on the south-west side of the Knapdale Valley.
2. Colluvium deposit on the north-west side of the Knapdale Valley.

Zone 2C material was sourced from various areas within the Knapdale Valley on the south-western and north-eastern sides. Additional material was borrowed from the western foothills of the Knapdale Range, outside of the Knapdale Valley.

Borrow areas within the Knapdale Valley are no longer available due to tailings deposition. As such, areas to the west of the Knapdale ridge line and in close proximity to the TSF embankment were selected for further investigation to find suitable quantities of Zone 2B and 2C for the Stage 2 raise.

3 ZONE 2 MATERIALS

3.1 Zone 2B Description

Zone 2B material is proposed to form the granular supporting layer for the BGM liner. Zone 2B material is expected to generally consist of Clayey Gravels (with sand) and Silty, Clayey Gravels (with sand) with an acceptable particle size in accordance with **Table 1**.

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Zone 2B materials were previously produced (in the Stage 1 and 2 works) by processing the borrowed material over a 50 mm screen.

The plasticity of the fine-grained fraction of the 2B material (i.e. the portion of the material with particle size finer than 0.075 mm) shall exhibit Atterberg Limits which plot on or above the 'A' Line.

TABLE 1: ZONE 2B – ACCEPTABLE PSD

Particle Size (mm)	Acceptable Range (% passing)
50	100
19	100 - 45
4.75	80 – 25
0.60	60 – 17
0.075	50 – 10

3.2 Zone 2C Description

Zone 2C Granular Filter material forms the intermediate filter within the TSF Embankment, separating and filtering Zone 2B from the Zone 3A rockfill.

Zone 2C material consisted of Gravel in a matrix of Clay, Silt and Sand, with Cobbles up to a maximum particle size of 150 mm. The acceptable particle size distribution for Zone 2C material was in accordance with **Table 2**.

Screening of the Zone 2C material was not undertaken as part of the previous works.

TABLE 2: ZONE 2C – ACCEPTABLE PSD

Particle Size (mm)	Acceptable Range (% passing)
150	100
37.5	100 - 55
19	75 – 35
4.75	45 – 25
0.075	20 – 2

4 INVESTIGATION OVERVIEW

The Zone 2 borrow investigation was undertaken on the 29th and 30th of May 2024. The weather on both days was sunny and approximately 30 degrees Celsius and no significant rainfall had occurred in the period preceding the works.

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The investigation was focussed on the foothills on the western side of the Knapdale ridge line (downstream of the TSF embankment). This area was subdivided into areas to the south and north of the TSF embankment stream line, refer **Diagram 1**.

Test pitting was performed using a Kubota U27-4 excavator, operated by Nathan Elliott (MMG). The investigation was supervised by Dale Ross (ATCW Senior Associate Engineer). A total of 22 (twenty-two) test pits were excavated. No soil samples were specified or taken for laboratory testing. Field dry strength tests and toughness tests were conducted to identify clay materials.

Test pits were generally excavated to refusal or terminated at the engineer's request due to unsuitable material being found.

A photo of the excavator used is presented in **Photo 1**. A photo of the general site conditions is presented in **Photo 2**.

Test pit locations are presented in **Attachment 1**.

DIAGRAM 1: INVESTIGATION AREAS

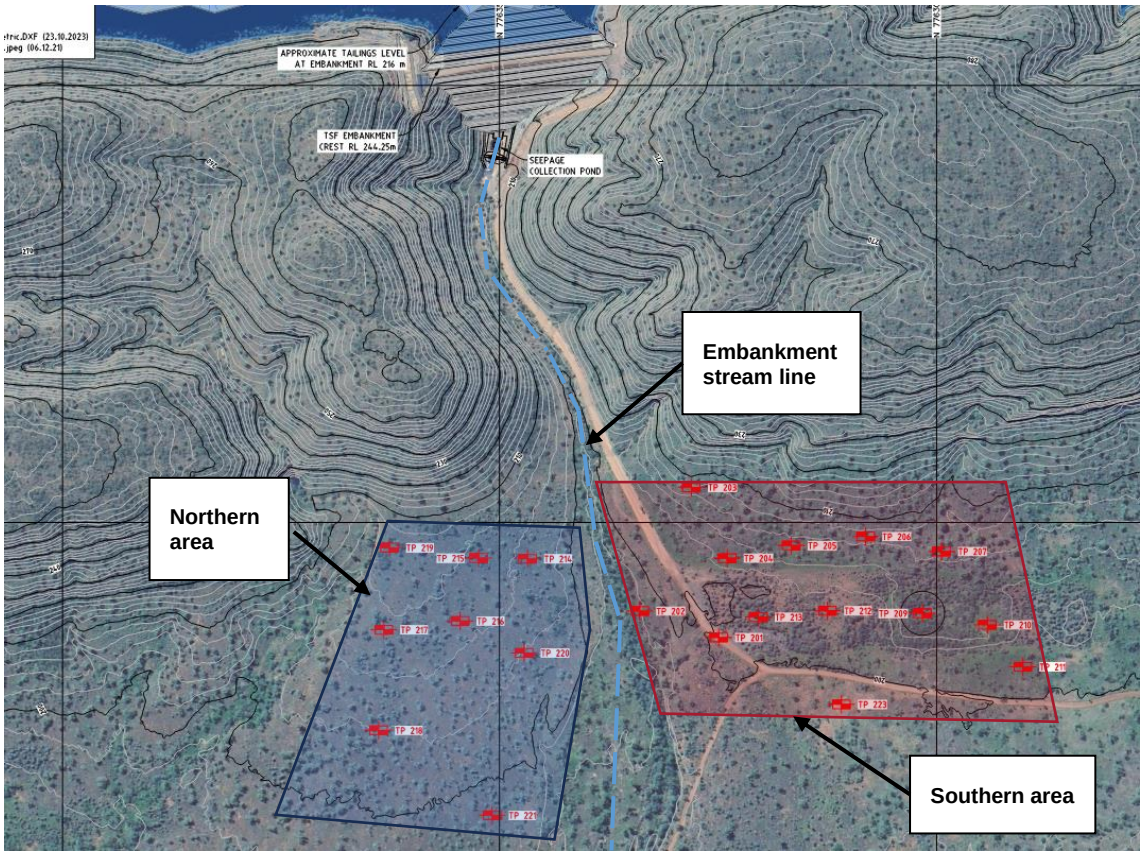

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PHOTO 1: KUBOTA U27-4 EXCAVATOR

PHOTO 2: GENERAL SITE CONDITIONS (NORTH OF EMBANKMENT STREAMLINE)

5 RESULTS OF INVESTIGATION

Southern Area

Significant quantities of Zone 2 material were not identified in the test pits conducted in the area to the south of the TSF embankment stream line. The majority of these test pits were generally deemed as not suitable for one of the following reasons:

- Near surface refusal;
- Excessive coarse materials (gravels, cobbles, boulders) in the soil matrix; or
- Low plasticity of fine-grained material (silt fines).

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Northern Area

Materials suitable for Zone 2B or 2C were identified in the majority of test pits conducted in the area to the north of the TSF embankment stream line. In this area, the subsurface conditions generally consisted of:

- A surficial layer of Gravels / Cobbles, typically 0.4 m to 0.8 m in thickness, underlain by:
- A Clayey Sandy Gravel, typically 0.6 to 1.7 m in thickness.

All materials encountered in this area were judged to be of Colluvial origin.

Some test pits within this area were deemed as not suitable due to either:

- Excessive gravels / cobbles; or
- Near surface refusal.

A summary of the test pitting is provided in **Table 3**. Geotechnical logs and photos of each test pit are provided in **Attachment 2**.

TABLE 3: TEST PITTING SUMMARY

Location	Test Pit	Depth to Refusal	Potential Zone 2B Material / Depth	Comments
Southern area	201	0.6 m	Not suitable	Excessive gravels / cobbles
	202	0.5 m	Not suitable	Silt material / too coarse
	203	0.0 m	Not suitable	Near surface refusal
	204	2.0 m	0 to 1.7 m	Clayey gravel with cobbles
	205	1.1 m	Not suitable	Silt fines
	206	0.4 m	Not suitable	Excessive gravels / cobbles
	207	0.7 m	Not suitable	Excessive gravels / cobbles
	209	1.6 m	Not suitable	Silt fines
	210	0.3 m	Not suitable	Near surface refusal
	211	0.3 m	Not suitable	Near surface refusal
	212	0.6 m	0 to 0.6 m	Clayey gravel with cobbles
	213	0.7 m	0 to 0.7 m	Clayey gravel with cobbles
Northern area	214	1.7 m	0 to 1.7 m	Clayey gravel with cobbles
	215	1.6 m	0.3 to 1.6 m	Clayey gravel with cobbles
	216	1.6 m	0.4 to 1.6 m	Clayey gravel with cobbles
	217	1.6 m	Not suitable	Gravel / cobbles Excessive screening required – low yield
	218	1.9 m	1.0 to 1.9 m	Clayey gravel with cobbles

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Location	Test Pit	Depth to Refusal	Potential Zone 2B Material / Depth	Comments
	219	1.3 m	Not suitable	Excessive gravels / cobbles
	220	1.5 m	0.8 to 1.5 m	Clayey gravel with cobbles
	221	1.9 m	0.8 to 1.9 m	Clayey gravel with cobbles
	222	1.4 m	0.4 to 1.4 m	Clayey gravel with cobbles
	223	0.3 m	Not suitable	Near surface refusal

6 PROPOSED BORROW AREA

ATCW has previously produced conceptual 3d models of the Stage 3 embankment raise, from which high-level quantities were estimated. The estimated quantities for Zone 2B and 2C are provided in **Table 4**.

Based on the investigation findings, an approx. 110,000 m^2 area to the north of the TSF embankment stream line is proposed to for sourcing of the full quantities of Zone 2B and 2C material. Excavation depths may

It is expected that production of Zone 2B will require screening using a 50 mm size screen. Oversized materials are expected to be able to be blended into the rockfill zones.

It is expected that Zone 2C material can be produced from this area without screening.

The proposed Zone 2B / 2C borrow area is shown in the Concept Design Report (ATCW Ref: 108003.67-R01).

TABLE 4: REQUIRED ZONE 2B & 2C QUANTITIES FOR STAGE 3 RAISE

Zone	Required Quantity
2B	12,500 m^3
2C	21,000 m^3

7 CLOSURE

This letter has provided a summary of a test pitting investigation to identify a Zone 2 borrow area for the proposed raise to the Dugald River TSF embankment.

Please contact the undersigned for any further queries.

Yours sincerely,

DALE ROSS

Senior Associate

DaleR@atcwilliams.com.au

ATC Williams Pty Ltd

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ATTACHMENTS

Attachment 1: Test Pitting Locations

Attachment 2: Test Pitting Logs & Photographs

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REFERENCES

[1] Australian Tailings Consultants (February 2009), “Dugald River Project Feasibility Study – Tailings Storage Facility – Preliminary Geotechnical Investigation”, Ref: 108003R06.

[2] ATC Williams (May 2013), “Dugald River Project, Process Water Dam & Tailings Storage Facility”, dated May 2013, ATCW Ref: 108003.11-R02, Rev 0.

ATTACHMENT 1: FIGURES

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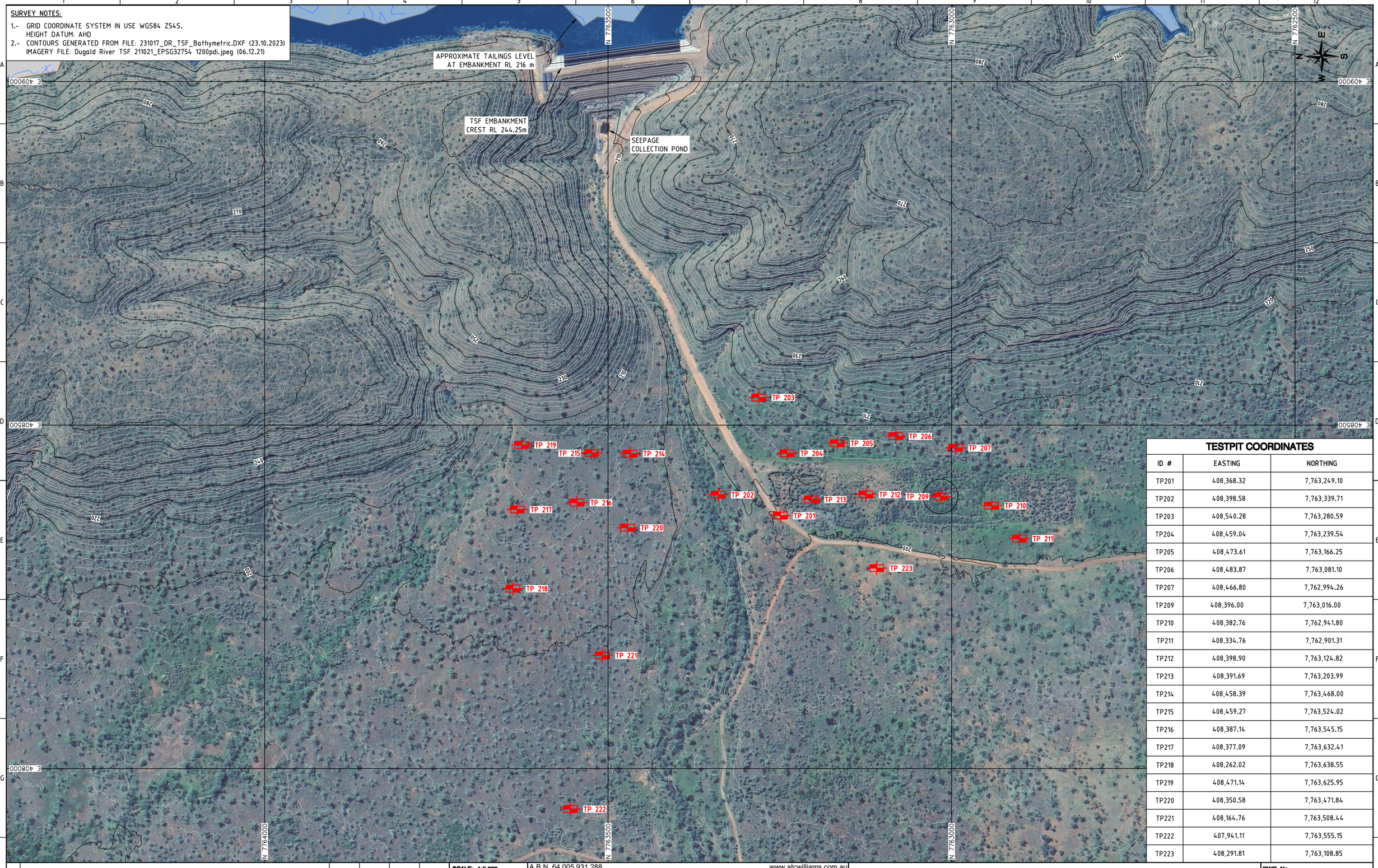
SURVEY NOTES:

1.- GRID COORDINATE SYSTEM IN USE WGS84 Z54S.
HEIGHT DATUM: AHD
2.- CONTOURS GENERATED FROM FILE: 231017_DR_TSF_Bathymetric.DXF (23.10.2023)
IMAGERY FILE: Dugald River TSF 211021_EPSG32754 1200pdi.jpeg (06.12.21)



TESTPIT COORDINATES

ID #	EASTING	NORTHING
TP201	408,368.32	7,763,249.10
TP202	408,398.58	7,763,339.71
TP203	408,540.28	7,763,280.59
TP204	408,459.04	7,763,239.54
TP205	408,473.61	7,763,166.25
TP206	408,483.87	7,763,081.10
TP207	408,466.80	7,762,994.26
TP209	408,396.00	7,763,016.00
TP210	408,382.76	7,762,941.80
TP211	408,334.76	7,762,901.31
TP212	408,398.90	7,763,124.82
TP213	408,391.69	7,763,203.99
TP214	408,458.39	7,763,468.00
TP215	408,459.27	7,763,524.02
TP216	408,387.14	7,763,545.15
TP217	408,377.09	7,763,632.41
TP218	408,262.02	7,763,638.55
TP219	408,471.14	7,763,625.95
TP220	408,350.58	7,763,471.84
TP221	408,164.76	7,763,508.44
TP222	407,941.11	7,763,555.15
TP223	408,291.81	7,763,108.85

No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D

SCALE:	1:5,000
JOB No.	108003.67
DATE	06.08.24
DESIGN	DR
DRAWN	HJ
CHECKED	DR
APPROVED	CN

A.B.N. 64 005 931 288
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melbourne@atcwilliams.com.au

MMG DUGALD RIVER
TAILINGS STORAGE FACILITY

ZONE 2 BORROW INVESTIGATION
TEST PITTING LOCATIONS

DWG. No.
FIGURE 1

SHEET SIZE | | Rev. | A

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SHEET 1 OF 1

ATTACHMENT 2: TEST PITTING LOGS

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TEST PIT: 201

Project	Dugald River TSF				
Location	West of TSF	East	408372.0 m	Sheet	1 OF 1
Position		North	7763246.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						Clayey GRAVEL (GC), with cobbles, dense, medium grained sand, coarse gravel, brown	D	D	0.00: Not suitable for use as Zone 2 Cobbles max. size approx. 200mm
				0.60					Terminated due to virtual refusal Hole Terminated at 0.60 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

ATC WILLIAMS 1.00.1 LIB.GLB Log IS AU TEST PIT 3B TEST PIT LOGS.GPJ <<DrawingFile>> 18/7/2024 16:57 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: ATC Williams 1.00.1 2021-12-24 Prj: ATC Williams 1.00.0 2021-12-22

MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 201**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 202

Project	Dugald River TSF				
Location	West of TSF	East	408389.0 m	Sheet	1 OF 1
Position		North	7763320.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GM	Silty GRAVEL (GM), with cobbles, boulders, dense, medium grained sand, coarse gravel, light brown	D	D	0.00: Not suitable for use as Zone 2 Boulders max. size approx. 300mm
				0.50					Terminated at engineer's request Hole Terminated at 0.50 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

ATC WILLIAMS 1.00.1 LIB.GLB Log IS AU TEST PIT 3B TEST PIT LOGS.GPJ <<DrawingFile>> 18/7/2024 16:57 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: ATC Williams 1.00.1 2021-12-24 Prj: ATC Williams 1.00.0 2021-12-22

MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 202**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 203

Project	Dugald River TSF				
Location	West of TSF	East	408540.0 m	Sheet	1 OF 1
Position		North	7763282.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
			0						Refusal at surface, test pit discontinued Hole Terminated at 0.00 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

ATC WILLIAMS 1.00.1 LIB.GLB Log IS AU TEST PIT 3B TEST PIT LOGS.GPJ <<DrawingFile>> 18/7/2024 16:57 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: ATC Williams 1.00.1 2021-12-24 Prj: ATC Williams 1.00.0 2021-12-22

MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 203**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 204

Project	Dugald River TSF				
Location	West of TSF	East	408457.0 m	Sheet	1 OF 1
Position		North	7763241.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GC	Clayey GRAVEL (GC), with cobbles, dense, medium grained sand, coarse gravel, light brown, fines plastic	D	D	0.00: Potential use as Zone 2 (1.7m thickness) Boulders max. size approx. 300mm
			1									
			2	2.00					Test pit discontinued due to virtual refusal Hole Terminated at 2.00 m			
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

ATC WILLIAMS 1.00.1 LIB.GLB Log IS AU TEST PIT 3B TEST PIT LOGS.GPJ <<DrawingFile>> 18/7/2024 16:57 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: ATC Williams 1.00.1 2021-12-24 Prj: ATC Williams 1.00.0 2021-12-22

MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 204**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 205

Project	Dugald River TSF				
Location	West of TSF	East	408474.0 m	Sheet	1 OF 1
Position		North	7763166.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES, dense, clay, medium grained sand, coarse gravel, brown	D	D	0.00: Colluvial Not suitable for Zone 2 material
				0.40				GM	Silty GRAVEL (GM), with cobbles, dense, medium grained sand, coarse gravel, grey	D	D	0.40: Alluvial
			1	1.10					Test pit terminated at engineer's request Hole Terminated at 1.10 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 205**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 206

Project	Dugald River TSF				
Location	West of TSF	East	408483.0 m	Sheet	1 OF 1
Position		North	7763085.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description				
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES, dense, clay, medium grained sand, coarse gravel, brown	D	D	0.00: Not suitable for Zone 2
				0.40					Test pit terminated due to virtual refusal Hole Terminated at 0.40 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

ATC WILLIAMS 1.00.1 LIB.GLB Log IS AU TEST PIT 3B TEST PIT LOGS.GPJ <<DrawingFile>> 18/7/2024 16:57 10.03.00.09 Datgel Lab and In Situ Tool - DGD | Lib: ATC Williams 1.00.1 2021-12-24 Prj: ATC Williams 1.00.0 2021-12-22

MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 206**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 207

Project	Dugald River TSF				
Location	West of TSF	East	408466.0 m	Sheet	1 OF 1
Position		North	7762995.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description				
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES, dense, clay, medium grained sand, coarse gravel, brown	D	D	0.00: Not suitable for Zone 2
				0.70					Test pit terminated due to virtual refusal Hole Terminated at 0.70 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 207**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 209

Project	Dugald River TSF				
Location	West of TSF	East	408396.0 m	Sheet	1 OF 1
Position		North	7763016.0 m		
Job No.	108003.67	Contractor	MMG	Date	29/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GM	Silty GRAVEL (GM), with cobbles, dense, medium grained sand, coarse gravel, brown	D	D	0.00: Roots down to 1.6m Not suitable for Zone 2 material
			1									
				1.60								
			2						Test pit terminated at engineer's request Hole Terminated at 1.60 m			
			3									
			4									

Sketch & Other Observations

Comments

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Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 209**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 210

Project	Dugald River TSF				
Location	West of TSF	East	408384.0 m	Sheet	1 OF 1
Position		North	7762946.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GM	Silty GRAVEL (GM), with cobbles, dense, medium grained sand, coarse gravel, brown	D	D	0.00: Not suitable for Zone 2
				0.30					Test pit terminated due to refusal Hole Terminated at 0.30 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

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Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 210**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 211

Project	Dugald River TSF				
Location	West of TSF	East	408339.0 m	Sheet	1 OF 1
Position		North	7762907.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GM	Silty GRAVEL (GM), with cobbles, dense, medium grained sand, coarse gravel, brown	D	D	0.00: Not suitable for Zone 2 material
				0.30					Test pit terminated due to refusal Hole Terminated at 0.30 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 211**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024
	APPENDIX B

TEST PIT: 212

Project	Dugald River TSF				
Location	West of TSF	East	408401.0 m	Sheet	1 OF 1
Position		North	7763126.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GC	Clayey Sandy GRAVEL (GC), with cobbles, dense, medium grained sand, coarse gravel, plastic fines, reddish brown	D	D	0.00: Potential use as Zone 2 (0.6m thickness)
				0.60					Test put terminated due to virtual refusal Hole Terminated at 0.60 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

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Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 212**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 213

Project	Dugald River TSF				
Location	West of TSF	East	408388.0 m	Sheet	1 OF 1
Position		North	7763202.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, reddish brown	D	D	0.00: Potential use as Zone 2 (0.7m thickness)
				0.70					Test pit terminated due to virtual refusal Hole Terminated at 0.70 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 213**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 214

Project	Dugald River TSF			Sheet	1 OF 1
Location	West of TSF	East	408448.0 m		
Position		North	7763401.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0					GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, reddish brown	D	D	0.00: Potential use as Zone 2 (1.7m thickness)
				0.60					0.6m fine grained proportion of material increasing			
			1									
				1.70					Test pit terminated due to virtual refusal Hole Terminated at 1.70 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

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Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 214**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 215

Project	Dugald River TSF				
Location	West of TSF	East	408460.0 m	Sheet	1 OF 1
Position		North	7763526.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES, with clay, sand, light brown	D	D	0.00: Potential use as Zone 2, from 0.3m depth (1.3m thickness)
				0.30								
								GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, red-brown	D	D	
			1						Becoming moist at depth 0.9m	M	D	
				1.60								
									Test pit terminated due to virtual refusal Hole Terminated at 1.60 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

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Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 215**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 216

Project	Dugald River TSF				
Location	West of TSF	East	408386.0 m	Sheet	1 OF 1
Position		North	7763533.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES, with silt, sand, light brown	D	D	0.00: Potential use as Zone 2, from 0.4m depth (1.2m thickness)
				0.40				GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, red-brown	D	D	
			1	1.60					Test pit terminated due to virtual refusal Hole Terminated at 1.60 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 216**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 217

Project	Dugald River TSF				
Location	West of TSF	East	408376.0 m	Sheet	1 OF 1
Position		North	7763637.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description				
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES/BOULDERS, with gravel, sand, clay, gravel sub-angular	D	D	0.00: Not suitable for Zone 2, excessive screening would be required
			1	1.60					Test pit terminated due to virtual refusal Hole Terminated at 1.60 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 217**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 218

Project	Dugald River TSF				
Location	West of TSF	East	408265.0 m	Sheet	1 OF 1
Position		North	7763636.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES/BOULDERS, with gravel, sand, clay, gravel sub-angular	D	D	0.00: Not suitable for Zone 2 down to 1.0m
			1	1.00				GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, red-brown	D	D	1.00: Suitable for Zone 2 from 1.0m (0.9m thickness)
				1.90								
			2						Test pit terminated due to virtual refusal Hole Terminated at 1.90 m			
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 218**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 219

Project	Dugald River TSF				
Location	West of TSF	East	408473.0 m	Sheet	1 OF 1
Position		North	7763621.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES/BOULDERS, with gravel, sand, clay, gravel sub-angular	D	D	0.00: Not suitable for Zone 2, excessive boulder size material
			1	1.30					Terminated due to engineer's request Hole Terminated at 1.30 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 219**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 220

Project	Dugald River TSF				
Location	West of TSF	East	408349.0 m	Sheet	1 OF 1
Position		North	7763465.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES/BOULDERS, with gravel, sand, clay, gravel sub-angular	D	D	0.00: Not suitable for Zone 2, excessive boulder size material
				0.80								
			1					GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, red-brown	D	D	0.80: Suitable for Zone 2 from 0.8m (0.7m thickness)
				1.50								
									Test pit terminated due to virtual refusal Hole Terminated at 1.50 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 220**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 221

Project	Dugald River TSF				
Location	West of TSF	East	408223.0 m	Sheet	1 OF 1
Position		North	7763499.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES/BOULDERS, with gravel, sand, clay, gravel sub-angular	D	D	
				0.80								
			1					GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, red-brown	D	D	0.80: Suitable for Zone 2 from 0.8m (1.1m thickness)
				1.90								
			2						Test pit terminated due to virtual refusal Hole Terminated at 1.90 m			
			3									
			4									

Sketch & Other Observations

Comments

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 221**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024
	APPENDIX B

TEST PIT: 222

Project	Dugald River TSF				
Location	West of TSF	East	407943.0 m	Sheet	1 OF 1
Position		North	7763553.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0						COBBLES/BOULDERS, with gravel, sand, clay, gravel sub-angular	D	D	
				0.40				GC	Clayey Sandy GRAVEL (GC), with cobbles and boulders, dense, medium grained sand, coarse gravel, plastic fines, red-brown	D	D	0.40: Suitable for Zone 2 from 0.4m (1m thickness)
			1						Becoming moist at 1.0m	M	D	
				1.40					Test pit terminated due to virtual refusal Hole Terminated at 1.40 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 222**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

TEST PIT: 223

Project	Dugald River TSF				
Location	West of TSF	East	408290.0 m	Sheet	1 OF 1
Position		North	7763110.0 m		
Job No.	108003.67	Contractor	MMG	Date	30/5/2024
Client	MMG	Machine	Kubota U27-4 Excavator	Logged	DMR
		Bucket Size			

Excavation					Sampling		Field Material Description					
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	GROUP SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
E			0	0.30					COBBLES/BOULDERS, with gravel, sand, clay, gravel sub-angular	D	D	0.00: Not suitable for Zone 2
									Test pit terminated due to refusal Hole Terminated at 0.30 m			
			1									
			2									
			3									
			4									

Sketch & Other Observations

Comments

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Date

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MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 223**
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APPENDIX F – STABILITY ANALYSES

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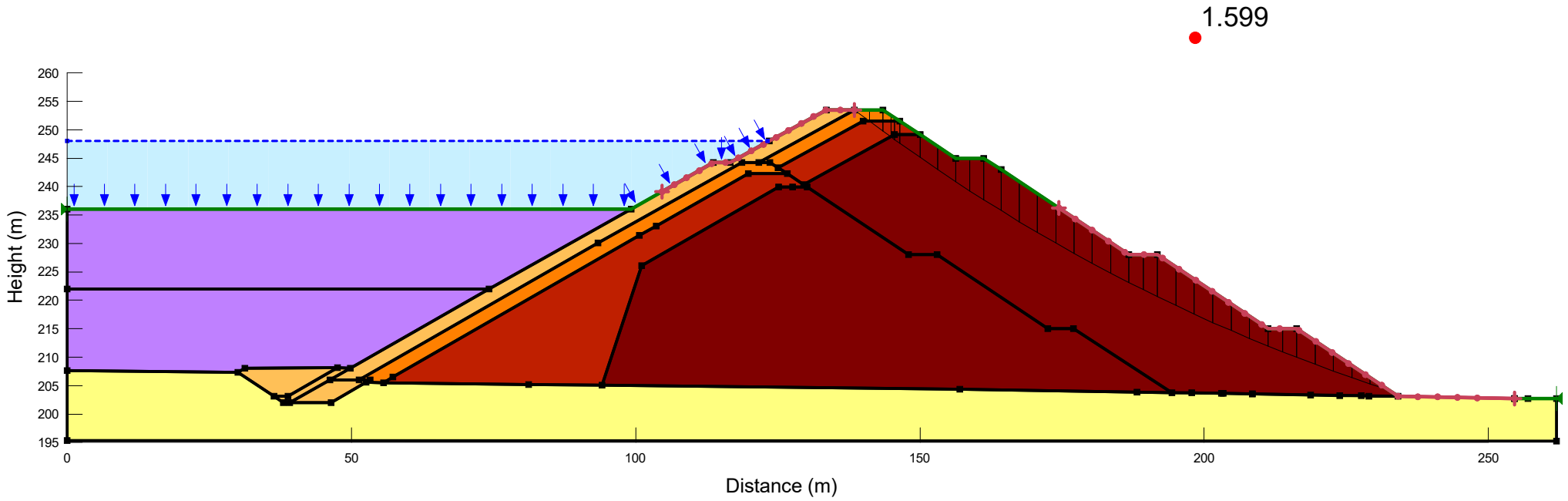
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Shear/Normal Strength Fn.	Piezometric Surface	Tau/Sigma	Minimum Shear Strength (kPa)	Constant Unit Wt. Above Piezometric Surface (kN/m³)
	Bedrock	Bedrock (Impenetrable)									
	Tailings	SHANSEP	20					1	0	0	20
	Zone 2B	Mohr-Coulomb	20	0	35	0		1			
	Zone 2C - Lower Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Lower Average				
	Zone 3A - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				
	Zone 3B - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				



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MMG DUGALD RIVER

STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Long Term - Downstream

Date: 29/08/2025	Job No: 250542	Appendix F1

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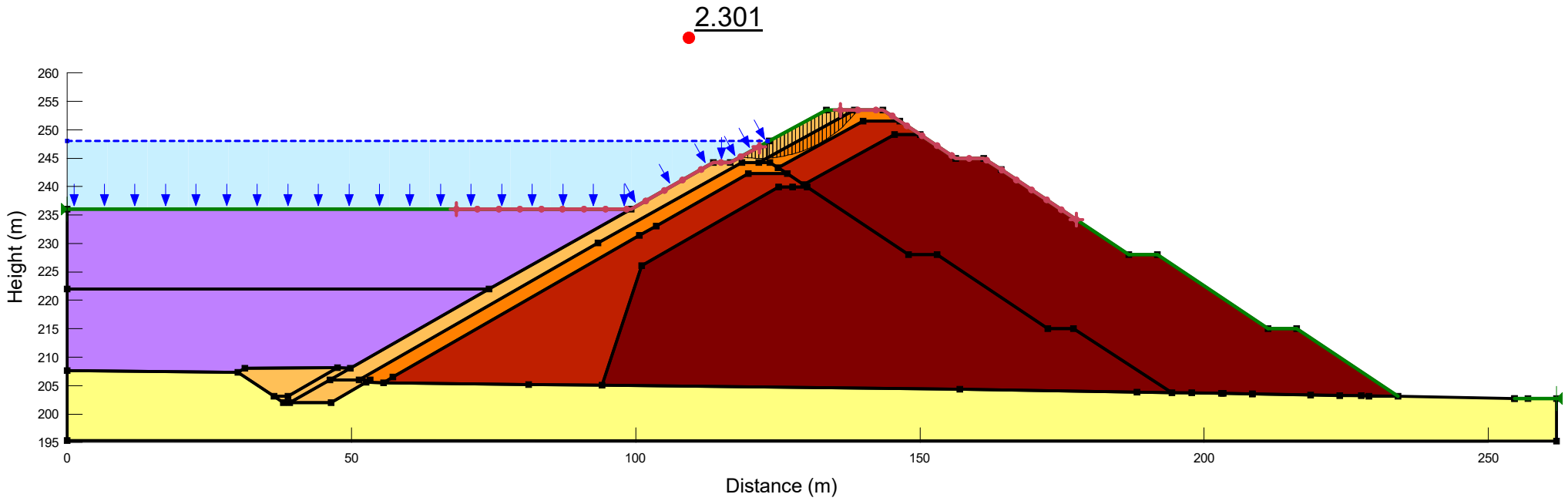
	Bedrock	Bedrock (Impenetrable)									
	Tailings	SHANSEP	20					1	0	0	20
	Zone 2B	Mohr-Coulomb	20	0	35	0		1			
	Zone 2C - Lower Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Lower Average				
	Zone 3A - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				
	Zone 3B - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				



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STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Long Term - Upstream

Date: 29/08/2025	Job No: 250542	Appendix F2

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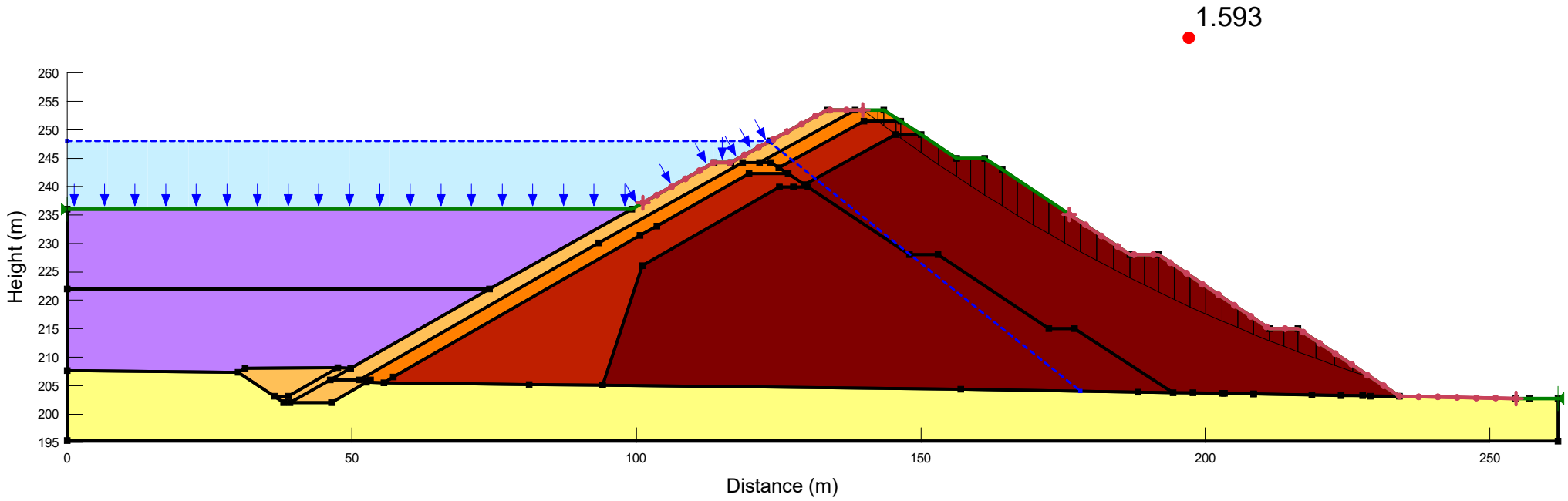
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface	Shear/Normal Strength Fn.	Tau/Sigma	Minimum Shear Strength (kPa)	Constant Unit Wt. Above Piezometric Surface (kN/m³)
	Bedrock	Bedrock (Impenetrable)									
	Tailings	SHANSEP	20				1		0	0	20
	Zone 2B	Mohr-Coulomb	20	0	35	0	1				
	Zone 2C - Lower Average	Shear/Normal Fn.	22.5			0	1	Rock Fill Function - Lower Average			
	Zone 3A - Average	Shear/Normal Fn.	22.5			0	1	Rock Fill Function - Average			
	Zone 3B - Average	Shear/Normal Fn.	22.5			0	1	Rock Fill Function - Average			



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STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Liner Leak - Downstream

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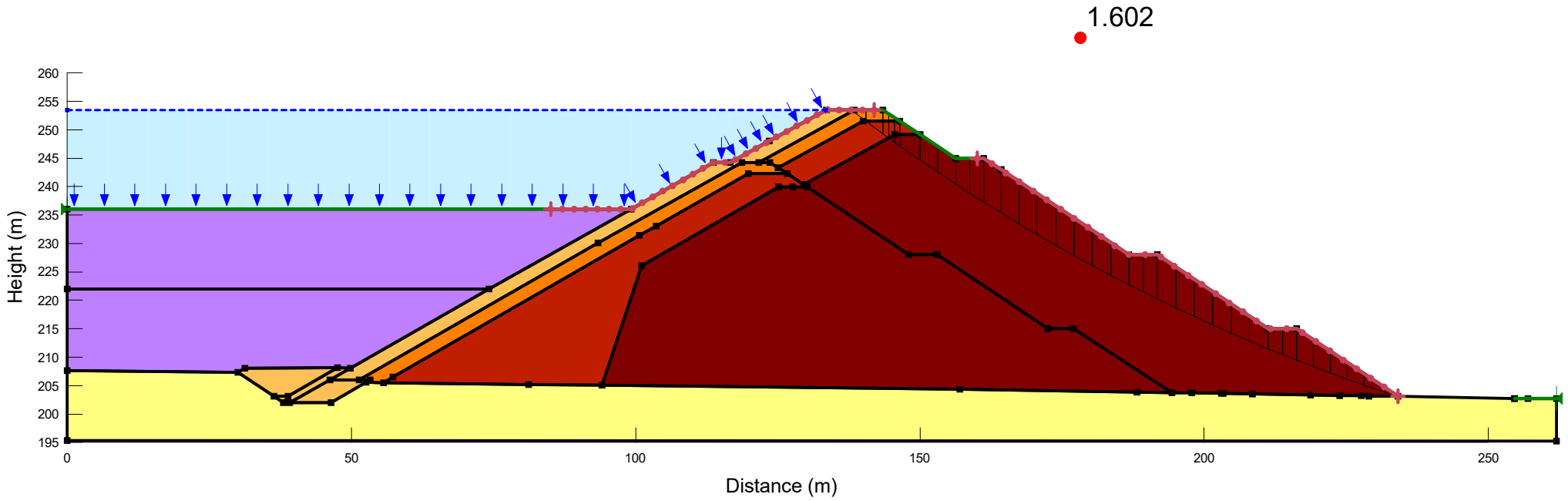
	Bedrock	Bedrock (Impenetrable)									
	Tailings	SHANSEP	20					1	0	0	20
	Zone 2B	Mohr-Coulomb	20	0	35	0		1			
	Zone 2C - Lower Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Lower Average				
	Zone 3A - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				
	Zone 3B - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				



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STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Dam Crest Flood - Downstream

Date: 29/08/2025	Job No: 250542	Appendix F4

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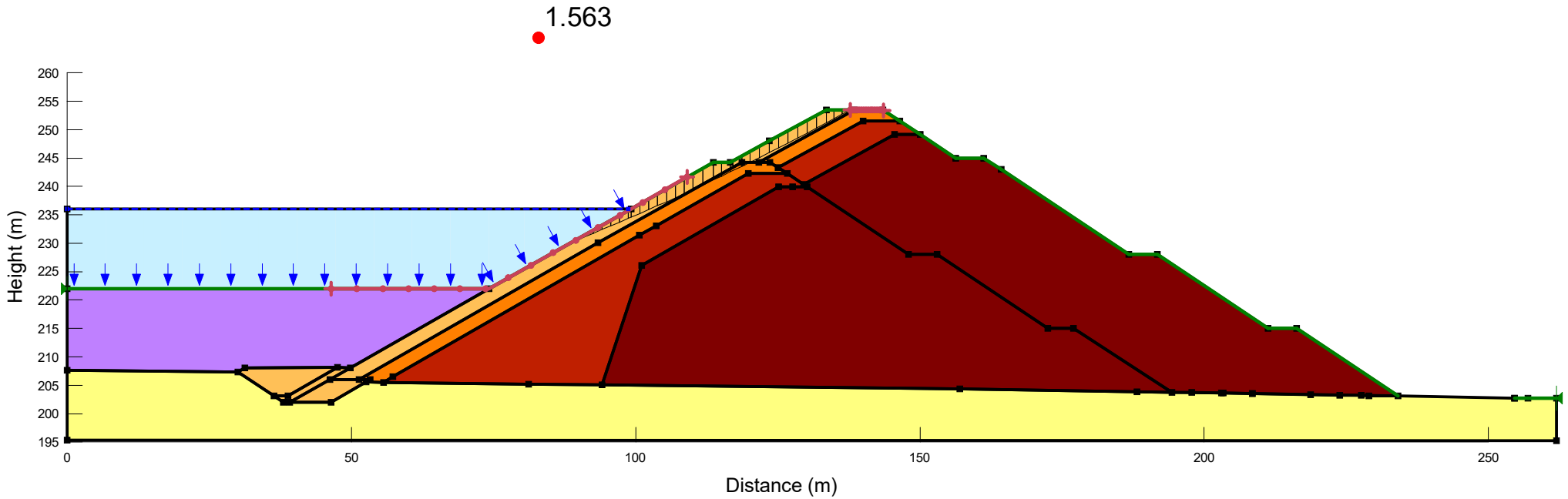
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Shear/Normal Strength Fn.	Piezometric Surface	Tau/Sigma	Minimum Shear Strength (kPa)	Constant Unit Wt. Above Piezometric Surface (kN/m³)
	Bedrock	Bedrock (Impenetrable)									
	Tailings	SHANSEP	20					1	0	0	20
	Zone 2B	Mohr-Coulomb	20	0	35	0		1			
	Zone 2C - Lower Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Lower Average				
	Zone 3A - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				
	Zone 3B - Average	Shear/Normal Fn.	22.5			0	Rock Fill Function - Average				



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MMG DUGALD RIVER

STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - End of Construction - Upstream

Date: 29/08/2025	Job No: 250542	Appendix F5

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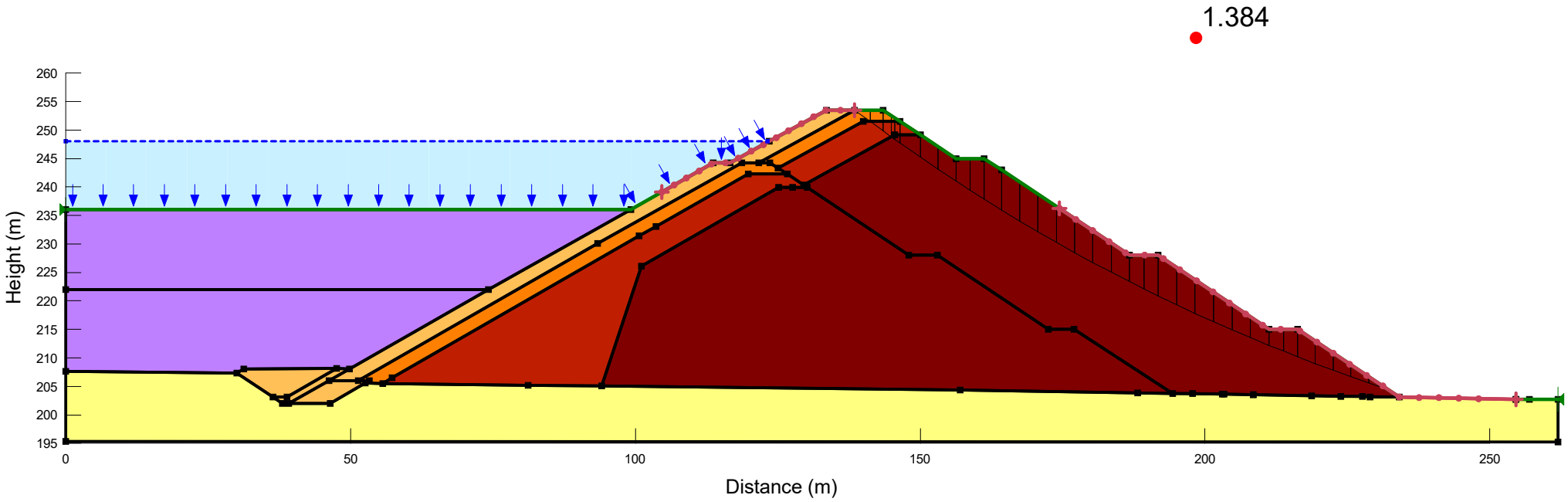
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Tau/Sigma	Minimum Shear Strength (kPa)	Constant Unit Wt. Above Piezometric Surface (kN/m³)	Piezometric Surface	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Shear/Normal Strength Fn.
	Bedrock	Bedrock (Impenetrable)									
	Tailings	SHANSEP	20	0	0	20	1				
	Zone 2B PS	Mohr-Coulomb	20				1	0	29	0	
	Zone 2C - PS	Shear/Normal Fn.	22.5				1			0	Rock Fill Function - Post Seismic
	Zone 3A - PS	Shear/Normal Fn.	22.5				1			0	Rock Fill Function - Post Seismic
	Zone 3B - PS	Shear/Normal Fn.	22.5				1			0	Rock Fill Function - Post Seismic



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STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Post Seismic - Downstream

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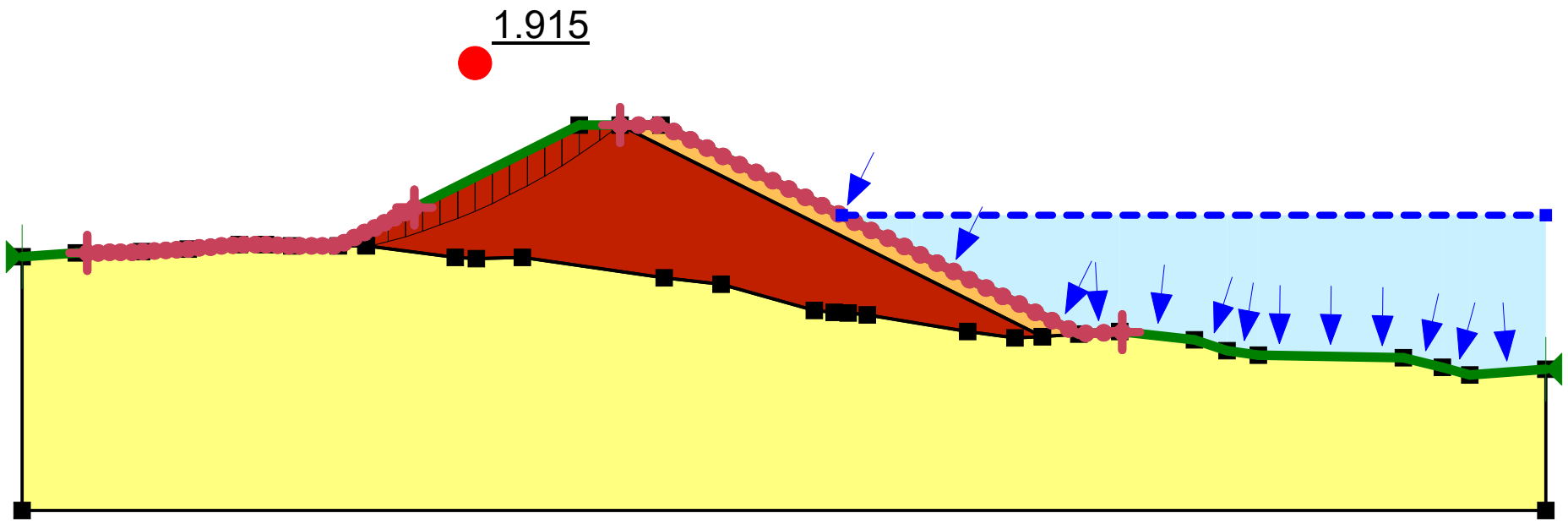
Color	Name	Slope Stability Material Model	Piezometric Surface	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Shear/Normal Strength Fn.
	Bedrock	Bedrock (Impenetrable)	1					
	Zone 2B	Mohr-Coulomb	1	20	0	35	0	
	Zone 3A	Shear/Normal Fn.		22.5			0	Rock Fill Function-3A/3B



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STAGE 3 RAISE DETAILED DESIGN

Northern Discharge Bund - Long Term - Downstream

Date: 29/08/2025	Job No: 250542	Appendix F7

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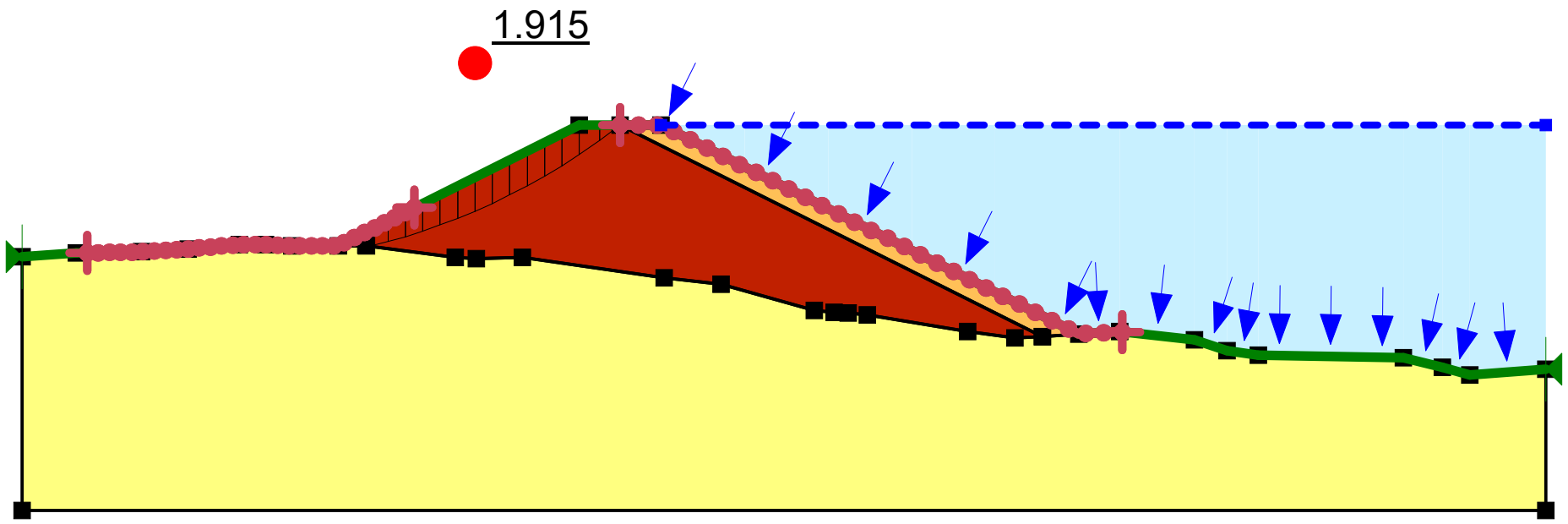
	Bedrock	Bedrock (Impenetrable)	1					
	Zone 2B	Mohr-Coulomb	1	20	0	35	0	
	Zone 3A	Shear/Normal Fn.		22.5			0	Rock Fill Function-3A/3B



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STAGE 3 RAISE DETAILED DESIGN

Northern Discharge Bund - Dam Crest Flood - Downstream

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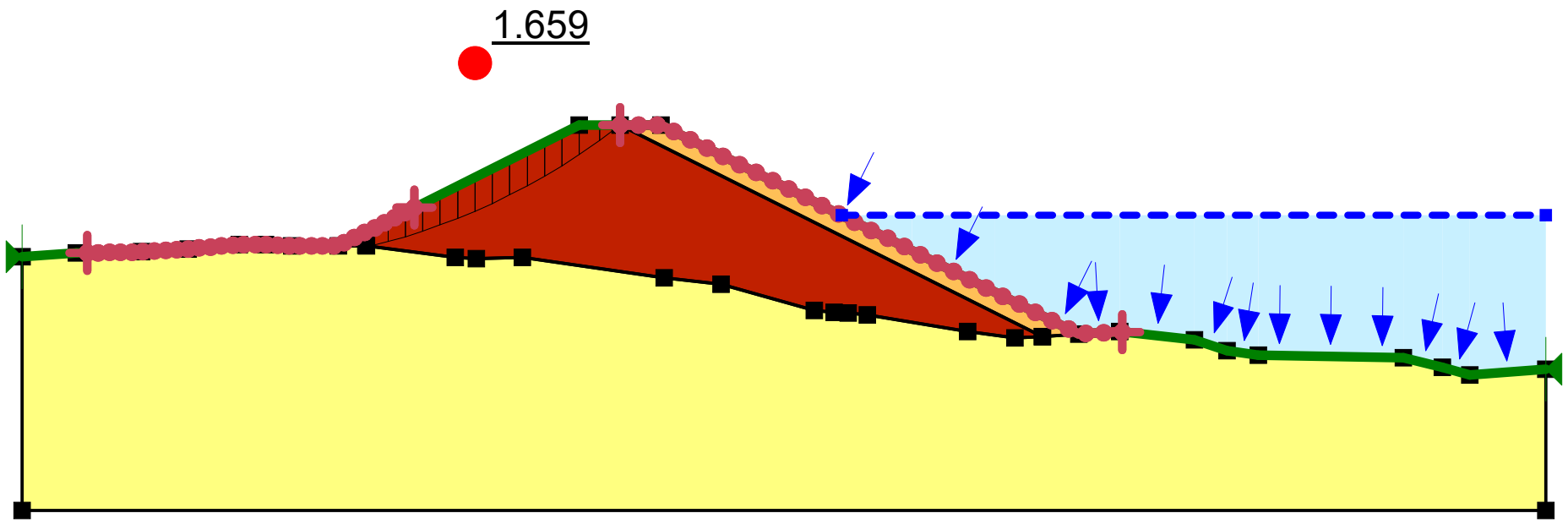
Color	Name	Slope Stability Material Model	Piezometric Surface	Unit Weight (kN/m³)	Shear/Normal Strength Fn.	Phi-B (°)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Bedrock	Bedrock (Impenetrable)	1					
	Zone 2B PS	Mohr-Coulomb	1	20		0	0	29
	Zone 3A PS	Shear/Normal Fn.	1	22.5	Rock Fill Function - Post Seismic	0		



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STAGE 3 RAISE DETAILED DESIGN

Northern Discharge Bund - Post Seismic - Downstream

Date: 23/09/2025 | Job No: 250542 | Appendix F9

APPENDIX G – QUANTITATIVE RISK ASSESSMENT REPORT

TAILINGS.WATER.WASTE.

REPORT

MMG Dugald River
ABN: 19 083 405 556

Tailings Storage Facility – Stage 3 Quantitative Risk Assessment (QRA) Report

250542-R02 REV 0
FEBRUARY 2026

TAILINGS.WATER.WASTE.

Document Control

Project Name:	Dugald River Mine
Document Title:	Quantitative Risk Assessment (QRA) Report
File Location:	S:\Dugald\250542 - TSF Raise Design\Documents\R02 - QRA\250542-R02 (Rev0).docx
Document Number:	250542-R02 (Rev0)

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
A	Draft Issue	11 August 2025	JL	AF / DMR
B	Draft Issue	20 Nov 2025	JL	AF / DMR
0	Final Issue	6 February 2026	JL	AF / DMR

Issue Register

Distribution List	Date
MMG Dugald River	6 February 2026

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TAILINGS.WATER.WASTE.

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APPENDIX B HAZARD SCREENING

APPENDIX C POTENTIAL FAILURE MODES AND INITIAL INCLUSION ASSESSMENT

1 INTRODUCTION

1.1 Background

In 2025, Minerals and Metals Group Ltd (MMG) commissioned ATC Williams (ATCW) to prepare the Detailed Design for the Dugald River Stage 3 Tailings Storage Facility (TSF), including a comprehensive risk assessment to support the proposed design.

As a member of the International Council on Mining and Metals (ICMM), MMG is committed to aligning its tailings management practices with the Global Industry Standard on Tailings Management (GISTM). The GISTM represents international best practice for the safe and responsible management of tailings storage facilities and is underpinned by the principle of zero harm to people and the environment.

Risk management is a central pillar of the GISTM. The standard requires that risk assessments be used to inform the design, construction, operation, and closure of TSFs. Specifically, GISTM mandates a comprehensive understanding of failure modes and the integration of risk-informed decision-making to ensure that risks are reduced to a level that is As Low As Reasonably Practicable (ALARP).

In addition, MMG has established a robust internal risk framework for tailings facilities that aligns with both global standards and Queensland regulatory framework.

While there is currently no statutory requirement in GISTM and Queensland mandating application of a Quantitative Risk Assessment (QRA) for TSF design, MMG elected to undertake this assessment to maintain consistency across its global portfolio and to enhance the rigour and defensibility of the design process. The use of a QRA allows for a more accurate and structured evaluation of the TSF's risk profile, supports the identification of critical failure modes, and informs risk mitigation strategies.

1.2 Scope of Work

The scope of this risk assessment includes the assessment of life safety risks presented in the form of individual and societal risks for the Dugald River Stage 3 TSF. This risk assessment does not include economic, financial, environmental, or cultural risks. **Diagram 1** presents the methodology adopted to deliver the Quantitative Risk Assessment (QRA).

The risk assessment has been undertaken in general accordance with the ANCOLD Guidelines on Risk Assessment (July 2022) **[1].**

The risk assessment is based on the Stage 3 Detailed Design Report **[2]** and the associated Technical Specifications **[3]**.

The engineering assessment summarises the outcomes of available studies extracted from existing reports and analyses, as well as additional engineering analysis carried out as part of the Stage 3 Detailed Design process.

ATCW has been involved in the design and construction of the existing Dugald River TSF and is responsible for delivering the Detailed Design of the Stage 3 Raise of the TSF. Considering the familiarity of key team members with the dam, no site inspection was undertaken as part of this risk assessment.

It is critical to emphasise that the risk and As Low as Reasonably Practical (ALARP) assessments documented in this report are anchored to the current detailed design outcomes **[2]** and technical specifications **[3]**. Any future deviation from the proposed design, operational status, technical specifications or as-constructed details necessitates a comprehensive reassessment of the risk profile to ensure continued alignment with safety and regulatory expectations.

Furthermore, this report is not intended to stand alone and should be reviewed in conjunction with the detailed information provided in the Stage 3 Detailed Design Report **[2]** and the associated Technical Specification **[3]**. These documents collectively inform the context and technical foundation necessary for a comprehensive understanding of the risk assessment.

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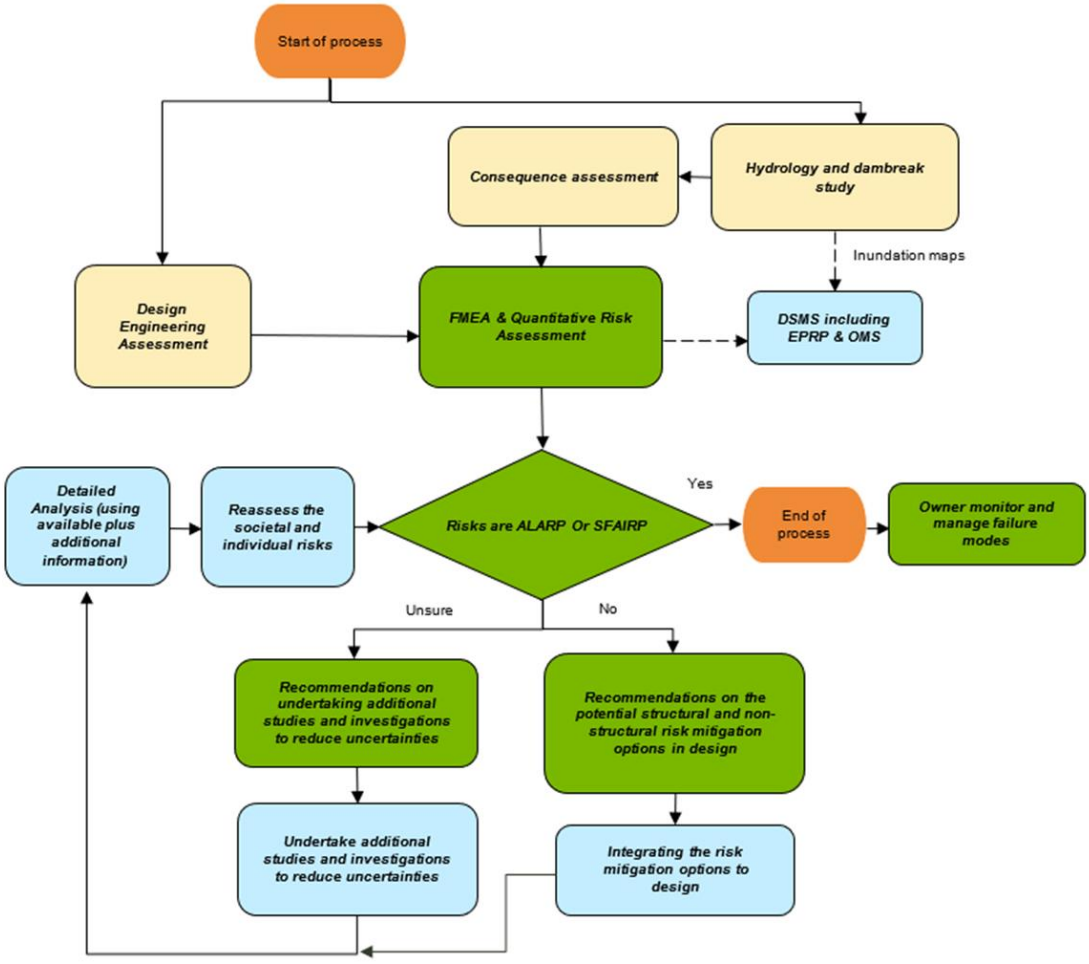
DIAGRAM 1 – ADOPTED RISK ASSESSMENT APPROACH



Yellow	= Completed during the detailed design
Green	= Included in the scope of work of this risk assessment
Blue	= Excluded from the scope of this QRA

1.3 Purpose of the Report

This Report documents the dam safety risk assessment for the Dugald River Stage 3 TSF and includes the following:

- Failure Mode Effect Analysis (FMEA) to identify the credible failure modes.
- Estimation of the conditional probability of failure in each identified credible failure mode (system response) using event tree analysis.
- Analysis to determine the societal and individual risks.
- Evaluation of the risks against the dam safety risk thresholds.
- Documenting the ALARP assessment framework and methodology.
- Conclusions and recommendations on the safety status of the dam.

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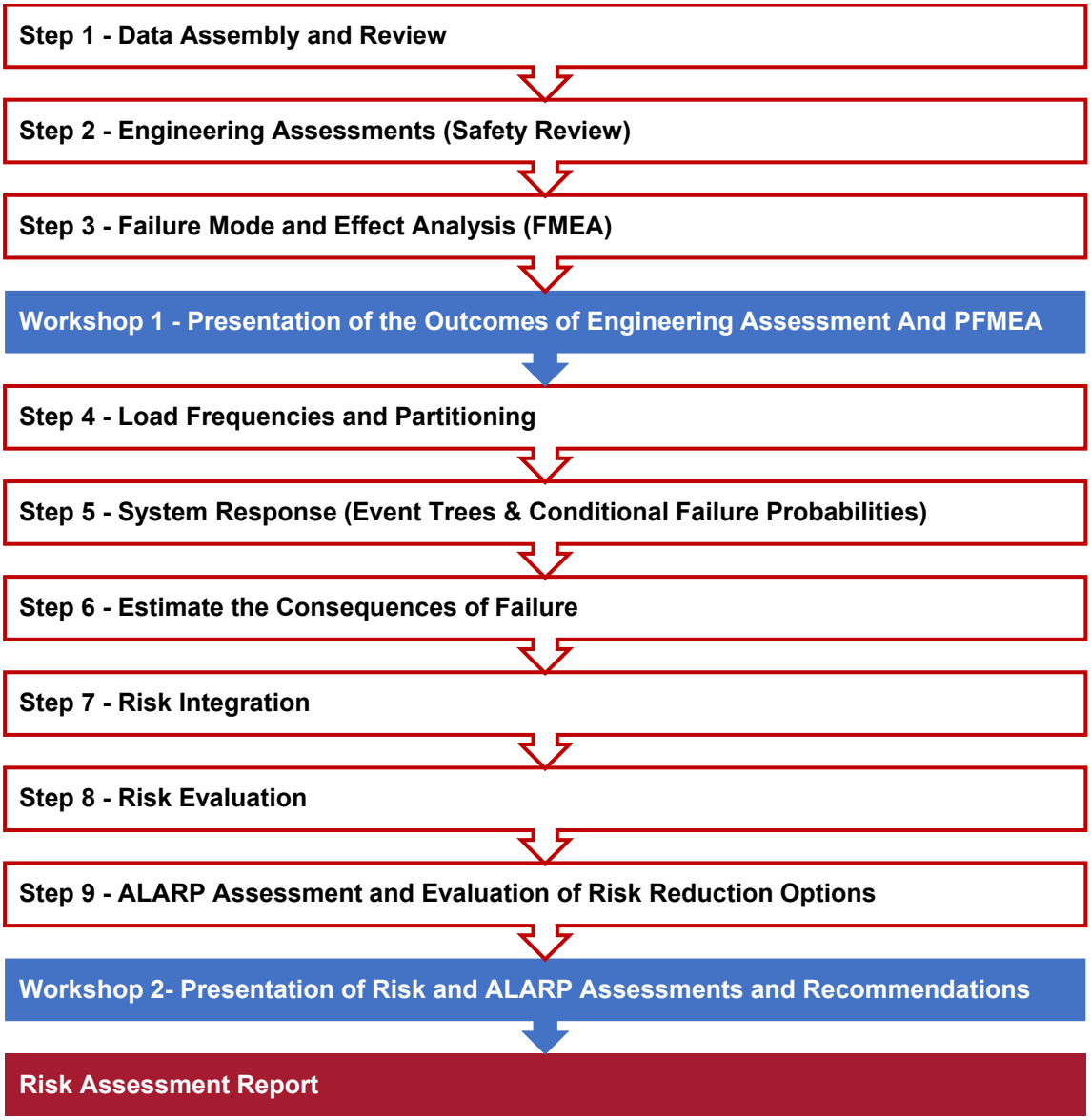
2 RISK ASSESSMENT METHODOLOGY

2.1 Introduction

The risk assessment process includes a sequence of predefined steps, as illustrated in **Diagram 2**.

The risk assessment methodology is based on the ANCOLD Guidelines on Risk Assessment **[1]**. The workflow also includes the presentation workshops and the deliverables as part of the process.

DIAGRAM 2 – RISK ASSESSMENT METHODOLOGY



2.2 Step 1 – Data Assembly and Review

All inputs to the risk assessment are based on data obtained from the investigations, design development, and technical specifications completed as part of the Detailed Design of the Stage 3 TSF.

Where gaps have been identified in the availability or quality of data relative to the typical information required to support a QRA, as recommended in the ANCOLD Guidelines **[1],** the design team has been engaged to address and resolve these gaps accordingly**.**

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2.3 Step 2 – Engineering Assessments

The inputs to the risk assessment are drawn from the available engineering assessments conducted during the investigations, design, and technical specifications phases of the Detailed Design of the Stage 3 TSF.

2.3.1 Dam Components Reviewed

The following dam components have been reviewed as part of the Engineering Assessment:

- Embankments, foundations and abutments;
- Emergency Spillway;
- Decant and Return Water System;
- Seepage Collection System;
- Tailings Deposition System; and
- Monitoring Instrumentation.

All dam components that could pose a risk of dam failure (i.e., failure to function as intended) have been considered in the FMEA process. The expected consequences of failure have been classified as either life safety; environmental; and/or operational and business consequences. Components that do not pose a risk of dam failure have been excluded from the FMEA process.

Only those components deemed to pose a risk towards life safety have been further considered in the risk assessment process.

2.3.2 Load States, Loads and Load Combinations

The dam components have been assessed for the following load states:

- Normal load state, i.e., normal operation with the storage level at or below the Normal Operating Pond;
- Flood load state, i.e., for the storage level elevated above the Normal Operating Pond, such as during a flood event; and
- Seismic load state, i.e., for an earthquake occurring with the storage level at the Maximum Operating Pond.

2.3.3 Methods for Analysis and Acceptance Criteria

Details about the methods for structural assessments and the acceptance criteria are outlined in the relevant Stage 3 Detailed Design Report **[2]**.

2.4 Step 3 – Failure Mode and Effect Analysis (FMEA)

A failure mode is a way that a dam failure can occur, described as a sequence of events that must occur to cause the loss of a dam component or the dam function. FMEA is defined as an inductive method of analysis where particular initiating conditions are postulated, and the full range of effects thereof on the system is assessed, thereby revealing whether the specific initiating conditions would result in one or more potential failure modes.

FMEA is generally a collaborative effort conducted in a workshop format, involving team members each contributing to a specific area based on available information and the dam condition. The overall methodology comprises a structured approach to the process, which is based on the ANCOLD Guidelines on Risk Assessment **[1]** and described in other international dam publications by ASDSO, FEMA, USSD, FERC, as well as ATCW's experience in FMEA. In consideration of the information on the dam obtained in Step 1, the FMEA process includes the following:

- System identification: Identification of the dam and its various components, sub-components, and their functions.

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- Hazard assessment: Identifying and screening potential hazards (failure initiating events) that could occur at the site and initiate potential failure modes. This step aims to identify, analyse and screen the hazards with justification as to whether each hazard is credible and should be considered further in the FMEA.
- Failure modes identification and analysis: The risk analysis is based on the outcomes of the FMEA and is progressed only for the credible failure modes identified to threaten the safety of the dams. The following steps involved in the FMEA process:
  - Identify all the potential failure modes for each credible hazard for all parts of the dam described in the system identification.
  - Assess whether potential failure modes would threaten the dam safety by assessing the potential pathways leading to the dam failure or its components.
  - Based on the findings of this assessment, the key failure modes that would contribute to the risk profile of each structure are identified for a detailed assessment in the risk analysis.

2.5 Step 4 – Load Frequencies and Partitioning

Potential failure modes are related to static loads and dynamic loads. The static loads are separated into normal load states, i.e. with the reservoir level at or below the Normal Operating Pond (or a level that is typically reached on an annual basis); and flood-related load states, i.e. with the reservoir level at peak flood levels up to the Probable Maximum Flood (PMF). In the case of the dynamic load state, the dynamic loads are considered in combination with the reservoir in the normal load state range.

The event tree method of estimating failure probabilities (see Step 5) requires dividing the loadings into discrete partitions. The normal and flood load frequencies are defined using flood frequency data (storage level vs. annual exceedance probability). The seismic load frequency is defined by a combination of the storage level exceedance probability (considering all historical storage levels vs. probability of the levels being exceeded) and seismic frequency data (typically peak ground acceleration vs. annual exceedance probability).

The reservoir level partitioning is based on information available on the historical records of the storage level and the hydrology study undertaken during the design.

The probabilistic seismic hazard assessment of the site is primarily used to inform the seismic loading partitioning.

2.6 Step 5 – System Response (Conditional Failure Probabilities)

Event tree analysis is used to estimate the conditional probability of failure for each failure mode (i.e., the system response) for each of the representative flood or seismic partition levels and loads, as determined in Steps 3 and 4 described above.

Event trees are constructed from left to right, starting with an initiating event and proceeding through potential failure mode development to dam breach. In developing event trees, each failure mode is broken down into a series of steps, events, or states of nature that are necessary to lead to failure. Each event tree consists of a series of linked nodes and branches. Each node represents an uncertain event or condition, while each branch represents one possible outcome of the event or one possible state that a condition may assume.

2.7 Step 6 – Consequences of Failure

The consequences of dam failure are an essential part of the risk analysis process. The Potential Loss of Life (PLL) values are determined during the dam break and consequence category assessment studies. They are reviewed as an element of this risk assessment study. The review outcomes assign the PLL for each load partition based on the failure modes and respective load states.

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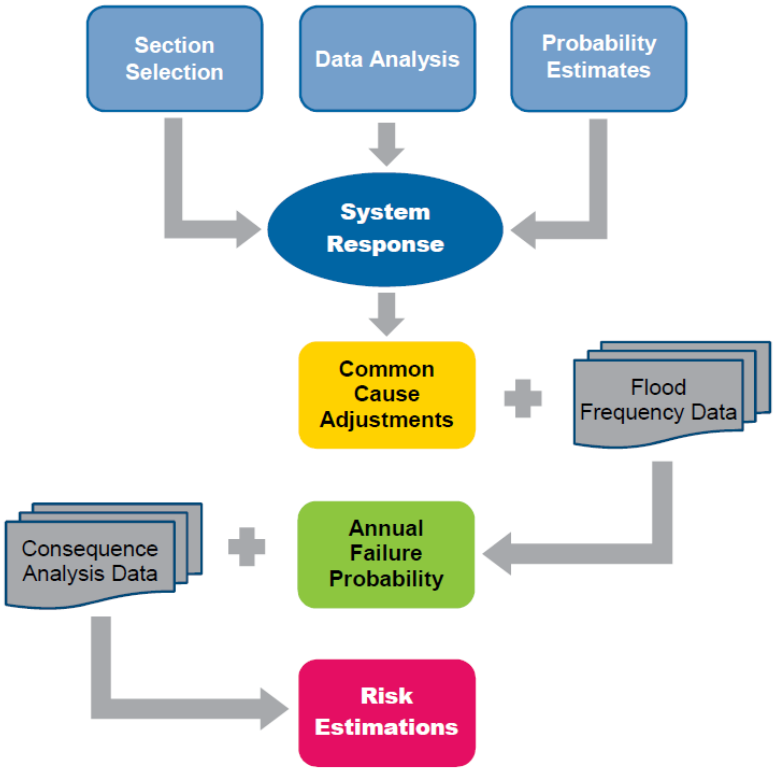
2.8 Step 7 – Risk Integration

Diagram 3 shows the process used for the risk integration of the hydrological data with the system response models developed for each failure mode. The seismic data is integrated using the same procedure. The system response curves, as described above, define the conditional failure probability for the failure mode and the hazard, i.e., the likelihood of piping failure versus the flood and normal hazard water level.

DIAGRAM 3 – RISK INTEGRATION FOR HYDROLOGICAL EVENTS WITH SYSTEM RESPONSE CURVES



Note: The application of common cause adjustment is not applied in this risk assessment due to the small conditional failure probabilities and the negligible effect of the adjustment.

2.8.1 Method for Estimating the Annual Probability of Failure

The conditional probabilities determined in Step 5 are then integrated with the load frequencies determined in Step 4 to determine the annual probabilities of failure over the full range of flood and seismic events, from which the various system responses will be derived.

2.8.2 Method for Estimating Annual Risk

The hydrological system response curve for each failure mode are divided into a number of partitions consistent with the flood frequency data partitioning and the likelihoods multiplied to derive the annual failure likelihoods (f) and the loss of life (N) pairs (f,N pairs) for each partition for use in developing the cumulative F-N curves.

2.9 Step 8 - Risk Evaluation

The life safety risks are evaluated by applying the societal and individual risk rating methodology for new dams and major augmentations, as described in the ANCOLD Guidelines on Risk Assessment **[1]**.

The F-N plot shown in **Graph 1** presents the likelihood of failure on the vertical axis (F) and the associated life loss estimate due to a breach (N) on the horizontal axis.

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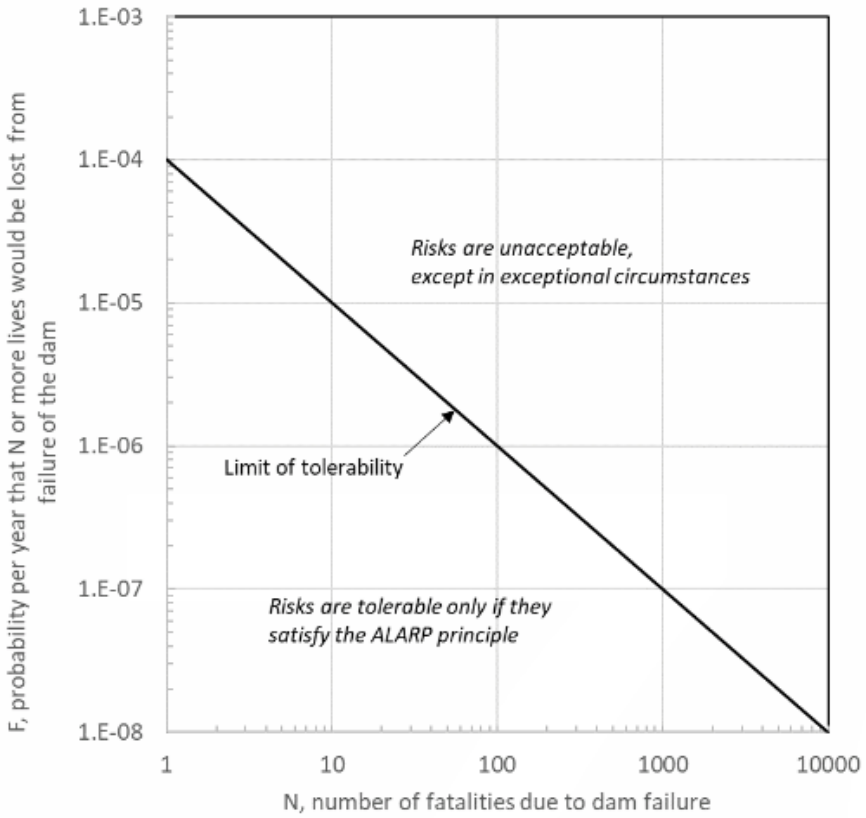
GRAPH 1 – ANCOLD SOCIETAL RISK GUIDELINE: NEW DAMS AND MAJOR AUGMENTATIONS



The position of the societal risk plot forms the basis of an evaluation process that considers whether the risk profile of the dam with the existing configuration is tolerable, and if not, inform the assessment in the next step below. In accordance with the ANCOLD guidelines **[1]**, the societal risk limit of tolerability for new dams and major augmentations is $1x10^{-4}$.

The individual risk rating is also determined for the dam and is defined as the increment of risk to the life of the person most at risk because of the dam. In accordance with the ANCOLD guidelines **[1]**, the individual risk limit of tolerability for new dams and major augmentations is $1x10^{-5}$.

2.10 Step 9 - ALARP Process and Evaluation of Risk Reduction Options

The ALARP process aims to manage risks by ensuring that they are reduced to a level that is as low as reasonably practicable. The ALARP process involves the appraisal of the structural and non-structural risk reduction measures.

In this process, the key uncertainties in the risk assessment are reviewed to identify future studies and investigations that could be undertaken to mitigate these uncertainties. The risk reduction options are reviewed through a range of other lenses, such as community expectations and industry practice.

Then, risk reduction associated with each agreed upgrade option are evaluated. This involves revising the conditional probability of failure estimates prepared in Step 5 and then rerunning the risk estimation completed in Step 8. As part of this process, the reduction and mitigation of the identified risks are assessed.

The outcome of the ALARP Assessment is presented in the QRA report.

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2.11 Assumptions and Limitations

The assumptions and limitations of the risk assessment are as follows:

- The scope of work includes the societal and individual risk rating in compliance with the ANCOLD Guidelines on Risk Assessment (2022) **[1]**. The financial, environmental, and economic risks have not been estimated as part of the scope of this study.
- The inputs to the risk assessment include best estimates of the material properties based on the outcome of the engineering assessments undertaken as part of the Detailed Design of the Stage 3 TSF. An uncertainty analysis has been carried out to address identified uncertainties.
- It should be recognised that procedures and data available for dam safety risk analysis, while quantitative, do not provide precise numerical results.

The risk analysis is limited to the hydrological loading (Normal operation and flood events) and seismic events as identified as the key initiating events.

3 DATA ASSEMBLY AND GAP ANALYSIS

The QRA and ALARP Assessments were primarily informed by the reports and documentation listed in **Table 1**.

TABLE 1 – DUGALD RIVER TSF ENGINEERING DOCUMENTATION

Author	Document	Date of Issue
ATC Williams	Stage 1 and 2 Design Report **[4]**	May 2016
ATC Williams	Stage 1 and 2 Technical Specifications **[5]**	September 2016
ATC Williams	Stage 1 and 2 Construction Report **[6]**	July 2017
ATC Williams	2024 Regulated Structures Annual Inspection Report **[7]**	October 2024
ATC Williams	2024 Intermediate Dam Inspection Report **[8]**	December 2024
ATC Williams	TSF Operations Plan **[9]**	August 2024
ATC Williams	Stage 3 Concept Design Report **[10]**	March 2025
ATC Williams	Stage 3 Dam Break and Consequence Category Assessment **[11]**	June 2025
ATC Wiliams	Stage 3 Water Balance Memorandum **[12]**	June 2025
ATC Williams	Stage 3 Detailed Design Report **[2]**	Under development
ATC Williams	Stage 3 Technical Specifications **[3]**	Under development

A data review and gap analysis has been carried out to identify the available key information and references, the criticality of the information, and the collective impact on the risk assessment.

Based on a review of the available reports and documentation and considering that ATCW has been involved in the design and construction of the existing TSF as well as the Detailed Design of the Stage 3 TSF, it is concluded that the existing data available is sufficient to conduct a quantitative risk assessment effectively.

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4 ENGINEERING ASSESSMENT

4.1 Basis of Engineering Assessment

4.1.1 Overview

The purpose of the engineering assessment is to assess the basis of design, analyses, and assumptions made during the Stage 3 detailed design and to identify any gaps against current engineering standards and guidelines.

The basis of the engineering assessment includes the nomination of the following:

- Relevant current engineering standards, guidelines and references;
- Dam components reviewed;
- Load states, loads and load combinations considered;
- Facility consequence categories;
- Water management criteria; and
- Seismic design criteria.

The data and findings derived from the engineering analyses integrate into the risk assessment framework. They serve as the primary source of information for identifying the Potential Failure Modes (PFMs) and evaluating their likelihood.

4.1.2 Standards, Guidelines and References

The engineering assessment has been undertaken in general accordance with the following regulatory requirements, current engineering standards, guidelines, and references:

- ANCOLD Guidelines on Risk Assessment (2022);
- ANCOLD Guidelines on Selection of Acceptable Flood Capacity for Dams (2000);
- ANCOLD Guidelines on Dam Safety Management (2003);
- ANCOLD Guidelines on the Consequences Categories for Dams (2012);
- ANCOLD Guidelines for Design of Dams and Appurtenant Structures for Earthquake (2019);
- ANCOLD Guidelines on Tailings Dams – Planning, Design, Construction, Operation and Closure (2019);
- Relevant Australian Standards;
- Geotechnical Engineering of Dams, 2nd Edition (Fell et al. 2015);
- A Unified Method for Estimating Probabilities of Failure of Embankment Dams by Internal Erosion and Piping Guidance Document (USBR, USACE, URS and UNSW 2024);
- Best Practices in Dam and Levee Safety Risk Analysis (US Bureau of Reclamation and USACE 2019); and
- Other international current practices as published by USBR and USACE.

4.1.3 Dam Components Reviewed

The following components of the Dugald River TSF have been reviewed as part of the Engineering Assessment:

- Embankments, foundations and abutments;
- Emergency Spillway;
- Decant and Return Water System;

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- Seepage Collection System;
- Tailings Deposition System; and
- Monitoring Instrumentation.

4.1.4 Load States, Loads and Load Combinations

The dam components have been assessed for the following load states:

- Normal load state, i.e., normal operation with the storage level at or below the Operating Pond
- Flood load state, i.e., for the storage level elevated above the Operating Pond, such as during a flood event.
- Seismic load state, i.e., for an earthquake occurring with the storage level at the Maximum Operating Pond.

4.1.5 Consequence Category

A dam break and consequence category assessment was carried out for the Stage 3 TSF **[11]**. A summary of the assigned Consequence Categories from that assessment is provided in **Table 2**.

TABLE 2 – CONSEQUENCE CATEGORY SUMMARY

Methodology	Scenario	Base Case
DETSI	Failure to Contain - Seepage	**Low**
	Failure to Contain – Overtopping	**Significant**
	Dam Break	**High**
ANCOLD	Dam Failure	**High C**
	Environmental Spill	**Low**
GISTM	Consequence Classification	**High**

4.1.6 Storage Capacity and Water Management Criteria

The facility has no defined maximum operating depth, as the TSF has been designed to accommodate extreme wet season inflows generating depths in excess of 15 m.

The maximum water elevation within the TSF, just prior to the 1st of November each year shall provide for the Wet Season Storage Allowance (DSA).

During the 12 months following the 1st of November, the pond water level may exceed the DSA, however it is a mandatory operating requirement that the DEHP shall be informed at any time during the operation of the facility if the water level exceeds the Maximum Reporting Level (MRL), which is the water level within the TSF equating to the volume below the spillway crest required to store the Extreme Storm Storage (ESS).

The water management criteria that apply to the Stage 3 TSF are summarised in **Table 3** on the basis of the assigned Consequence Categories listed in **Section 4.1.5**.

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TABLE 3 – GOVERNING WATER MANAGEMENT CRITERIA

Item	Criteria	Governing Requirement
Design Storage Allowance (DSA)	1:20 AEP wet season runoff	DETSI
Extreme Storage Storage (ESS)	1:10 AEP, 72-hr	DETSI
Contingency Freeboard	Wave run-up from 1:10 AEP wind	DETSI
Spillway Capacity	1:100,000 AEP plus wave run-up for 1:10 AEP wind (ANCOLD); and PMF	ANCOLD

4.1.7 Seismic Design Criteria

The appropriate design seismic events for the Stage 3 TSF are summarised in **Table 4** on the basis of the assigned Consequence Categories listed in **Section 4.1.5**.

TABLE 4 – GOVERNING SEISMIC DESIGN CRITERIA

Item	Criteria	Requirement
Operating Basis Earthquake (OBE)	1:475 AEP to 1:1.000 AEP	ANCOLD
Safety Evaluation Earthquake (SEE)	1:2000 AEP probabilistic ground motion	ANCOLD
Seismic Design Criteria	1:2,475 AEP	GISTM

4.2 Geological and Geotechnical

4.2.1 Geology

The DRM project is located within the Mary Kathleen Zone of the Eastern Foldbelt of the Mt Isa Inlier, on Proterozoic sandstone, siltstone and quartzite. Based on the BMR Quamby Sheet 6957, 1980 Regional Geology Sheet, the 14 km long, 3 km wide Knapdale Range consists of Knapdale Quartzite of the Mount Albert Group, which overlie the Corella Formation calc-silicates. Separating the quartzite from the Corella Formation is a low angle, mylonitic thrust fault.

The quartzite is a massive formation of medium grained, pink-grey metamorphosed sandstone, striking predominantly north-south with a dip of foliation angle in the range of 60 to 80 degrees to the west. There are no known faults running through the valley.

4.2.2 Geotechnical Investigations

Geotechnical investigations of the Knapdale Valley and TSF Embankment footprint areas were carried out in two campaigns as follows:

1. Preliminary investigation (Dec 2008) – Investigation of TSF Embankment area only; and
2. Main investigation (Oct 2012) – Additional investigation of TSF Embankment area, potential borrow sources within the Knapdale Valley floor and foothills, and potential quarry locations.

A summary of the major findings is presented as follows:

- The TSF Embankment area subsurface strata consist of moderate strength, highly fractured, highly to moderately weathered quartzite for the upper 5 m. The rock becomes less fractured and defect spacing decreases at depths between 5 m and 10 m;
- Rock mass permeability of the TSF Embankment foundation rock and TSF impoundment floor is considered to be low (in range of 10^{-7} to 10^{-9} m/sec).

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- Groundwater within the Knapdale Valley is confined to within the joints and defects of the rock mass and fluctuates seasonally within a depth of 10 m below surface level;
- Quartzite rock within the Knapdale Valley was found to be generally suitable for quarrying rockfill for embankment construction; and
- Granular and low permeability residual, colluvial and alluvial materials existing within the Knapdale Valley were found to be generally suitable for embankment construction. Such materials were typically found on the floor and foothills of the valley, particularly on the south-western side and within the southern end.

4.2.3 Identified Gaps

The foundation conditions of the Stage 1 and 2 TSF are very well understood. ATCW Engineers were present at the time of the construction and supervised the foundation preparation.

ATCW Engineers will also be present during the construction of the Stage 3 TSF and foundations.

Consequently, there are no identified gaps in the geological and geotechnical knowledge of the Dugald River TSF.

4.3 Engineering Embankment Assessment

4.3.1 Overview

This Section presents the review and assessment of the TSF embankments. This assessment includes the following;

- A review of the construction records and deviations from the design;
- Historical monitoring performance;
- Outcomes of slope stability assessments for static and seismic loading based on design report, including deformation analyses; and
- An evaluation of the freeboard for flood surcharge.

4.3.2 Design and Construction History

A summary of the design and construction timeline is provided below:

- Detailed design of Stage 1 and 2 completed in 2016 by ATCW;
- Stage 1 civil construction works commenced in June 2016;
- MMG decision to construct both Stage 1 and Stage 2 concurrently in August 2016;
- Completion of Stage 2 construction in June 2017;
- Concept design of Stage 3 completed in September 2025 by ATCW;
- Detailed design of Stage 3 commenced in March 2025 by ATCW.

ATCW had a full-time site presence during the construction of the Stage 1 and 2 TSF to provide technical support and QA/QC oversight and to ensure the works were conducted in accordance with the technical specification requirements. A review of the construction documentation indicates that there were no major deviations and that the design intentions have been met.

4.3.3 Assessment of Historical Performance Based on Visual Observations and Monitoring Data

4.3.3.1 Overview

The historical performance analysis of the Dugald River TSF outlined in this Section relies on the most recent Annual Surveillance Report completed in 2024 by ATCW **[8]**. The Surveillance Inspection was conducted in October 2024.

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4.3.3.2 Overall Outcomes of Surveillance

The surveillance audit and inspection results, along with a review of pertinent documentation, indicate that the Dugald River TSF is behaving in accordance with design expectations and in line with current best practice design criteria (i.e. flood capacity, seismic and structural stability, seepage and resistance to piping); and is in a safe condition that does not introduce any additional risks nor elevate the existing risk to the safety of the community, mining personnel or the ongoing operations of the Dugald River Mine.

Furthermore, it is concluded that Dugald River TSF is being operated, inspected and monitored in accordance with the requirements of the Operation Plan.

Nevertheless, some recommendations for improvement of the dam safety and operations and maintenance practices have been identified, as summarised in the 2024 Intermediate Surveillance Report **[8]**.

4.3.3.3 Outcomes of Monitoring

Historical and ongoing monitoring of the Dugald River TSF has comprised embankment movement monitoring, decant pond level monitoring, tailings beach development monitoring, and seepage monitoring.

Daily, weekly and monthly routine inspections are conducted by site operations personnel. ATCW has conducted annual routine inspections since 2018.

A summary of the historical monitoring, based on the 2024 Intermediate Surveillance Report, is summarised below:

- Movement Monitoring – Assessment of the maximum total displacements since monitoring began in October 2018 indicates that the total displacements (maximum of 75 mm vertical and 19 mm lateral) are well within design expectations for the TSF. Some isolated daily measurements correspond to the "Yellow" and more severe triggers ("Orange" or "Red"). However, the results have been reviewed and are believed to be attributed to survey noise, which is not considered a cause for concern.
- Seepage Monitoring – Records of seepage return pumping were reviewed as part of the 2024 Intermediate Surveillance Report, and the system is considered to be operating in accordance with the design intent, with an average reported flow rate of approximately 2 L/sec.
- Pore Pressure Monitoring – As the TSF Embankment is BGM-lined and of granular and rockfill material constructed on rock foundations, piezometric surface development is not expected. Hence, no embankment piezometers are installed. Based on general observations, the embankment materials appear to be freely draining into the foundation drain and discharging into the SCP in accordance with the design intent.
- Groundwater Monitoring – Groundwater level and water chemistry testing have been conducted in the monitoring bores downstream of the TSF Embankment, although no formal reporting of this testing was reviewed as part of the 2024 Intermediate Surveillance Report. However, from discussions with DRM personnel, it is understood that the results indicate no change from background (i.e. pre-TSF) data.

4.3.4 Stability Analyses

The embankment stability assessment was undertaken as part of the Stage 3 Detailed Design. The results of the stability analyses for the Stage 3 configuration are summarised in **Table 5**.

The stability analyses were carried out for a single cross-section, representing the maximum height and critical embankment section for stability.

It is noted that a post-seismic loading condition was not analysed for the following reasons:

- Seismic loading is not expected to result in a strength loss of either the embankment or foundation (materials not judged to be susceptible to strain weakening); and
- The rockfill embankment and rock foundation are judged not susceptible to liquefaction.

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TABLE 5 – STABILITY ANALYSES RESULTS

Scenario	Description	Failure Direction	FoS Required	FoS Modelled
Long-Term	Tailings at RL 236 m Pond at RL 248 m	Downstream	1.5	1.60
		Upstream		2.30
Liner Leak	Tailings at RL 236 m Pond at RL 248 m	Downstream	1.5	1.59
End of Construction	Tailings at RL 222 m Pond at RL 236 m	Upstream	1.3	1.58
Dam Crest Flood	Tailings at RL 236 m Pond at RL 253.5	Downstream	1.3	1.59
Dam Crest Flood (With Buttress)	Tailings at RL 236 m Pond at RL 253.5 m	Downstream	1.3	1.98

4.3.5 Deformation Analysis

The Stage 3 embankment raise has been assessed for seismic-induced deformation using empirical methods. The assessment results indicate maximum crest settlements of less than 15 mm.

4.3.6 Spillway Assessment

As part of the Stage 3 design, emergency spillway sizing has been conducted for the design flood (critical duration PMF). This assessment conservatively considered the pond starting at the spillway invert level (RL 251.35 m). The same spillway routing methodology from the Stage 3 design has been used to assess the performance of the spillway for smaller critical duration storm events, which are summarised in **Table 6**.

TABLE 6 – EMERGENCY SPILLWAY FLOOD PERFORMANCE

Storm AEP	Critical Duration (hrs)	Peak Outflow (m^3/sec)	Peak Flood Depth (m)	Peak Flood Level	Overtopping?
1:10	9.0	14.45	0.28	RL 251.63 m	No
1:100	4.5	23.86	0.39	RL 251.74 m	No
1:1,000	4.5	39.17	0.56	RL 251.91 m	No
1:10,000	3.0	58.89	0.74	RL 252.09 m	No
1:100,000	3.0	89.78	0.99	RL 252.34 m	No
PMP (1:10,000,000)	3.0	197.60	1.72	RL 253.07 m	No

The spillway flood performance has also been evaluated for a scenario considering a 50% blockage of the spillway. The outcomes of this hydrology assessment are outlined in **Table 7**.

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TABLE 7 – EMERGENCY SPILLWAY FLOOD PERFORMANCE (50% CAPACITY)

Storm AEP	Critical Duration (hrs)	Peak Outflow (m^3/sec)	Peak Flood Depth (m)	Peak Flood Level	Overtopping?
1:10	9.0	9.15	0.34	RL 251.69 m	No
1:100	12.0	16.85	0.51	RL 251.86 m	No
1:1,000	12.0	27.84	0.72	RL 252.07 m	No
1:10,000	5.0	39.47	0.91	RL 252.26 m	No
1:100,000	5.0	61.7	1.23	RL 252.58 m	No
PMP (1:10,000,000)	5.0	144.7	2.18	RL 253.53 m	Yes

The spillway is constructed within natural rock, making the initiation of erosion highly unlikely. In the event of spillway flow, the Stage 3 spillway is located sufficiently far away from the Stage 3 embankment such that there is no risk of erosion of the embankment toe due to spillway flow.

4.3.7 Assessment of Wave Run-up

An assessment of the wave run-up has been undertaken as part of the Stage 3 Detailed Design. The assessment has been conservatively carried out under extreme flood loading conditions.

The maximum wave run-up and set-up are estimated to be 0.79 m and 0.01 m respectively for a 1 in 10 AEP wind event. **Table 8** summarises the outcomes of the wave run-up assessment.

TABLE 8 – WAVE RUN-UP ASSESSMENT

Design Event	Peak Storage Level (m)	Wave Runup + Setup (m)	Available Dry freeboard (m)	Assessment
1 in 100,000 AEP Flood	RL 252.13 m	0.80	0.57	Pass
PMP Flood	RL 252.89 m	N/A	0.61	Pass

5 FAILURE MODE AND EFFECT ANALYSIS (FMEA)

5.1 Introduction

The FMEA is a systematic approach to identifying credible failure modes for a structure. This structured process involves identifying the structure systems\components, potential hazards and all conceivable failure modes.

The following subsections describe the system identification and document the justification of the exclusion or inclusion of potential hazards and the failure modes for further assessment.

5.2 System Identification

The system identification has been completed based on the available reports and relevant information in tabular format, using the generic template developed for this risk assessment.

The definition of the system and components includes the following activities:

- Identify the system, sub-systems, components, and any sub-components for evaluation; and
- Identify the primary and auxiliary functions of the components.

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The Dugald River TSF as a system comprises seven main areas (sub-systems), as follows:

- Embankment and its foundation
- Northern discharge bund and its foundation
- Emergency spillway
- Impoundment area
- Drainage and Seepage Collection
- Tailings delivery system
- Decant and return water system

Each sub-system included in the scope of the risk assessment is broken into components, i.e. embankment wall, foundation, seepage collection system, decant system pumping infrastructure and discharge pipes.

A copy of the system identification is enclosed in **Appendix A.**

5.2.1 Excluded Sub-Systems

The northern discharge bund has been excluded from the risk assessment process for the following reasons:

- The ultimate Stage 3 tailings level deposited adjacent to the northern discharge bund is approximately equivalent to the foundation level. Therefore, no release of tailings is anticipated under a hypothetical failure scenario;
- This location represents the highest elevation of the tailings beach at the northern end; no water is expected to pond against the northern discharge bund during normal operations due to the low point of the beach being located centrally and adjacent to the main embankment;
- Water is only estimated to pond against the embankment following periods of high or extreme rainfall, and the depth of water will be limited to the level of the Stage 3 emergency spillway invert (RL 251.35 m). This equates to approximately 5.35 Mm^3 of stored water;
- Preliminary hydraulic modelling indicates that a hypothetical failure scenario would result in the release of stored waters northwards, via an unnamed tributary to Cabbage Tree Creek. There are no MMG nor third party personnel expected to be routinely within the flow path. The flood waters are also not expected to overtop the Little Eva Pit flood protection levee. Consequently, negligible life safety consequences are expected from a failure of the northern discharge bund.
- The northern discharge bund has therefore been excluded from the QRA process due to negligible life safety consequences.

5.3 Identification and Screening of Potential Hazards

Failure initiating events are either external causes or internal vulnerabilities with the potential to trigger a threat to the proper functioning of the dam that is beyond the control of the dam owner.

The hazard screening is summarised in tabular format. A copy of the hazard screening is enclosed in **Appendix B**.

The following initiating events have been screened for inclusion in the risk analysis:

- Seismic events;
- Hydrological/Floods events;
- Fire;
- Wind; and
- Intrinsic Deficiencies under Normal Operating Conditions.

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5.4 Potential Failure Modes Identification

The potential failure modes identification process aims to identify all possible failure modes of the dam and determine which failure modes are to be assessed in more detail during the risk assessment process based on the dam condition and any issues that may threaten the safety of the structure. The potential failure mode analysis does not include an effects and criticality analysis.

Potential failure modes are either included or excluded for further analysis as part of a failure mode screening assessment. Potential failure modes are excluded when they are assessed as not credible or have a significantly low likelihood of occurrence or negligible consequences, such that it will not have a tangible impact on the risk assessment outcomes.

Based on the outcomes of the engineering assessments, 25 potential failure modes (PFMs) for the Dugald River TSF have been identified. **Table 9** summarises the identified failure modes and their credibility assessment outcomes. Additional information regarding justifications for the credibility of each potential failure mode is provided with further details in **Appendix C**.

It is important to note that the scope of the FMEA has been limited to identifying potential failure modes that could result in global dam failure, specifically those with life safety consequences. Potential failure modes associated with environmental, operational, or economic adverse impacts are outside the scope of this assessment and have not been progressed for further assessment.

TABLE 9 – IDENTIFIED POTENTIAL FAILURE MODES AND CREDIBILITY ASSESSMENT

No.	FM ID	Failure Mode	Initiating Event	Credibility
1	DR TSF-Emb-OT-1	Overtopping erosion due to insufficient installed flood capacity	Flood	Not Credible
2	DR TSF-Emb-OT-2	Overtopping erosion due to insufficient available flood capacity caused by the spillway blockage	Flood	Not Credible
3	DR TSF-Emb-OT-3	Overtopping erosion due to insufficient available flood capacity caused by wind-induced wave effects	Flood, Wind	Not Credible
4	DR TSF-Spill-OT-4	Partial breach due to progressive headcut erosion at the spillway	Flood	Not Credible
5	DR TSF-Emb-OT-5	Overtopping erosion due to failure of the Return Water system	Normal, Flood	Not Credible
6	DR TSF-Emb-OT-11	Overtopping erosion due to long-term deformation of the embankment and loss of freeboard	Normal, Flood	Not Credible
7	DR TSF-Emb-OT-12	Overtopping erosion due to deformation of the embankment and loss of freeboard post-seismic events	Earthquake	Not Credible
8	DR TSF-Emb-OT-22	BGM Liner Failure resulting in excessive seepage and displacement of the embankment materials	Normal, Flood, Earthquake	Not Credible
9	DR TSF-Emb-OT-23	Sloughing of the embankment upstream face due to wind-induced	Wind	Not Credible

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No.	FM ID	Failure Mode	Initiating Event	Credibility
		wave effects, resulting in loss of freeboard and overtopping erosion		
10	DR TSF-Emb-SS-6	Overtopping due to instability of the downstream slope, causing slumping and loss of freeboard	Normal, Flood, Earthquake	Credible
11	DR TSF-Drg S-SS-7	Overtopping due to instability of the downstream slope resulting from failure of the seepage collection system	Normal, Flood, Earthquake	Not Credible
12	DR TSF-Emb-SS-8	Overtopping due to the instability of the upstream slope, causing slumping and loss of freeboard	Normal, Flood, Earthquake	Excluded due to negligible consequences, as a global failure of the embankment is not anticipated
13	DR TSF-Emb-BGM-9	BGM Liner Failure Leading to Seepage and Instability of the Upstream Slope	Normal, Flood, Earthquake	Excluded due to negligible consequences, as a global failure of the embankment is not anticipated
14	DR TSF-Emb-SS-18	Overtopping due to instability of the downstream slope resulting from failure of the Return Water System component	Flood, Normal	Not Credible
15	DR TSF-Emb-IE-15	Internal erosion of the embankment	Normal, Flood, Earthquake	Not Credible
16	DR TSF-Emb-IE-16	Internal erosion of the embankment into the foundation or at the embankment foundation contact	Normal, Flood	Not Credible
17	DR TSF-Emb-IE-17	Internal erosion through the soil/rock foundation	Normal, Flood	Not Credible
18	DR TSF-Emb-SS-25	Internal erosion along a buried conduit	Normal, Flood	Not Credible
19	DR TSF-Emb-LIQ-13	Embankment Breach due to flow liquefaction or foundation liquefaction	Earthquake	Not Credible
20	DR TSF-Emb-OT-14	Embankment Breach due to overtopping by liquefied tailings	Earthquake, Normal	Not Credible
21	DR TSF-Emb-BGM-10	BGM Liner Failure Leading to Excessive Seepage and Loss of Water Containment	Normal, Flood, Earthquake	Excluded due to negligible consequences, as a global failure of the embankment is not anticipated

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No.	FM ID	Failure Mode	Initiating Event	Credibility
22	DR TSF-Emb-IE-19	Fire damage to BGM Liner	Normal	Not Credible
23	DR TSF-Emb-SE-20	Overtopping due to slope instability caused by the formation of erosion gullies from surface water runoff	Flood	Not Credible
24	DR TSF-TD S-OP-21	Failure of Tailing Delivery System	Flood, Normal	Excluded due to negligible life safety consequences
25	DR TSF-Drg S-OP-24	Failure of the Seepage Collection System Pump	Flood, Normal	Excluded due to negligible life safety consequences

5.5 Identified Credible Failure Modes for Risk Analysis

The credible failure modes identified in the Dugald River TSF Stage 3 FMEA to progress to the risk assessment are summarised in **Table 10**.

TABLE 10 – IDENTIFIED CREDIBLE FAILURE MODES FOR RISK ASSESSMENT

FM ID	Failure Mode	Component	Initiating Event
DR TSF-Emb-SS-6	Overtopping due to instability of the downstream slope, causing slumping and loss of freeboard	Main Embankment	Normal, Flood

5.6 Selected Sections and Operational Conditions

The embankment cross-sections to be considered for the risk assessment have been selected based on the following factors:

- Construction methodology and geotechnical conditions of the foundation, including the type of foundation materials.
- Maximum embankment height, dam features and components, including the location of the emergency spillway and permanent decant pond.
- The length of the embankment and the type of credible failure modes determine the number of critical cross-sections to select.

A single critical cross-section has been selected for the main embankment, representing the maximum embankment height as shown in Error! Reference source not found.. The risk assessment has been carried out for the ultimate tailings deposition level with a nominal operating decant pond depth of 1.5 m (RL 236.0 m), which represents realistic operating conditions at the end of tailings deposition based on probabilistic water balance modelling carried out for the Stage 3 Detailed Design **[12]**. This is considered conservative for risk assessment purposes.

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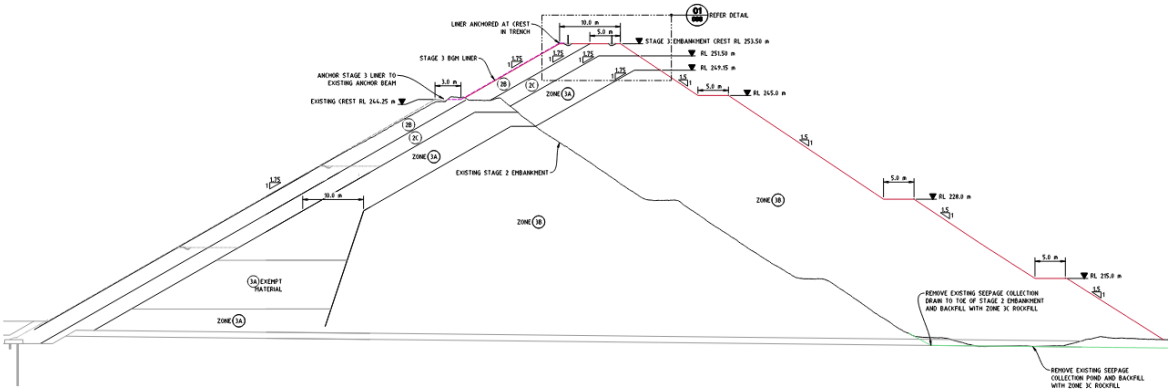
DIAGRAM 4 – TYPICAL DETAILS FOR SELECTED CROSS SECTION



6 LOAD FREQUENCIES AND PARTITIONING

6.1 Introduction

Potential failure modes have been evaluated under normal operating conditions, flood events, and seismic loading. However, the failure mode advanced for detailed risk assessment is considered credible only under normal and flood conditions and has been assessed as not credible under seismic loading.

These flood and normal loads have been partitioned to cover the full range of events likely to impact the dam, from annual to extreme events. Partitions have been set based on physical features that may change the likelihood of failure or discrete steps in the loading range.

6.2 Water Load Frequencies and Partitions

The normal and flood load state reservoir level frequency data have been combined to develop a water load curve.

The reservoir level has been partitioned into eight discrete ranges using nine partitioning lines. The partition levels are associated with significant structural features (like the spillway invert) that might represent a change in system response, or flood events of interest. The hydrological load partitioning data is summarised in **Table 11**.

As described in **Section** Error! Reference source not found., the risk assessment is based on the Stage 3 ultimate tailings deposition level with a nominal operating decant pond depth of 1.5 m (RL 236.0 m) assigned an AEP of 1.

TABLE 11 – HYDROLOGICAL LOAD PARTIONING DATA

Flood Partition	Partition likelihood	Significance of Partitioning	Reservoir Level (m)	AEP of the Flood Partition	Representative Reservoir Level (m AHD)	AEP of Representative Reservoir Level
	1 in 1	Operating Pond	236.00	1.00E+00		
N1					236.00 to 243.74	9.00E-01
	1 in 10	1 in 10 AEP, 72-hr	243.74	1.00E-01		
F1					243.74 to 244.25	7.78E-02
	1 in 16	Stage 2 Crest Level	244.25	2.22E-02		
F2					244.25 to 245.05	1.22E-02
	1 in 100	1 in 100 AEP, 72-hr	245.05	1.00E-02		
F3					245.05 to 246.00	9.00E-03
	1 in 1,000	1 in 1,000 AEP, 72-hr	246.00	1.00E-03		
F4					246.00 to 247.00	9.00E-04

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Flood Partition	Partition likelihood	Significance of Partitioning	Reservoir Level (m)	AEP of the Flood Partition	Representative Reservoir Level (m AHD)	AEP of Representative Reservoir Level
	1 in 10,000	1 in 10,000 AEP, 72-hr	247.00	1.00E-04		
F5					247.00 to 248.26	9.00E-05
	1 in 100,000	1 in 100,000 AEP, 72-hr	248.26	1.00E-05		
F6					248.26 to 251.35	9.88E-06
	1 in 538,644	Stage 3 Spillway Invert	251.35	1.22E-07		
F7					251.35 to 251.68	2.23E-06
	1 in 10,000,000	PMP, critical duration	251.68	1.00E-07		

7 SYSTEM RESPONSE – CONDITIONAL FAILURE PROBABILITIES

7.1 Overview

Event tree analysis has been used to estimate the conditional probability of failure for the single credible failure mode (i.e. the system response) for a range of representative flood or operation levels and loads.

The failure mode advanced for detailed risk assessment is "Overtopping due to instability of the downstream slope causing slumping and loss of freeboard".

The annual failure probability due to slope failure has been derived from “Silva, F.S., Lambe, T.W., & Marr, W.A. (2008), Probability and Risk of Slope Failure” **[13]**.

7.2 Event Tree Analysis

ATCW have prepared the event tree for the identified failure mode and have completed the load partitioning and estimations of the conditional failure probabilities.

The event tree has been developed based on the following generic sequence of events, as presented in U.S. Army Corps of Engineers (2025), "RMC-TotalRisk" **[14]** and in **Diagram 5**. The likelihood at each event tree node considers the storage level at each flood stage reservoir partition.

Conditional probabilities are typically estimated by professional judgment and using industry-accepted methods and references. Where professional judgement is required to assign subjective probabilities, the probability mapping scheme presented in ANCOLD **[1]** can be referenced as reproduced in **Table 12**.

TABLE 12 – MAPPING SCHEME AFTER BARNEICH ET AL. (1996) [1]

Description of Condition or Event	Order of Magnitude Probability Assigned
Occurrence is virtually certain.	1
Occurrences of the condition or event are observed in the database.	10^{-1}
The occurrence of the condition or event is not observed, or is observed in one isolated instance, in the available database; several potential failure scenarios can be identified.	10^{-2}
The occurrence of the condition or event is not observed in the available database. It is difficult to think about any plausible failure scenario; however, a single scenario could be identified after considerable effort.	10^{-3}
The condition or event has not been observed, and no plausible scenario could be identified, even after considerable effort.	10^{-4}

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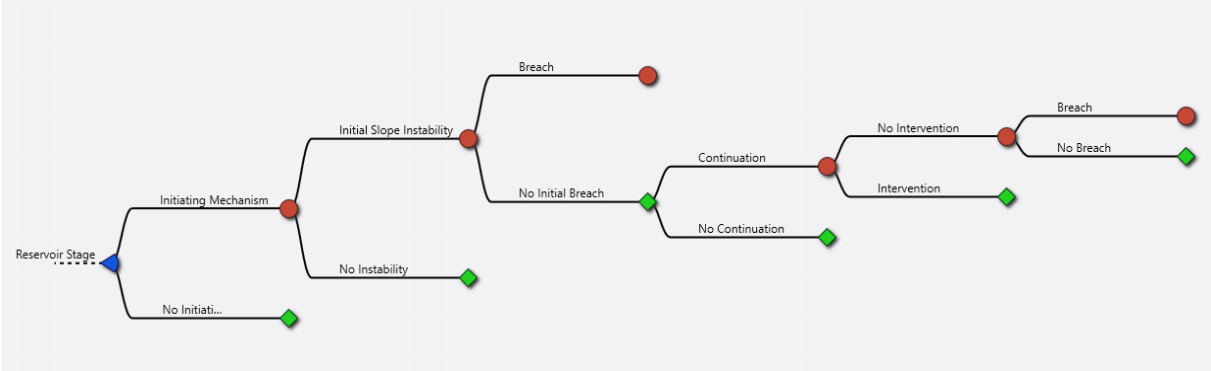
DIAGRAM 5 – EVENT TREE FOR OVERTOPPING DUE TO INSTABILITY OF THE DOWNSTREAM SLOPE CAUSING SLUMPING AND LOSS OF FREEBOARD (SLOPE INSTABILITY FAILURE)



The basis and key assumptions in the event tree analysis are described in the following subsections.

7.2.1 Initiating Mechanism

The probability of an initiating mechanism occurring (e.g. unidentified foundation weakness; elevated phreatic surface level; incorrect materials characterisation etc.) has conservatively been assumed to be 1.

7.2.2 Initial Slope Instability and Breach

Silva, Lambe and Marr **[13]** present a graphical representation depicting the correlation between the factor of safety for slope instability and the annual probability of failure. The graph, as shown in **Graph 2**, classifies earthfill structures into four categories based on the level of engineering, ranging from best (Category I) to poor (Category IV), considering the practices followed for design, investigation, testing, analyses and documentation, construction, and operation and monitoring. Whilst the Dugald River Stage 3 TSF is a rockfill dam, **Graph 2** is considered appropriate for application in this context.

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GRAPH 2 – SLOPE INSTABILITY FACTOR OF SAFETY VERSUS ANNUAL PROBABILITY OF FAILURE

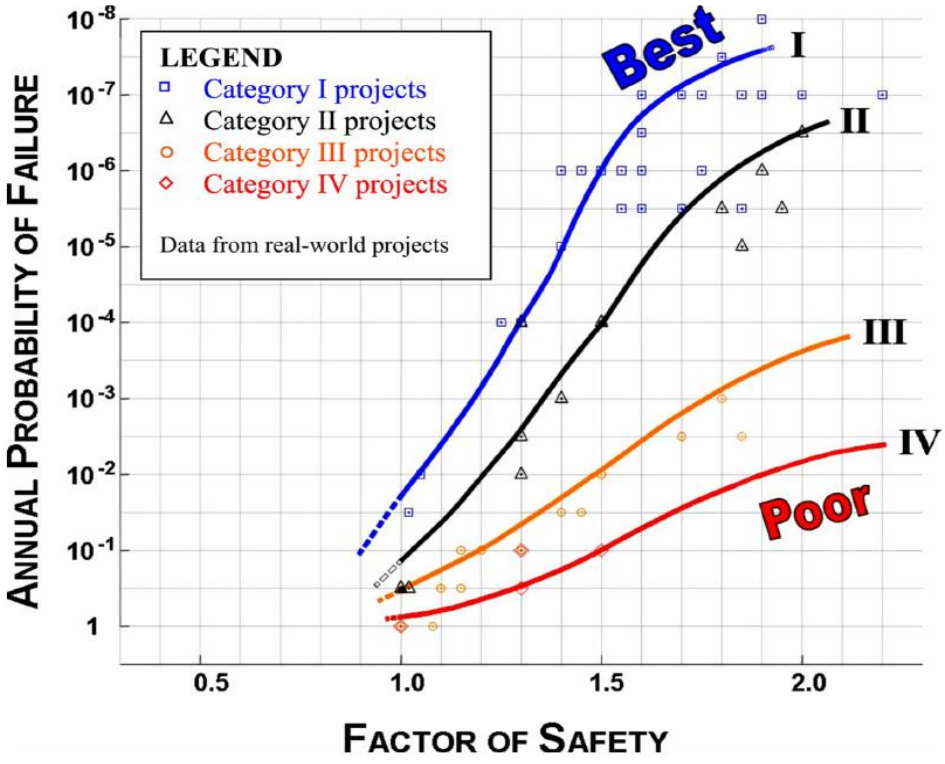

Fig. 1. Factor of safety versus annual probability of failure

An interpolated Category of 1.8 has been assigned to the Dugald River Stage 3 TSF as summarised in **Table 13**, based on the assumption that construction supervision and QA/QC processes will align with those implemented for Stage 2, as required by the Stage 3 Design Drawings and Technical Specifications.

TABLE 13 – INTERPOLATED EMBANKMENT CATEGORY AFTER SILVA, LAMBE & MARR [13]

Category	Assigned Level of Engineering	Weighting	Justification
Investigation	Category II	0.40	Exploratory field investigations carried out for Stage 1 and 2. No specific investigations for Stage 3, however conditions remain unchanged.
Testing	Category II	0.40	Laboratory and compaction testing to be carried out on the Zone 2B and 2C materials. However, no testing of the rockfill materials is proposed due to the large particle size and difficulty in obtaining undisturbed specimens.
Analyses and documentation	Category II	0.40	Factor of Safety determined based on effective stress parameters and pore pressures. Factor of Safety analysis not carried out based on measured data (as structure is not yet constructed).
Construction	Category I	0.20	Assumes full time construction supervision by a qualified geotechnical engineer, and construction control tests by qualified engineers and technicians in accordance with the Technical Specifications.

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Category	Assigned Level of Engineering	Weighting	Justification
			A comprehensive Construction Report is to be prepared by ATCW following completion of construction.
Operation and Monitoring	Category II	0.40	Periodic inspections by qualified engineer (annual surveillance and routine inspections). Selected field measurements (deformation monitoring). No pore pressure or strength performance monitoring. Routine maintenance.
Interpolated Category		**1.80**	

It is noted that the recommendations from Silva, Lambe and Marr **[13]** reflect the total annual probability of failure for a given FoS (i.e., the end node of the Event Tree).

To align with this approach, the potential slip surface has been defined with an entry point at or below the reservoir level. This represents a conservative scenario wherein the minimum FoS would lead to a loss of containment of the stored tailings and water. This assumption implies that the initial slope failure results in a full embankment breach upon slope instability. Note that this slip surface differs from those presented in **Section 4.3.4**.

Accordingly, the subsequent branches have each been conservatively assigned a probability of 1.0 to reflect the assumption of full progression to failure upon an initial slope instability.

The minimum Factor of Safety (FoS) at each load partition is summarised in **Table 14**, alongside the interpreted annual failure probability from **Graph 2**.

Where the estimated FoS exceeded 3, failure due to downstream slope instability is deemed non-credible, corresponding to an annual probability of failure less than 1E-08. For FoS values between 2.1 and 3, the annual failure probability has been limited to a minimum of 1E-07 based on the available dataset. For FoS values below 2.1, the annual probability of failure is estimated using **Graph 2**.

TABLE 14 – CONDITIONAL ANNUAL PROBABILITIES OF FAILURE DUE TO SLOPE INSTABILITY

Reservoir Level (m)	AEP of the Flood Partition	Minimum FoS (Loss of Containment)	Annual Failure Probability
236.00	1.00E+00	3.23	Not Credible
243.74	1.00E-01	2.47	1.00E-07
244.25	2.22E-02	2.41	1.00E-07
245.05	1.00E-02	2.22	1.00E-07
246.00	1.00E-03	2.15	1.00E-07
247.00	1.00E-04	2.04	1.50E-07
248.26	1.00E-05	1.99	2.00E-07
251.35	1.22E-07	1.77	8.30E-07
251.68	1.00E-07	1.74	1.10E-06

8 ADOPTED CONSEQUENCES OF FAILURE IN RISK ASSESSMENT

The estimated risks concerning the consequences of dam failure, specifically life safety risks, have been evaluated. Life safety risks have been estimated by considering the Potential Loss of Life (PLL) as the consequences, measured in the number of deaths, and have been evaluated for each normal and flood load state.

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The Population at Risk (PAR) and the PLL estimates have been based on the outcomes from the Stage 3 TSF Dam Break and Consequence Category Assessments **[11]**. The identified PAR include itinerant MMG inspection and maintenance personnel working within the vicinity of the TSF embankment and seepage collection system, and Harmony personnel working within the Little Eva Pit, located approximately 14 km downstream of the DR TSF.

The incremental PLL at various reservoir levels have been split between the day and night periods. The PLL values adopted in the risk integration are presented in **Table 15**.

The Sunny Day scenario represents a condition in which the storage level is at the normal operating pond level at the time of failure. A specific dam break and PLL assessment has been carried out for this scenario for the purposes of the Risk Assessment, assuming a representative reservoir level of RL 243.2 at the end of deposition based on the outcomes of probabilistic water balance modelling **[12]**. Under this scenario, no overtopping of the Little Eva Pit diversion infrastructure is expected. Consequently, the PLL is driven by contributions from the itinerant MMG personnel.

The Post Flood scenario represents a condition in which the storage level is at the spillway invert level at the time of failure (RL 251.35 m). This situation is represented by the Stage 3 dam break modelling **[11]**, in which overtopping of the Little Eva Pit diversion infrastructure is estimated and hence the PLL is driven by the contribution from the Harmony personnel within the Little Eva Pit.

The Flood scenario represents a condition in which an extreme flood is occurring and the spillway is in operation. Under these conditions, a PLL of 0.0001 has been estimated under the assumptions that neither MMG personnel nor Harmony personnel within the Little Eva Pit will be working under these severe flooding conditions. The PLL for the range of reservoir levels between each of these scenarios have been linearly interpolated.

TABLE 15 – DAY AND NIGHT INCREMENTAL PLL FOR RISK ASSESSMENT

Scenario	Load State	Representative Reservoir Level	Incremental PLL (Day)	Incremental PLL (Night)
Sunny Day	Normal	RL 243.20 m	0.184	0.001
Post Flood	Normal	RL 251.35 m	0.284	0.100
Flood	Flood	> RL 251.35 m	0.0001	0.0001

9 RISK INTEGRATION AND EVALUATION

9.1 Risk Integration

9.1.1 Overview

The estimated annual probability of each failure mode has been integrated with the consequences of dam failure to determine the annual risk over the full range of static (normal operation and flood) events. The results are presented in the following sections.

9.1.2 Annual Probabilities of Failure

- The estimated Total Annual Probability of Failure for the Stage 3 embankment is **5.50E-08**.
- The estimated Total Annual Probability of Failure meets the USBR Risk Guidelines (2019) **[15]** criteria of 1E-04. This value of 1E-04 is commonly used as a threshold as it is approximately the lowest probability of death per year for an individual throughout their lives.
- USBR Guidelines indicate that when the annualised failure probability is above the USBR threshold level (1E-04), there is generally increasing justification to reduce or better understand the risks. Below this threshold level, justification is generally decreasing to reduce or better understand the risk. It should be noted that GISTM and ANCOLD do not have any criteria for evaluating the Total Annual Probability of Failure. This assessment has been undertaken in the context of best practice.

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9.1.3 Societal Risk

The Societal Risk Rating has been determined based on the ANCOLD Guidelines on Risk Assessment (2022) **[1]** as follows:

- Societal Risk Rating = F_n x N, where:
  - F_n is the estimated annual probability that N or more lives would be lost from failure of the dam; and
  - N is the estimated number of fatalities due to dam failure.

The total societal risk posed by the failure of the Stage 3 TSF is assessed to be **5.16E-09**. This satisfies the ANCOLD societal risk criteria for new dams or major augmentations of 1E-04.

9.1.4 Individual Risk

The individual risk rating is estimated by adopting the methodology outlined by Maslin et al. **[16]**. The proposed methodology was later modified by Lang and Foster **[17]**.

The adopted methodology is consistent with the ANCOLD Guidelines on Risk Assessment **[1]**.

The method is based on the following factors and assumptions, based on the outcomes of the Stage 3 Dam Break and Consequence Category Assessment **[11]**:

- Individual Risk Rating = $\sum IR_{fs}$,
- IR_{fs} = Individual risk for each failure scenario = $(f * EF_{day} * TF_{day} * WEF_{day} * FF) + (f * EF_{night} * TF_{night} * WEF_{night} * FF)$, where:
  - f = probability of failure for each scenario
  - EF = Exposure Factor, the proportion of time that the individual is most at risk
    - Two estimates have been carried out to determine the individual or group most at risk: a) MMG personnel in the vicinity of the Stage 3 TSF; and b) Harmony personnel within the Little Eva Pit extents.
    - An EF of 0.23 has been adopted for the group of MMG personnel, representing the total combined exposure of all routine activities in the vicinity of the Stage 3 TSF (refer to **[11]** for further details).
    - An EF of 1 has been adopted for the Harmony personnel, representing the assumption that there will be ongoing mining operations within the Little Eva Pit (i.e., day shift and night shift).
  - TF = Time of day Factor, the proportion of time that a person will be awake or asleep.
    - Assumed 10 hours for day and 14 hours for night.
    - TF_{day} = 0.42 and TF_{night} = 0.58.
  - WEF = Warning and Evacuation Factor, the probability that a person most at risk does not receive a warning or ignores the warnings. Based on the recommendations of Lang & Foster **[17]**, the warning effectiveness factor in Maslin et. al. **[16]** should not be used because it is already accounted for in the historical fatality rates adopted in the modified methodology. As such, the WEF is considered to be 1.
  - FF = Fatality Factor, the conditional probability of fatality given the person has not evacuated.
    - Lang & Foster **[17]** recommend using the RCEM curves **[18]** to estimate a Fatality Factor based on the Depth × Velocity (DV) and warning time.
    - Peak DV values are documented in the Stage 3 Dam Break and Consequence Category Assessment Report **[11]**.

    The adopted FF are 0.8 for the MMG personnel and 0.01 for the Harmony personnel (refer to **[11]** for further details).

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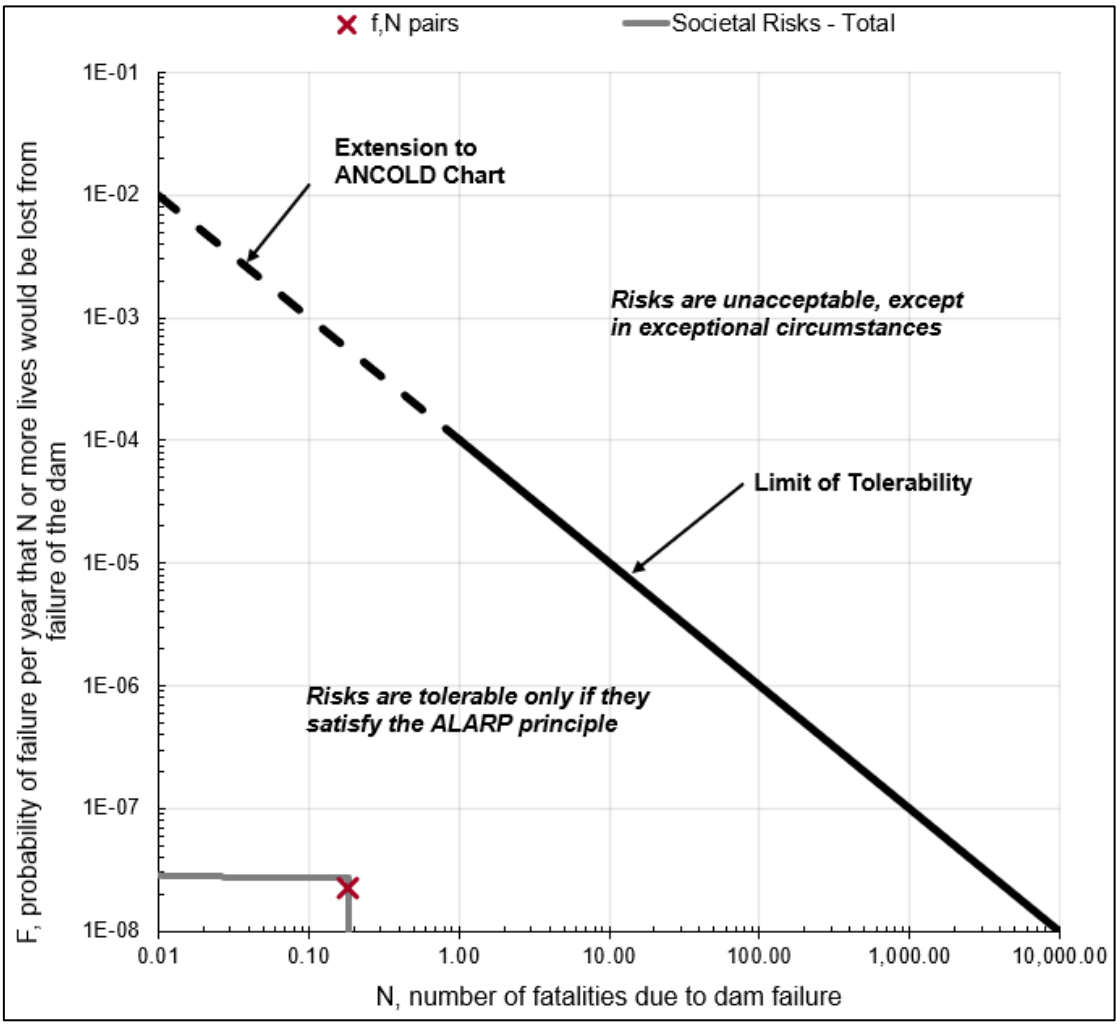
- The Individual Risk is assessed to be 1.03E-09 for the MMG personnel, and 1.33E-10 for the Harmoney personnel. Consequently, the MMG personnel represent the group most at risk, with a total Individual Risk imposed by the Stage 3 TSF of **1.03E-09**. The Individual Risk estimate satisfies the ANCOLD criteria for new dams or major augmentations (1E-05).

9.1.5 Risk Evaluation

The best estimate of the societal risk of the Dugald River Stage 3 TSF, based on the assumptions outlined above, is presented in **Graph 3**.

The F-N curve plots more than 4 orders of magnitude below the ANCOLD Limit of Tolerability, on the basis of the assumed structural and operational conditions.

GRAPH 3 – STAGE 3 TSF SOCIETAL RISK PLOT



9.2 Key Uncertainty Analysis

The key uncertainties that are likely to impact the outcomes of the overall risk assessment have been identified as follows:

- Probability of the slope instability event occurring; and
- Failure consequences (i.e., the estimated PLL for each load partition).

These uncertainties have been assessed through Monte Carlo simulation using the RMC-TotalRisk software **[14]**. The Monte Carlo simulation has been carried out to propagate the estimated

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uncertainties in event tree branch probabilities through the tree in order to obtain the uncertainty in the end branch probability of failure.

To assess the uncertainty in the probability estimates for slope instability, a range of plausible failure probabilities has been considered, based on the following factors:

- The factor of safety and associated annual probabilities of failure, estimated using both lower-bound and upper-bound embankment strength parameters for the Zone 2C, 3A and 3B rockfill. For the purposes of this assessment, the upper-bound and lower-bound Leps rockfill strength functions **[19]** have been adopted as summarised in **Table 16**;
- The annual probabilities of failure corresponding to a Category II project classification. This may manifest if only part-time construction supervision occurs; and
- The annual probabilities of failure corresponding to a Category I project classification. This may manifest if there are improvements to the investigation, testing, design, and operation and maintenance regimes.

A summary of the estimated Factors of Safety for loss of containment across the range of lower-bound and upper-bound embankment strength parameters is presented in **Table 17**. The sensitivity assessment indicates that there is minimal sensitivity of the FoS to the adopted embankment strength parameters.

TABLE 16 – ROCKFILL STRENGTH PARAMETERS

Material	Lower Bound	Base Case	Upper Bound
Zone 2C	Leps Lower Bound (Capped at 40°)	Leps Lower-Average (Capped at 40°)	Leps Upper Bound (Capped at 40°)
Zone 3A	Leps Lower Bound (Capped at 40°)	Leps Average (Capped at 40°)	Leps Upper Bound (Capped at 40°)
Zone 3B			

TABLE 17 – SENSITIVITY ASSESSMENT FOR EMBANKMENT FACTOR OF SAFETY

Reservoir Level (m)	Minimum FoS (Loss of Containment)		
	Lower Bound	Base Case	Upper Bound
236.00	3.04	3.23	3.23
243.74	2.30	2.47	2.47
244.25	2.29	2.41	2.41
245.05	2.12	2.22	2.26
246.00	2.06	2.15	2.16
247.00	2.00	2.04	2.09
248.26	1.94	1.99	2.02
251.35	1.77	1.77	1.79
251.68	1.74	1.74	1.78

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To assess the uncertainty in the consequences of failure, a consequence distribution has been considered by assuming that the base case consequence estimates may vary by a factor of 2.

The inputs into the Monte Carlo uncertainty simulation are summarised in **Table 18** and **Table 19**. The outcomes of the Monte Carlo simulation are presented in **Graph 4** alongside the societal risk plot for the "Best Estimate" assessment.

The outcomes of the uncertainty assessment indicate that the 99% Confidence Interval plots approximately 4 orders of magnitude below the ANCOLD Limit of Tolerability for new dams or major augmentations. This demonstrates that, whilst the risk assessment results indicate some sensitivity to the input assumptions, the societal risk plot remains well below the ANCOLD limit of tolerability.

TABLE 18 – INPUTS TO MONTE CARLO UNCERTAINTY SIMULATION (INITIAL SLOPE INSTABILITY)

Reservoir Level (m)	Distribution	Annual Probability of Failure		
		Min	Most Likely	Max
236.00	Triangular	Not Credible	Not Credible	Not Credible
243.74	Triangular	2.00E-08	1.00E-07	1.00E-07
244.25	Triangular	2.00E-08	1.00E-07	1.00E-07
245.05	Triangular	2.00E-08	1.00E-07	1.50E-07
246.00	Triangular	2.00E-08	1.00E-07	2.27E-07
247.00	Triangular	2.00E-08	1.50E-07	3.07E-07
248.26	Triangular	2.00E-08	2.00E-07	4.29E-07
251.35	Triangular	4.38E-08	8.32E-07	1.70E-06
251.68	Triangular	4.57E-08	1.12E-06	2.35E-06

TABLE 19 – INPUTS TO MONTE CARLO UNCERTAINTY SIMULATION (CONSEQUENCE OF FAILURE)

Reservoir Level (m)	Distribution	Potential Loss of Life					
		Day			Night		
		Min	Most Likely	Max	Min	Most Likely	Max
236.00	Triangular	0.092	0.184	0.368	0.001	0.001	0.002
243.74	Triangular	0.092	0.184	0.368	0.001	0.001	0.002
244.25	Triangular	0.095	0.191	0.381	0.004	0.008	0.015
245.05	Triangular	0.101	0.201	0.402	0.009	0.018	0.036
246.00	Triangular	0.107	0.214	0.427	0.015	0.030	0.061
247.00	Triangular	0.113	0.227	0.454	0.022	0.043	0.087
248.26	Triangular	0.122	0.243	0.487	0.030	0.060	0.120

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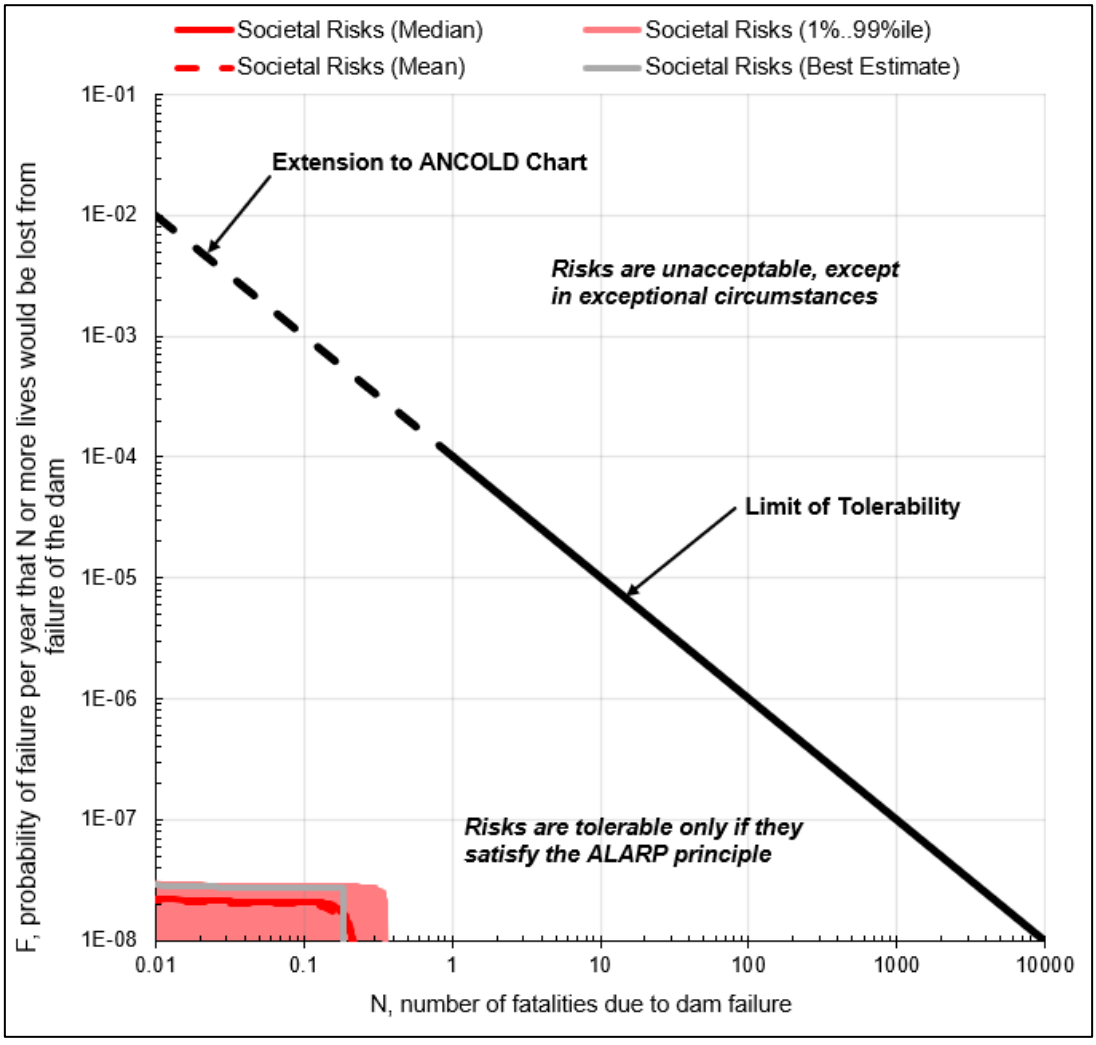
Reservoir Level (m)	Distribution	Potential Loss of Life					
		Day			Night		
		Min	Most Likely	Max	Min	Most Likely	Max
251.35	Triangular	0.142	0.284	0.568	0.050	0.100	0.200
251.68	Triangular	0.001	0.001	0.002	0.001	0.001	0.002

GRAPH 4 – STAGE 3 TSF SOCIETAL RISK PLOT (MONTE CARLO SIMULATION)



9.3 Degree of Confidence in Outcomes

As described in ANCOLD Guidelines **[1]**, the degree of confidence in the outcomes is based on evidence; that is; the knowledge and data available at the time.

The degree of confidence that the risk rating plots below the limit of tolerability for both societal and individual risk takes into account both the uncertainties in the likelihood and consequence estimates, and the risk plotting position for the proposed augmentation, as described in the 2021 ANCOLD Paper "Development of a practical SFAIRP framework for dams" (Pearse et. al., 2021) **[20]**.

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As described in **[20]**, the degree of confidence depends on two primary factors:

- The relative uncertainty of the risk estimate from the state of knowledge assessment; and
- The risk plotting position relative to the Limit of Tolerability.

Although adequate data with sufficient detail is incorporated into the risk assessment (i.e. the engineering inputs and consequence assessments), a 'Medium' level of uncertainty has been interpreted for the risk analysis, primarily attributed to the inherent uncertainties associated with the future construction practices and embankment material selection.

Given the 'Medium' uncertainty in the risk estimate and the risk profile plotting more than 4 orders of magnitude below the limit of tolerability (at the 99% Confidence Interval), the degree of confidence that the risk position of the dam is below the ANCOLD Limit of Tolerability for Societal Risk is **Very Strong**.

In addition, given the 'Medium' uncertainty in the risk estimate and the Individual Risk estimate (1.03E-09) falling approximately 4 orders of magnitude below the ANCOLD Individual Risk criteria (1E-05), the degree of confidence that the Individual Risk of the dam satisfies the ANCOLD requirements is **Very Strong**.

10 SUMMARY OF RISK ASSESSMENT OUTCOMES

The Risk Assessment has been undertaken in accordance with the requirements of the ANCOLD Guidelines on Risk Assessment **[1]**. The following has been concluded for the individual and societal risks:

- The Total Annual Probability of Failure is **5.50E-08**, which satisfies the USBR Risk Guidelines (2019) **[15]** criteria of 1E-04.
- The total societal risk imposed by the failure of the Stage 3 TSF is assessed to be **5.16E-09**, which satisfies the ANCOLD societal risk rating criteria for new dams or major augmentations below the safety threshold of 1E-04.
- The societal risks F-N curve plots more than 4 orders of magnitude below the ANCOLD limit of tolerability based on best estimates. The uncertainty assessment indicates that there is a 99% confidence level that the F-N curve plots approximately 4 orders of magnitude below the ANCOLD limit of tolerability.
- Given the 'Medium' uncertainty in the risk estimate and the FN plot position at the 99% confidence interval (4 orders of magnitude below the limit of tolerability), the degree of confidence that the risk position of the dam plot is below the safety threshold is **Very Strong.**
- The Individual Risk is assessed to be **1.03E-09,** which satisfies the ANCOLD criteria for new dams or major augmentations (1E-05), indicating a diminishing justification for considering further risk reduction actions.

11 AS LOW AS REASONABLY PRACTICABLE DEMONSTRATION

11.1 Overview

To demonstrate that the risks are "as low as reasonably practicable" (ALARP), the methodology described in Commentary C11-7 of the ANCOLD Guidelines on Risk Assessment **[1]** has been adopted.

As outlined in the ANCOLD Guidelines **[1]**, ALARP and related concepts, such as "so far as is reasonably practicable" (SFAIRP), constitute the central principle for evaluating public health and safety risks in the risk evaluation phase of a risk assessment. In ANCOLD's view, the way in which ALARP is addressed in the 2022 guidelines **[1]** makes it equivalent to the common understanding of the requirements to reduce risks SFAIRP.

Therefore, to demonstrate that the risks are ALARP in this report, the recommended ANCOLD methodology has been enhanced with the SFAIRP assessment framework outlined in **[20]**. The overall process is summarised graphically in **Diagram 6.**

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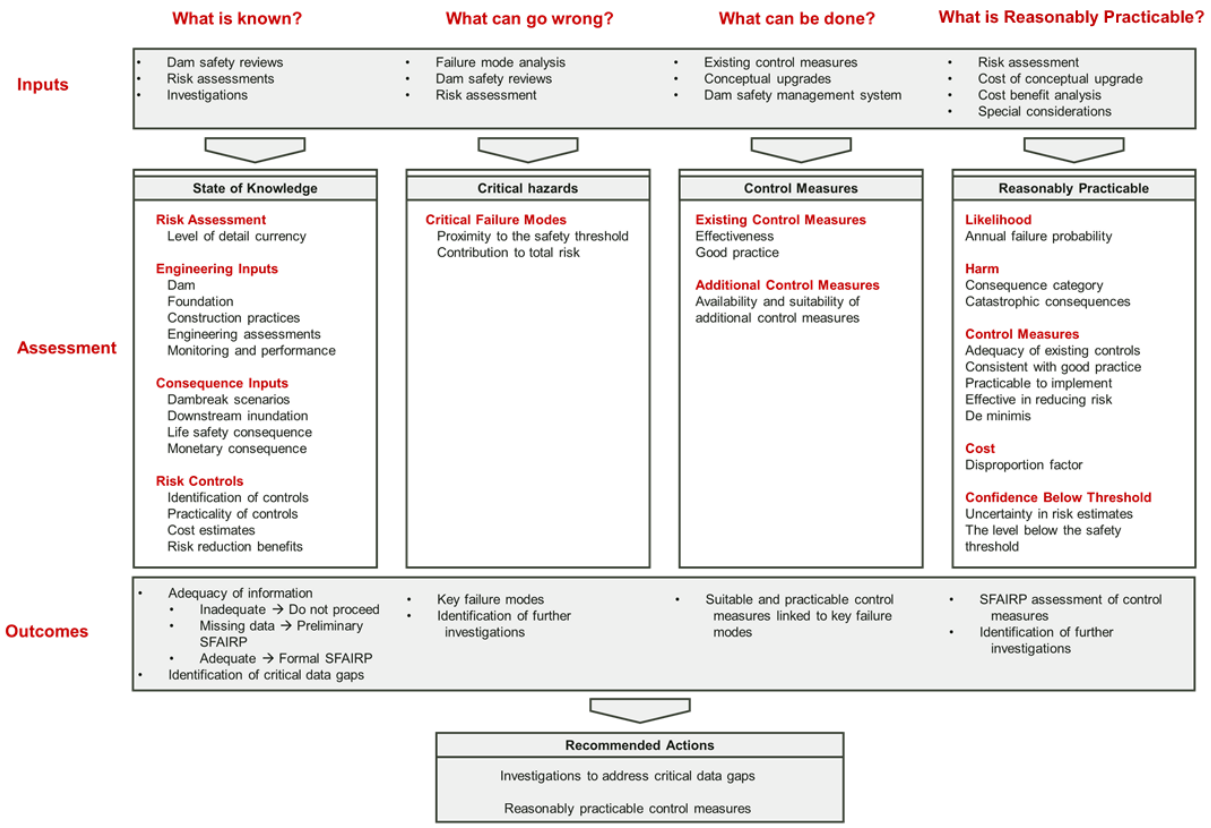
DIAGRAM 6 – DIAGRAMMATIC SUMMARY OF THE ASSESSMENT PROCESS FOR IDENTIFYING CONTROL MEASURES TO MEET ALARP (SFAIRP) PRINCIPLES



11.2 State of Knowledge and Data Gaps

Based on the currently available information and records, it is considered that adequate and sufficiently detailed data have been incorporated into the risk assessment, engineering analyses, and consequence evaluations. While some uncertainties remain with respect to the future construction practices, these are assessed as insignificant, as the risk assessment has been informed by the proposed technical specifications and historical construction methodologies adopted during earlier stages.

Furthermore, uncertainties are identified during the FMEA workshop and documented as 'Adverse Factors' in the corresponding spreadsheet to facilitate regular review and ensure they receive appropriate attention throughout the construction phase.

11.3 Critical Hazards

The critical failure modes are those that contribute most to the current risk plotting position of the dam. The only credible failure mode contributing to the Dugald River TSF Stage 3 life safety risks is "Overtopping due to instability of the downstream slope, causing slumping and loss of freeboard", as presented in **Table 20**.

TABLE 20 – STAGE 3 TSF CRITICAL HAZARDS

Identified Critical Hazard	Annual Probability of Failure	Societal Risk Value	Individual Risk Value
DR TSF-Emb-SS-6	5.50E-08	5.16E-09	1.03E-09

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11.4 Existing And Identified Additional Control Measures

11.4.1 Assessment of Existing Control Measures

A series of control measures is in place to ensure the safety and integrity of the dam and its surrounding environment. The existing control measures demonstrate a comprehensive and diligent approach to managing dam safety risks.

The key existing control measures that effectively mitigate dam safety risks related to the single identified critical hazard (slope instability) are:

1. **Design Meets or Exceeds Industry-Standards**:

   A comprehensive slope stability assessment has been carried out for the Stage 3 Embankment in accordance with industry standards. The stability assessment adopts conservative loading conditions (including elevated phreatic surface levels and pore water conditions) and conservative material parameters.

   The results of the stability assessments indicate that the achieved FoS exceed the ANCOLD guidelines. The embankment design also meets current best practice guidelines (GISTM).

2. **Embankment Construction Materials:**

   The embankments are to be constructed from coarse rockfill and lined on the upstream face with BGM Liner.

   In a scenario where slope instability occurs and overtopping of the dam commences, the coarse rockfill materials and the presence of the BGM liner provide erosion protection of the downstream face to protect against further lowering of the crest.

   However, this feature does not directly address the risk of slope stability-induced overtopping. While the materials used to construct the embankment may reduce the severity of erosion should slope stability-induced overtopping occur, they provide no capacity to prevent the slope instability and overtopping itself. As such, the embankment makeup and geometry should be considered a secondary or consequence-mitigating feature rather than an effective control for managing slope instability/overtopping risk.

3. **Construction Supervision:**

   The Stage 3 Embankment will be constructed under full-time supervision from a qualified geotechnical engineer. As part of the supervision, a quality assurance plan will be in place with appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications and that the foundation and material selection are fit for purpose.

   However, while essential for overall dam reliability, the construction program does not directly mitigate the risk of slope instability-induced overtopping occurring during operations. It has limited influence on embankment loading, storage capacity, and water level management, and therefore offers limited effectiveness as a control for managing slope instability/overtopping risk.

4. **Maintenance Activities**:

   A systematic and well-defined maintenance program is currently followed to conduct regular maintenance activities on critical dam components for the Stage 2 Embankment. This proactive approach addresses wear and tear, corrosion, and potential vulnerabilities, ensuring that the dam remains in optimal condition and reducing the risk of unexpected failures. In addition, the maintenance program aims to address the gaps identified in annual surveillance. An equivalent standard of the maintenance program will be implemented for the Stage 3 Embankment.

   However, while essential for overall dam reliability, the maintenance program does not directly mitigate the risk of slope instability-induced overtopping. It has limited influence on embankment loading, storage capacity, and water level management, and therefore offers limited effectiveness as a control for managing slope instability/overtopping risk.

5. **Operation and Maintenance Plan:**

   An Operation and Maintenance Plan (O&M) is in place to guide day-to-day operations and upkeep procedures for the Stage 2 Embankment. This plan outlines the best practices for

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routine maintenance, response protocols for abnormalities, and emergency procedures, ensuring efficient risk management and incident handling. An equivalent standard of the Operation and Maintenance Plan will be implemented for the Stage 3 Embankment.

However, while the O&M Plan plays a critical role in maintaining operational discipline and facilitating early intervention for emerging issues, it does not directly address the risk of slope instability/overtopping and therefore offers limited effectiveness as a standalone control for this failure mode.

6. **Operational Trigger Action Response Plans:**

   TARPs will halt operational activities and water inflow if any anomalies are identified. These plans serve as proactive measures to promptly address unforeseen or abnormal conditions. By establishing specific criteria for anomalies and delineating the appropriate responses, operational TARPs provide a structured approach to ensure the safety and integrity of the facility. Identifying anomalies triggers a swift and systematic response, allowing for the immediate cessation of operations to prevent potential risks or hazards.

   Consistent with the other administrative control measures described above, this existing measure provides limited effectiveness as a standalone control for managing slope instability/overtopping risk.

7. **Emergency Plan:**

   An Emergency Plan is developed and implemented to effectively manage and respond to potential emergencies or hazardous situations. The plan incorporates clear communication channels, evacuation procedures, containment strategies, and emergency response coordination to mitigate risks and protect nearby communities and the environment.

   Consistent with the other administrative control measures described above, this existing measure provides limited effectiveness as a standalone control for managing slope instability/overtopping risk.

8. **Design and Investigation Documents**:

   Design and investigation documents describe the engineering evaluations conducted during the planning and construction phases. These documents provide essential insights for the continued safe operation and management of the dam.

   However, similar to other administrative controls, these documents do not directly mitigate the risk of slope instability/overtopping.

9. **Construction Report and Records**

   Detailed construction reports and records are retained. However, similar to other administrative controls, these documents do not directly mitigate the risk of slope instability/overtopping.

Overall, reliable and effective risk control measures and multiple lines of defence are already in place (or will be in place following construction) to control the hazard. The level of existing control measures is consistent with good industry practice.

Whilst there are practical and effective additional control measures available to manage the risk of the critical hazard (described in the following Section of this report), the opportunities to improve controls for the identified critical hazard are determined to be **Weak** in accordance with the ALARP/SFAIRP framework outlined in **[20]**.

11.4.2 Identification of Additional Controls (Risk Mitigation Options)

The potential additional control measures (Risk Mitigation Options) to mitigate the risks associated with the critical hazard have been identified and evaluated as part of the ALARP assessment process. The following proposed measures are specifically designed to address and reduce the risks linked to the identified critical hazard (downstream slope instability):

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11.4.2.1 Risk Mitigation Option 1: Placement of Surplus Excavation Material along the Downstream Face

The controlled placement of surplus excavation material along the downstream toe, won from the spillway and access road construction, will contribute to overall embankment stability by providing additional buttressing at the downstream toe.

The implementation of this measure is available, suitable, and practicable, as it involves the utilisation of materials already available from site excavations, and can be integrated into the Stage 3 construction programme.

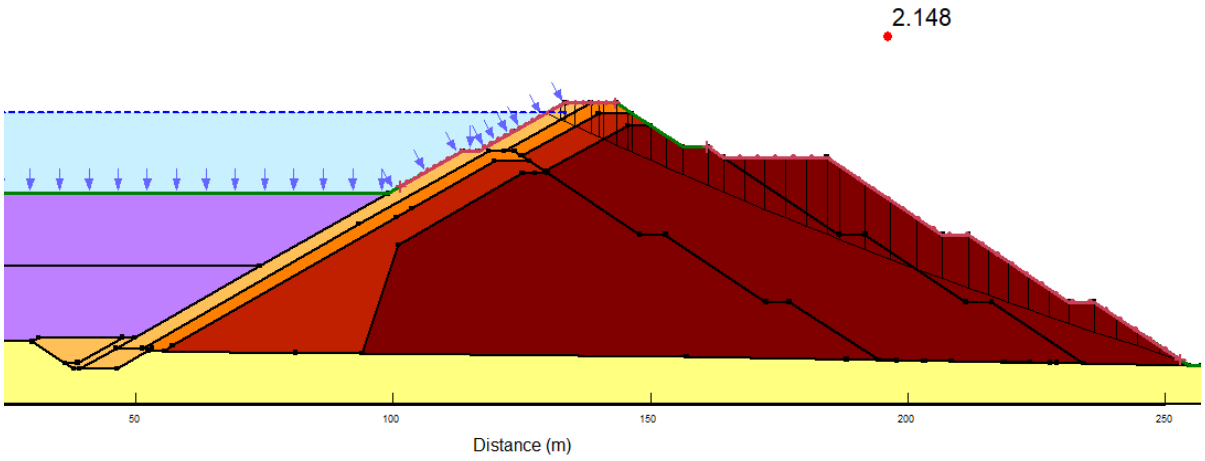
Implementation of this additional control measure has been assessed to increase the Factor of Safety (FoS) for slope stability, increasing it from 1.74 to 2.15 as shown in **Diagram 7** for the maximum flood partition. Similar magnitudes of increases to the FoS apply to the remaining flood partitions.

However, this measure is expected to have a negligible effect on the annual probability of failure (less than one order of magnitude). Consequently, this measure is estimated to result in a negligible improvement in overall societal risk (less than one order of magnitude).

This negligible improvement is attributed to the fact that the annual failure probabilities for slope instability already reflect extremely low values (refer to **Section 7.2.2**) at the lower flood partitions. As a result, increasing the factor of safety does not further reduce the annual failure probability. Given the available dataset, this assumption is considered suitably conservative.

Overall, this measure is assessed to result in a **negligible improvement** to the overall risk profile.

DIAGRAM 7 – CRITICAL SLIP SURFACE AFTER BUTTRESSING WITH SURPLUS EXCAVATION MATERIAL



11.4.2.2 Risk Mitigation Option 2: Increase the Height of the Proposed Little Eva Pit Flood Protection Levee

Increasing the height of the Little Eva Pit Flood Protection Levee would prevent overtopping of the Levee in a dam break situation and, hence, eliminate the contribution of the Harmony personnel working within the Little Eva Pit from the Life Loss estimates.

The implementation of this measure is available, suitable, and practicable. However, implementation of this measure may be complex, as the proposed flood protection levee is a third-party asset, and the design, construction, operations, and maintenance of the asset is to be managed by Harmony.

This risk mitigation measure will not influence the annual probability of failure, but is assessed to decrease the overall societal risk to approximately 2.37E-09 (after discounting the contribution from the Harmony personnel). This represents an improvement **of less than one order of magnitude**.

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11.4.3 Summary Outcomes of Assessment of Existing and Identified Control measures

The identified additional control measures have been assessed against the criteria outlined in the ALARP methodology **[1]** and SFAIRP framework **[20]**. The key outcomes of this evaluation are summarised below:

- Reliable and effective risk control measures and multiple lines of defence are already in place to control the hazard. As discussed in **Section 11.4.1**, the opportunities to improve controls for the identified critical hazard are determined to be **Weak**.
- Both proposed measures are engineering controls, meaning they mitigate risk through engineering means rather than administrative processes.
- Both identified controls are assessed as available, suitable, and practicable, in alignment with accepted industry best practice and dam safety engineering standards.
- Neither of the presented options is determined to be *de minimis*.
- Both potential control measures are to be progressed further through the reasonably practicable test.

11.5 Risk Reduction Achieved with Additional Control Measures

Table 21 summarises the estimated level of risk reduction that would be achieved if the additional control measures were implemented. **Graph 5** presents a comparison of the societal risk profile for each mitigation option compared to the base case.

TABLE 21 – STAGE 3 TSF ESTIMATED SOCIETAL RISK – EXISTING AND POST-IMPLEMENTATION OF THE ADDITIONAL CONTROL MEASURES

Risk Mitigation Option	Annual Probability of the Associated Critical Hazard		Total Societal Risks		Comment
	Existing	Post-Additional Control Measures	Existing	Post-Additional Control Measures	
Placement of Surplus Excavation Material along the Downstream Face	5.50E-08	5.50E-08	5.16E-09	5.15E-09	Implementation is expected to result in a negligible change to the overall risk profile. Progress to the reasonable practicable test.
Raise the Little Eva Pit Flood Protection Levee	5.50E-08	5.50E-08	5.16E-09	2.37E-09	Implementation is expected to result in a marginal change to the overall risk profile. Progress to the reasonable practicable test.

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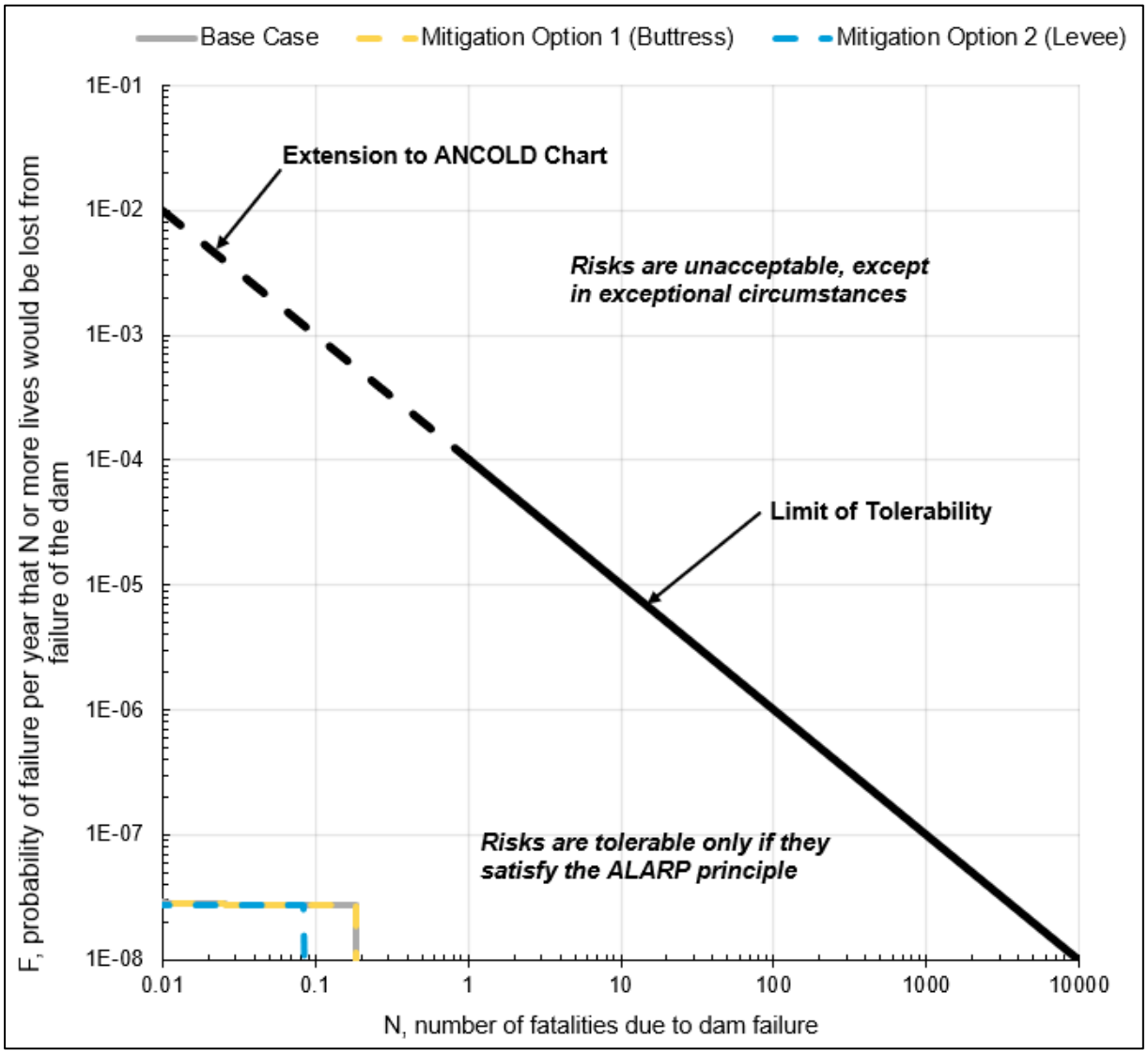
GRAPH 5 – STAGE 3 TSF SOCIETAL RISK PLOT (RISK MITIGATION OPTIONS)



11.6 Cost to Save a Statistical Life (CSSL) and Gross Disproportion Factor

The Cost to Save a Statistical Life (CSSL) and the Gross Disproportion Factor for the proposed risk mitigation options have been estimated in accordance with the methodology outlined in ANCOLD (2022) **[1]**. Furthermore, the disproportion factor (F_D) and the justification rating for the implementation of each option have been determined with reference to Table 8.6 and 8.7 of the ANCOLD 2022 guidelines **[1]**, respectively.

The CSSL estimate has been limited to a qualitative assessment due to ATCW's limited knowledge of the capital and operational costs (and benefits) of implementing the proposed risk mitigation; as well as quantification of the economic, financial, and public safety consequences and/or benefits.

At this stage, all associated costs informing the ALARP assessment are considered order-of-magnitude estimates, derived from professional judgment and relevant historical project experience. Consequently, the estimated CSSL is also classified as an order-of-magnitude estimate. Should the outcomes of the ALARP assessment indicate the need to implement any of the proposed risk mitigation options, more detailed design work and refined cost estimates will be required to support the ALARP assessment.

The achieved risk reduction (denominator in the CSSL) for the proposed risk mitigation options is in the order of 1E-09 (i.e., the difference in societal risk between the base case and the relevant Risk Mitigation Option).

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Therefore, the CSSL is well above the threshold for a "**Poor**" Justification Rating in accordance with Table 8.7 of the ANCOLD 2022 guidelines **[1]** and as summarised in **Table 22**.

TABLE 22 – SUMMARY OF GROSS DISPROPORTION ASSESSMENT

Risk Mitigation Option	CSSL	Gross Disproportion Factor	Justification Rating
Place Surplus Material at Downstream Toe	> 7.7	1.0	**Poor**
Raise the Little Eva Pit Flood Protection Levee	> 7.7	1.0	**Poor**

11.7 Reasonably Practicable Assessment of Risk Mitigation Option

Table 23 summarises the reasonable practicability test outcomes for the proposed additional control measure.

TABLE 23 – REASONABLY PRACTICABLE TEST FOR STAGE 3 TSF ADDITIONAL CONTROL MEASURES

Risk Mitigation Option	Overall Assessment	Justification
Place Surplus Material at Downstream Toe	Not Reasonably Practicable	There is a strong degree of confidence that the dam's risk position plots below the applicable safety threshold. Therefore, the implementation of the additional control measure is deemed "Not Reasonably Practicable" based on the following key considerations: • The overall opportunities to improve controls for the critical hazard are determined to be **Weak** (**Section 11.4.1).** • The mitigation option is anticipated to have a **negligible impact** on the annual failure probability (AFP) and the overall societal risk (**Section 11.5**). • The overall justification rating for the gross disproportion assessment is assessed to be **Poor** (**Section 11.6**).
Raise the Little Eva Pit Flood Protection Levee	Not Reasonably Practicable	There is a strong degree of confidence that the dam's risk position plots below the applicable safety threshold. Therefore, the implementation of the additional control measure is deemed "Not Reasonably Practicable" based on the following key considerations: • The overall opportunities to improve controls for the critical hazard is determined to be **Weak** (**Section 11.4.1).** • The annual failure probability (AFP) is **not anticipated to improve** following the implementation of the risk mitigation option. (**Section 11.5**). • The overall improvements to the societal risk following the implementation of the risk mitigation option are estimated to be **less than one order of magnitude** (**Section 11.5**). • The overall justification rating for the gross disproportion assessment is assessed to be **Poor** (**Section 11.6**).

12 CONCLUSIONS AND RECOMMENDATIONS

The risk assessment and ALARP assessment outcomes indicate that the Stage 3 TSF societal risk profile is lower than the ANCOLD limit of tolerability for major augmentations **[1]** to an extent which ATCW consider to be "ALARP".

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ATCW consider that neither of the risk reduction mitigation measures are considered reasonable nor practicable and hence neither are recommended for implementation.

Nevertheless, it is noted that the determination on whether the ALARP principle is satisfied is a matter for judgement by MMG.

Notwithstanding, the following recommendations are made to effectively monitor and manage the risks and enhance the dam safety management system:

- Regularly update the dam safety plans, including the Operation and Maintenance Plan and the Dam Safety Emergency Plan.
- Regularly review and update the surveillance program based on the recommendations made in the ANCOLD Guidelines on Dam Safety Management System **[21]**. This ensures early detection of any potential issues or anomalies.
- Reassess the credibility of the identified potential failure modes if any modifications are made to the design or proposed operational status. Similarly, any identification of poor construction practices or deviations from specifications post-construction requires an immediate review of the failure modes to ensure the continued integrity and safety of the dam structure.
- Review the risk assessment outcomes if there are material changes to the assumed downstream conditions, such as the structure and alignment of the Little Eva Pit Flood Protection Levee and/or the number of Harmony personnel expected to be working within the Little Eva Pit.
- Ensure that the dam operations and management staff receive appropriate training and have the necessary skills to carry out the operation and maintenance tasks or to respond effectively to various scenarios in an emergency.

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APPENDICES

APPENDIX A – SYSTEM IDENTIFICATION

ID	Component	Sub-Component	Primary Function	Secondary Function	Details
SUB-SYSTEM 1		**Main Embankment**			
1.1	Dam Crest		Provides access to survey monuments , spillway, and BGM Liner anchor		Crest Level = RL 253.5 m (Stage 3 Design) Crest Width = 10 m Embankment height (Max) = 47.5 m Crest Length = 292 m
1.2	Embankment fill		Structural stability, tailings confinement		Zoned rockfill embankment with BGM liner protection along the US face Spec: Fill material shall meet the specification for each of the following material zones: • Zone 2B (BGM Support Layer) - Clayey GRAVEL (with Sand); Silty, Clayey GRAVEL (with Sand); Poorly Graded GRAVEL with clay - Atterberg Limits must plot on or above the 'A' line - Max particle size of 50 mm • Zone 2C (Granular Filter Material) - Poorly Grade GRAVEL with Clay, Silt or Sand (and Cobbbles); Clayey GRAVEL or Silty GRAVEL with Sand (and Cobbles); Poorly Grade Sandy GRAVEL (with Cobbles) - Max particle size of 150 mm • Zone 3A (Transition Rockfill) - HW-SW rock, well graded and consist of clean, hard and durable particles - max particle size of 400 mm • Zone 3B (General Rockfill) - HW-SW rock, well graded and consist of clean, hard and durable particles - max particle size of 800 mm • Zone 3C (Rockfill Drain) - SW-FR rock - max particle size of 600 mm
1.3	Upstream & Downstream Batter		Structural stability		US 1.75H : 1V with a 3m bench DS 1.5H : 1V with 5m benches
1.4	Upstream & Downstream protection		Erosion Protection		Embankment constructed with rockfill not prone to surface erosion
1.5	Foundation		Structural support		Foundation to be cleared and stripped of all surface soils and loose, fractures, weathered rock. Final preparation shall consist of the removal of loose soil or rock, or water softened material, by machine excavation.
1.6	Foundation Grouting		Seepage interception		Upstream reinforced concrete toe plinth constructed along a upstream toe of the embankment. Dowelled into rock. Foundation grouting at regular intervals along the length of the plinth to a minimum depth of 6 m and a total interception depth of the order of 10 m. Extension of toe plinth and foundation grouting is proposed for the Stage 3 raise.
1.7	Decant Pond				The decant pond forms at the western end of the facility against the Main Embankment. Due to recent heavy rainfalls, the decant pond has been extensive and has covered the majority of the tailings beach in recent years.
SUB-SYSTEM 2		**Northern Discharge Bund**			
2.1	Dam Crest		Provides access to discharge pipelines		Crest Level = RL 253.5 m (Design) Crest Width = 5 m Embankment height (Max) = 9.5 m Crest Length = 73 m

2.2	Embankment fill		Structural stability, tailings confinement		Zoned rockfill embankment with surface rip-rap protection along the upstream face Spec: Fill material shall meet the specification: • Zone 2B (BGM Support Layer) - Clayey GRAVEL (with Sand); Silty, Clayey GRAVEL (with Sand); Poorly Graded GRAVEL with clay - Atterberg Limits must plot on or above the 'A' line - Max particle size of 50 mm • Zone 3A (Transition Rockfill) - HW-SW rock, well graded and consist of clean, hard and durable particles - max particle size of 400 mm
2.3	Upstream & Downstream Batter		Structural stability		US 2H : 1V DS 2H : 1V
2.4	Upstream & Downstream protection		Erosion Protection		Embankment constructed with rockfill not prone to surface erosion
2.5	Foundation		Structural support		Foundation to be cleared and stripped of all surface soils and loose, fractures, weathered rock. Final preparation shall consist of the removal of loose soil or rock, or water softened material, by machine excavation.
2.6	Decant Pond				Decant pond typically forms away from the Northern Discharge Bund
SUB-SYSTEM 3	**Emergency Spillway**				
3	Emergency overflow structure		Safe passage of excess decant and flood water		Stage 3 Spillway designed for PMF event Invert level= RL 251.35 m Base width= 50m. Batter slopes vary due to rock quality
Other SUB-SYSTEM					
4	Decant and Return Water System		Safe passage of excess decant		The primary Return Water System (RWS) infrastructure comprises: 1. Decant Pump Station: Single end-suction centrifugal water pump with variable speed drive motor. Capable of a maximum output of 90 m3 /hr at 6.5 m of suction head. 72 m long floating suction provides feed water to the Decant Pump. Suction line comprised of 6 sections of HDPE pipeline supported by pipe floats. 2. Discharge Pipeline: Comprises a 150 m long, HDPE pipeline linking the Decant Pump Station to the Booster Pump Station 3. Booster Pump Station: Single end-suction centrifugal water pump in fixed speed configuration. Located above the TSF final filling level 4. Return Water Pipeline - Approximately 5.3 km of HDPE running from Booster Pump Station to Process Plant.
5	Drainage and Seepage Collection System		Maintaining a facility with minimal water		Stage 3: Decommission existing seepage collection pond. New seepage collection system will comprise extension of the existing rockfill seepage collection drain in the base of the foundation which discharges into a seepage monitoring sump. The sump will be a circular concrete soak well installed in a rock-filled interception trench. The downstream side of the trench will be lined with an impermeable geosynthetic.
6	Tailing Delivery System		Tailings deposition		Tailings deposition is rotated between the northern and southern discharge points, as required to maintain a centralised decant pond
7	Impoundment Area				

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APPENDIX B – HAZARD SCREENING

Failure Initiating Events	Screening Criteria	Comments
Aircraft Impact	1. The event is of equal or lesser damage potential than the events for which the dam is designed. The design significantly exceeds the requirement.	The impact of a large aircraft is conceivable but is extremely unlikely except in areas of high air traffic (for example, approach to a major airport) This structure is approximately 60km from Cloncurry airport. So a regional plane of up to 50 passengers could impact the dam. Significantly less likely event than natural events that would also cause a dam failure.
Avalanche	6. Not an initiator.	No hills or mountains around the storage and dam that are snow covered.
Barometric pressure in regard to seiche effects	6. Not an initiator.	Barometric pressure in regard to seiche effects for large reservoirs can be a hazard. This structure does not maintain a large scale lake.
Chemical Reaction	5. The event is judged to have an insignificant effect on the dam.	The chemical composition of the stored tailings and water will have an insignificant impact on the integrity of the embankment.
Earthquakes (seismic)	**POTENTIAL INITIATING EVENT**	Seismic loading-induced liquefaction, impact on the embankment (crack), and foundation liquefaction should be assessed
Fire	**POTENTIAL INITIATING EVENT**	Bush fires at the abutments may transition to the BGM Liner, resulting in a loss of water storage capabilities and potential erosion or slope instability
Floods	**POTENTIAL INITIATING EVENT**	Flood overtopping of dam crest and erosion of embankment and toe Pore pressures cause embankment instability, slope failure and loss of freeboard Embankment settlement cracking leading to internal erosion Internal erosion through defects and high permeability zones Spillway erosion could happen during the flood
Ground vibration	1. The event is of equal or lesser damage potential than the events for which the dam is designed. The design significantly exceeds the requirement.	Adjacent mine blasting may induce vibrations at the TSF, however the dam is designed for vibrations from very rare seismic events which would significantly exceed ground vibrations from blasting.
Hail	5. The event is judged to have an insignificant effect on the dam.	No critical flow control equipment involved in dam operation that could be affected by hail.
Inadequacy of maintenance (i.e., unwanted vegetation, tree roots, animal burrows, surface erosion,…)	4. The event is included in the definition of other event(s).	Inadequacy of maintenance could result in the development of defects leading to internal erosion and slope stability failure which has already been considered in other failure initiation events (Flood, Earthquake and stored water).
Intrinsic Deficiencies	4. The event is included in the definition of other event(s).	E.g. construction defects or not constructed to design standards, material deterioration, or change of material characteristics leading to internal erosion and slope stability failure which has already been considered in other failure initiation events(Flood, Earthquake and stored water).
Lightning strike	5. The event is judged to have an insignificant effect on the dam.	Lightning strike, particularly in regards to its effect on vital operating, control or monitoring equipment, is conceivable. This event will not have dam safety risk and just impose operational risk.
Meteor Strike	6. Not an initiator.	Not an initiator. Significantly less likely event than other natural events that would also cause a dam failure.
Operator Access	4. The event is included in the definition of other event(s).	The inability of operators to get to the dam during critical times. This is integrated to the event trees (developed for FM initiated from

		flood, earthquake and stored water) allowing a node for unsuccessful intervention.
Operator error	4. The event is included in the definition of other event(s).	Failure to operate the RWS appropriately could result in higher operational decant pond prior to flooding increasing the chance of flood risks. Not rotating the discharge spigots could raise the water level in an isolated section, overfilling also covered in flood and stability risks.
Pore Pressures (Dam Wall)	4. The event is included in the definition of other event(s).	Included in flood and earthquake loadings and during the normal operations in the context of the intrinsic deficiencies.
Pore Pressures (Foundations)	4. The event is included in the definition of other event(s).	Included in flood and earthquake loadings and during the normal operations in the context of the intrinsic deficiencies.
Reservoir Level Fluctuations	4. The event is included in the definition of other event(s).	Included in flood and earthquake loadings and during the normal operations in the context of the intrinsic deficiencies.
Reservoir rim landslide	1. The event is of equal or lesser damage potential than the events for which the dam is designed. The design significantly exceeds the requirement.	Reservoir rim landslide is conceivable given that the TSF is bounded by the Knapdale Valley Range, however the topography along the impoundment rim is relatively gentle and and land slide would not result in inflow volumes greater than the design designed (e.g. 1 in 10,000 flood inflows).
Security breaches	5. The event is judged to have an insignificant effect on the dam.	Not meant to be accessed by the public, and located in a remote location. However, access by unauthorised people is possible. The ability to cause dam safety issues is limited, however operational issues mainly with return water or tailings spills could be caused.
Stored Water in normal operation	**POTENTIAL INITIATING EVENT**	The stored water is itself a hazard, given that the dam is an imperfect container (hence the need to consider failure modes under normal operating conditions)
Temperature	4. The event is included in the definition of other event(s).	The high or low temperature could result in the development of defects leading to internal erosion and slope stability failure which has already been considered in other failure initiation events.
Terrorism	NOT ASSESSED	Terrorism is conceivable (but usually excluded from dam safety risk assessment studies)- ANCOLD 2022
Toxic Gas	6. Not an initiator.	Not expected to cause dam failure.
Transportation Accident	6. Not an initiator.	Not expected to cause dam failure.
Tsunami	6. Not an initiator.	Tsunami is conceivable for some low dams in coastal areas, not applicable to this site
Upstream dams	6. Not an initiator.	No dams upstream of the TSF.
Upstream natural landslide	3. The event cannot occur close enough to the dam to affect it.	No upstream landslide potential
Vandalism	1. The event is of equal or lesser damage potential than the events for which the dam is designed. The design significantly exceeds the requirement.	Vandalism is conceivable and is usually sufficiently likely to require analysis. However, it is not expected as the structure is not meant to be accessed by public, and is located in a remote location. Damage due to vandalism would not be expected to result in dam failure
Volcanic Activity	3. The event cannot occur close enough to the dam to affect it.	No hazardous volcanic activity close enough to the dam to effect it.
War	NOT ASSESSED	Act of war is conceivable (but usually excluded from dam safety risk assessment studies)
Wind	**POTENTIAL INITIATING EVENT**	Wind, particularly set-up and seiche effects, needs to be considered. This will be combined with flood effects in overtopping failure Modes

APPENDIX C – POTENTIAL FAILURE MODE CREDIBILITY ASSESSMENT

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#	FM ID	Broad FM	Failure Mode	Component	Initiating Event	Potential Mechanism & Pathway	Effect		Class of the Failure	Expected Consequence of Failure			Failure Detection	Existing Controls	Actions	Adverse Factors	Assessment (Life Safety risks are just considered)	Comments (Acceptance or Rejection Reason)
							Primary	Secondary		Life Safety	Environmental	Operation/Business						
Overtopping (OT)																		
1	DR TSF-Emb-OT-1	Overtopping	Overtopping erosion due to insufficient installed flood capacity	Main Embankment	Flood	A flood event which exceeds the spillway capacity; due to inadequate design; results in the overtopping of the embankment crest. The force of the overtopping flow erodes the embankment material, creating scour holes or channels along the embankment slope and downstream areas. Then headcut erosion initiates. Continued erosion and scouring compromise the stability and integrity of the embankment structure, reducing its load-bearing capacity and resulting in a breach formation allowing the uncontrolled release of containment. The intervention will fail due to the site flood situation.	Erosion of the crest	Loss of freeboard and overtopping	Full Dam Breach	Yes	Yes	Yes	Storm data and flood warning monitoring from Bureau of meteorology	- The storage capacity and freeboard is designed to contain extreme floods up to the PMF (Stage 3 Design Report). - The hydrology assessments consider a conservative assumption of an initial water level at the spillway invert level (Stage 3 Design Report) - The hydrology assessments account for increases to the design rainfall as a result of climate change (Stage 3 Design Report)	- Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and decant pond that allows early detection of low points and mitigation of any initiated crest erosion - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Construct the embankment with free draining coarse rockfill, which adds erosion resistance to the downstream face (Engineering judgement)	- No scour assessment of the downstream rockfill face has been conducted - Intervention during a flood event would be difficult/impossible	Not Credible	Spillway capacity is designed to pass floods up to the PMF, as well as the 1:100,000 AEP + 1:10 AEP wind wave run-up, thus conforming to ANCOLD, DESI and GISTM requirements for a 'High' Consequence Category Dam. Climate change influences have also been considered in the design in accordance with guidance provided by Australian Rainfall and Runoff. Furthermore, the flood routing has conservatively considered the initial storage level at spillway invert. This PFM is therefore assessed as Not Credible for the Main Embankment
2	DR TSF-Emb-OT-2	Overtopping	Overtopping erosion due to insufficient available flood capacity due to the spillway blockage	Main Embankment	Flood	A flood event which exceeds the spillway capacity, due to full or partial blockage; results in the overtopping of the embankment crest. The force of the overtopping flow erodes the embankment material, creating scour holes or channels along the embankment slope and downstream areas. Then headcut erosion initiates. Continued erosion and scouring compromise the stability and integrity of the embankment structure, reducing its load-bearing capacity and resulting in a breach formation allowing the uncontrolled release of containment. The intervention will fail due to the site flood situation.	Erosion of the crest	Loss of freeboard and overtopping	Full Dam Breach	Yes	Yes	Yes	Routine inspection of spillway for blockages and obstructions	- The storage capacity and freeboard is designed to contain extreme floods up to the PMF (Stage 3 Design Report). - The hydrology assessments consider a conservative assumption of an initial water level at the spillway invert level (Stage 3 Design Report) - The hydrology assessments account for increases to the design rainfall as a result of climate change (Stage 3 Design Report)	- Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and decant pond that allows early detection of low points and mitigation of any initiated crest erosion and/or spillway blockage - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Construct the embankment with free draining coarse rockfill, which adds erosion resistance to the downstream face (Engineering judgement)	- No scour assessment of the downstream rockfill face has been conducted - Intervention during a flood event would be difficult/impossible	Not Credible	A blockage scenario would reduce the flood capacity of the spillway, thus resulting in potential overflow during more frequent flood events than the PMF. Hydrology studies have been carried out to assess the performance of the spillway under a 50% blockage scenario. The outcomes of the assessment indicate that the Stage 3 emergency spillway is capable of passing all events up to and including the 1:100,000 AEP flood in the case of a 50% blockage. The outcomes indicate that under a PMP flood, overtopping will occur in the case of a 50% blockage. The overtopping would be limited to approximately 30 mm depth above the embankment crest at the peak of the flood. The probability of a spillway blockage occuring; combined with the probability of the decant pond starting at the spillway invert; combined with the probability of the PMP flood (nominally 1 in 10,000,000 AEP) is considered to be negligible. Therefore, this PFM has been excluded due to negligible probability.
3	DR TSF-Emb-OT-3	Overtopping	Overtopping erosion due to insufficient available flood capacity due to wind induced wave effects	Main Embankment	Flood/Wind	Reservoir level rises during extreme storm events; this raised level correlated with the wave action results in progressive erosion and overtopping of the embankment crest. The erosion extends to the downstream edge of the crest and initiates erosion of the crest, loss of freeboard and erosion of the downstream slope forming the full breach. The intervention will fail due to inability of site personnel to access the embankment due to access restrictions during a flood.	Erosion of the crest	Loss of freeboard and overtopping	Full Dam Breach	Yes	Yes	Yes	Storm and wind data and warnings monitoring from Bureau of meteorology Routine monitoring of decant pond level	- The storage capacity and freeboard is designed to contain extreme floods up to the PMF, as well as the 1:100,000 AEP flood plus the wave run-up from the 1:10 AEP wind event (Stage 3 Design Report) - The hydrology assessments consider a conservative assumption of an initial water level at the spillway invert level (Stage 3 Design Report) - The hydrology assessments account for increases to the design rainfall as a result of climate change (Stage 3 Design Report) - Wave run-up estimates based on latest available wind data from the Bureau of Meteorology (Stage 3 Design Report)	- Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and decant pond that allows early detection of low points and mitigation of any initiated crest erosion - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Construct the embankment with free draining coarse rockfill, which adds erosion resistance to the downstream face (Engineering judgement)	- No scour assessment of the downstream rockfill face has been conducted - Intervention during a flood event would be difficult/impossible	Not Credible	The wave run-up is estimated to be ~0.8m for the 1 in 10 AEP wind event. Under normal operations when the storage level is maintained at or below the MRL of RL 249.55 m, there is 1.8 m dry freeboard available to the spillway invert. This PFM is therefore assessed to be Not Credible during normal operations. The spillway is designed to pass the 1:100,000 AEP flood + 1:10 AEP wind wave run-up, assuming an initial water level at spillway invert. The probability of a flood event exceeding the 1:100,000 AEP threshold occuring concurrently with wind conditions surpassing the 1:10 AEP threshold The probability of a flood event occuring which exceeds the 1:100,000 AEP; combined with the probability of the decant pond starting at the spillway invert; combined with the probability of wind conditions surpassing the 1:10 AEP conditions is negligible. On this basis, this PFM is assessed to be Not Credible and excluded from the risk assessment due to negligible likelihood.
4	DR TSF-Spill-OT-4	Overtopping	Partial breach due to progressive headcut erosion at the spillway	Emergency Spillway	Flood	The spillway operates during flood events. The process of progressive scour initiates at the spillway sill and chute, primarily due to the erosion of the riprap and protective layers. This erosion progress towards the spillway crest leading to lowering of the spillway crest. In situations of severe flooding, any intervention attempts are likely to be unsuccessful. The erosion continues its progression, potentially resulting in a partial breach of storage capacity and a loss of containment.	Erosion of the spillway chute	Loss of freeboard and partial breach	Partial breach	Yes	Yes	Yes	Storm data from Bureau of meteorology Localised erosion of the spillway chute could be identified during the routine inspections.	- The Stage 3 spillway is designed to be constructed within a competent rock base (Stage 3 Design Report)	- Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the emergency spillway that allows early detection and mitigation of any initiated spillway erosion - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Construct the spillway through competent rock in accordance with specifications and with appropriate QA/QC procedures and full-time construction supervision	- No scour/erodibility assessment of the spillway has been conducted	Not Credible	The Stage 3 spillway will be excavated to a competent rock base. This material is not considered to be prone to large scale erosion in the case of a spill. If scour occurs along the spillway rock chute, it is not expected to be significant enough to substantially lower the spillway invert. Any minor reduction in the spillway invert would result in only a partial breach with limited consequences. This PFM is assessed to be not credible and excluded from the risk assessment due to the negligible likelihood and minor consequences.
5	DR TSF-Emb-OT-5	Overtopping	Overtopping erosion due to failure of the Return Water system	Main Embankment	Normal, Flood	Return Water System functionality could be compromised due to the inadequate design or the failure of components (intake, pipe and outlet) resulting in restricted hydraulic capacity or partial/full blockage. This can happen in normal operation or flood events, resulting in elevating the ponded water against the embankment, unwanted spill, or overtopping of the embankment crest during a flood.	Elevated pond or Erosion of the crest in flood	Unwanted release or Loss of freeboard and overtopping	Full Dam Breach	Yes	Yes	Yes	Routine inspection of the Return Water System Storm data and flood warning monitoring from Bureau of meteorology	- The Stage 3 spillway has been designed to pass the PMF, assuming an initial water level at spillway invert (Stage 3 Design Report) - The hydrology assessments account for increases to the design rainfall as a result of climate change (Stage 3 Design Report) - The spillway has been designed independent from the RWS (Stage 3 Design Report)	- Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the RWS that allows early detection and mitigation of the risk of RWS failure - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Maintain, exercise and review a site specific water management plan.	- Failure of the RWS may result in elevated reservoir levels	Not Credible	Under normal operations (i.e. sunny day), the failure of the decant system is expected to be detected through observation of elevated ponding against the embankments and/or throughput data to the Process Plant. Additionally, the spillway could redirect the elevated ponded water until the issue is resolved or the excess water is pumped out. The spillway has been designed assuming an initial water level at spillway invert, with no reliance on the Return Water System. The spillway has been designed for the maximum conceivable flood event (i.e., PMF) and considers potential impacts due to climate change. As such, the failure of the RWS is not expected to impact on the flood capacity of the spillway and hence not result in overtopping. Therefore, this PFM is assessed to be Not Credible
11	DR TSF-Emb-OT-11	Overtopping	Overtopping erosion due to long term deformation of embankment and loss of freeboard	Main Embankment	Normal, Flood	Loading is applied to the dam due to the impoundment of water, creating stress within the dam structure. Over time, the dam materials may undergo long-term deformation processes such as consolidation and creep. Where the deformation is more than available freeboard, embankment would be overtopped under normal operations (where the water is ponding against the embankment) or flood events compromising the overall stability of the dam. Ineffective surveillance practices or insufficient maintenance may lead to the oversight of low points on the crest, preventing successful intervention. Embankment breaches primarily caused by overtopping.	Erosion of the crest	Loss of freeboard and overtopping	Full Dam Breach	Yes	Yes	Yes	-Visible pond level and loss of freeboard. Regular surveys of the embankment crest should be analysed for trends, anomalies, or sudden changes that could indicate downstream slope instability or long term deformations. -Regular Inspections: Trained personnel visually inspect the dam crest to detect the low points.	- Embankment designed to industry standards and provides for adequate freeboard considering long term deformation of the embankment (Stage 3 Design Report) - The embankment is to be constructed on rock foundations which minimises the expected long term deformation of the structure (Engineering judgement)	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications - Install survey monuments on the embankment and downstream benches and implement a routine monitoring plan to track embankment deformations and for early identification of excessive movements. - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment that allows early detection and mitigation of excessive settlement or deformations - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.	- Numerical modelling of long-term embankment settlements has not been carried out	Not Credible	Nine survey monuments are proposed to be installed along the Stage 3 embankment crest and downstream bench. Under normal operations, the decant pond will not pond against the embankment crest as any elevated ponded waters will discharge via the spillway. The maximum decant pond level under normal operations corresponds to the spillway invert at approximately RL 251.35 m. This requires long-term crest settlements in excess of 2.15 m to cause any overtopping along the embankment crest. The maximum total vertical displacements to date since monitoring began in October 2018 is 75 mm. This is well within design expectations for large Rockfill embankments such as the TSF embankment. A Trigger Action Response Plan (TARP) is in place which requires activation of the Emergency Response Plan for movements in excess of 5 mm/day. The probability that the magnitude of crest settlements that is required to result in loss of freeboard (i.e. 2.15m) is allowed to continue undetected is negligible. Therefore, this PFM is assessed to be not credible under normal operations (Suny Day Failure).
12	DR TSF-Emb-OT-12	Overtopping	Overtopping erosion due to deformation of embankment and loss of freeboard post seismic events	Main Embankment	Earthquake	Significantly large seismic event occurs resulting in the embankment and foundation materials undergoing strain weakening. Embankment undergoes post-seismic deformation. Cumulative static settlement and seismic deformation exceeds crest freeboard. Water/tailings overtops the embankment crest, and flows over the downstream slope. The overtopping flow continues to erode the embankment material, creating scour holes or channels along the embankment slope and downstream areas, and headcut erosion initiates. Continued erosion and scouring compromise the stability and integrity of the embankment structure, reducing its load-bearing capacity. Intervention prove ineffective due to the abrupt and unpredictable nature of this failure mode. Embankment breaches primarily caused by overtopping.	Erosion of the crest	Loss of freeboard and overtopping	Full Dam Breach	Yes	Yes	Yes	Visual Inspection: Cracks: Look for cracks on the dam crest, slopes, and downstream toe. Significant cracking can indicate internal movement and potential instability. Deformation: Observe for any bulging, tilting, or settlement of the dam crest. Seepage: Increased seepage or leakage from the dam can indicate internal damage to water flow paths. Instrumentation Monitoring: Survey monuments: Track vertical settlements of the dam crest to assess overall stability.	- Embankment designed to industry standards and provides for adequate freeboard considering seismic deformation of the embankment (Stage 3 Design Report) - The embankment is to be constructed from rockfill and on rock foundations which are less susceptible to strain weakening (Engineering judgement) - Seismic deformation assessments have been carried out for the Stage 3 Embankment (Stage 3 Design Report)	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications - Install survey monuments on the embankment and downstream benches and implement a routine monitoring plan to track embankment deformations and for early identification of excessive movements. - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment that allows early detection and mitigation of excessive settlement or deformations - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.	- Seismic deformation estimates are limited to empirical estimates only	Not Credible	A detailed slope stability assessment was carried out during the design. The stability assessment considered various scenarios. The results of the stability analysis indicate that the achieved FoS exceed ANCOLD Guidelines. The minimum computed FoS along the upstream face is 2.34 at the end of filling. A post-seismic loading condition was not analysed for the following reasons: 1. Seismic loading is not expected to result in a strength loss of either the embankment or foundation (materials not judged to be susceptible to strain weakening); and 2. The rockfill embankment and rock foundation are judged to not be susceptible to liquefaction. Seismic deformation estimates were carried out using empirical database methods. The estimated settlements following seismic events are 6mm (Swaisgood, 2003) and 14 mm (Pells and Fell, 2003). The available freeboard between the spillway invert and the embankment crest is 2.15m. Therefore, this PFM is assessed to be Not Credible
22	DR TSF-Emb-OT-22	Overtopping	BGM Liner Failure resulting in excessive seepage and displacement of the embankment materials	Main Embankment	Normal, Flood, Earthquake	BGM Liner can fail due to Seam Failure, Puncture or Tear, Aging, UV exposure (if not covered), chemical degradation, or low interface shear strength between the BGM liner and the support layer, leading to slippage or wrinkling. Continued leaking through the damaged BGM liner can cause a sustained and uncontrolled loss of the stored water. The rate of seepage may increase rapidly and the velocity of the flowing water may displace the embankment materials, leading to excessive crest settlements and overtopping erosion.	Excessive seepage from embankment	Overtopping erosion of the crest	Full Dam Breach	Yes	Yes	Yes	- Observation of increased seepage out of the downstream face of the embankment or in the foundation. This may be by visual observation, or by seepage measurement, or more sophisticated methods such as thermal monitoring of the foundation or the downstream slope. - Settlements, deformation and cracking in the embankment or area downstream of the dam. -Regular Inspections: Trained personnel visually inspect the exposed BGM liner for defects, punctures, seam failure etc.	- BGM liner designed to industry standards and supplier requirements (Stage 3 Design Report) - The embankment materials (coarse rockfill) would require a sufficiently high flow velocity in order to dislodge and transport these particles, unlikely to be observed from seepage flows (Engineering judgement)	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment and BGM liner is constructed to the design specifications - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankmentand BGM liner that allows early detection and mitigation of liner failure and excessive seepage - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.	- Defects within the BGM liner will be difficult to repair - No scour/sediment transportation assessment has been conducted for the embankment materials due to seepage flows - Assessment of tensile performance of BGM liner in response to potential settlement of the supporting layer has not been conducted.	Not Credible	The presence of defects presenting within the BGM Liner is credible due to either poor construction practices; improper maintenance; manufacturing defects; and/or degradation. Once defects are present below the water surface, repairs are difficult. Seepage through the BGM liner defect may occur, and minor displacement of the rockfill embankment shell may occur. However, crest settlements in excess of 2.15 m would be required for overtopping to occur (assuming an initial water level at spillway invert). This failure mode would require a combined probability of the following: - The presence of an unidentified and unmitigated defect in the BGM liner; - Seepage flows which have sufficiently high velocities to displace coarse rockfill materials; - Embankment crest settlements in excess of 2.15 m as a result of the displaced rockfill materials; - An initial pond level at the spillway invert at the time of failure; and - Sufficiently high overtopping flows to induce headcut erosion of the coarse rockfill materials. The combined probability of these events is considered to be negligible. This PFM is therefore assessed to be Not Credible due to negligible probability.
23	DR TSF-Emb-OT-23	Overtopping	Sloughing of the embankment upstream face due to wind induced wave effects, resulting in loss of freeboard and overtopping erosion	Main Embankment	Wind	Wave action occurs which results in sloughing/erosion of the embankment upstream face. While BGM provides impermeability, it does not provide mechanical reinforcement. The erosion results in a loss of freeboard and the stored water begins overtopping the embankment crest, causing progressive erosion. The erosion continues until a full breach is formed. Intervention fails due to access restrictions to the crest during high wind events.	Erosion of the crest	Loss of freeboard and overtopping	Full Dam Breach	Yes	Yes	Yes	Wind data from Bureau of meterology Localised erosion of the upstream face could be identified during routine inspections.	- The embankment freeboard has been designed to safely accommodate the 1:100,000 AEP flood plus the wave run-up from the 1:10 AEP wind event (Stage 3 Design Report) - The design nominates a BGM liner to be installed along the embankment upstream face (Stage 3 Design Report)	- Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Establish a comprehensive dam safety management program that includes routine inspections, assessments, and emergency response plans to enable early detection of low points and mitigation of any initiated crest erosion - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and decant pond - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Install the BGM Liner to supplier specifications with appropriate QA/QC procedures and full-time construction supervision - Construct the embankment with free draining coarse rockfill, which adds erosion resistance to the downstream face (Engineering judgement)	- No scour assessment of the upstream rockfill face has been conducted	Not Credible	The embankment is to be constructed from coarse rockfill which is less susceptible to erosion. A BGM liner will also be installed along the upstream face of the embankment which effectively mitigates the potential for upstream erosion. In a scenario in which the BGM liner fails and erosion of the upstream face occurs due to wave action, crest erosion in excess of 2.15 m (depth between crest and spillway invert) would be required for overtopping to occur. The probability of this pathway occuring, in conjunction with the probability of an initial reservoir level at the spillway invert, is negligible. On this basis, this PFM is assessed to be Not Credible and excluded from the risk assessment due to negligible likelihood.
Slope Stability (SS)																		
6	DR TSF-Emb-SS-6	Slope Stability	Overtopping due to instability of the downstream slope causing slumping and loss of freeboard	Main Embankment	Normal, Flood	Reservoir level rises during flood events, or water sits against the embankment during normal operating conditions due to poor operational practices and pond mismanagement. Pore water pressure develops within the embankment. The effective stress reduces within the embankment. A deep-seated sliding occurs, causing loss of freeboard and the release of storage containment. Erosion develops into full breach formation. This process may also occur due to chemical alteration of the embankment materials resulting in reduced shear strength parameters.	Downstream slide	Loss of freeboard and breach	Full Dam Breach	Yes	Yes	Yes	-Visible pond develops and is established for a period of time. Regularly collected data from instrumentation and monitoring systems should be analysed for trends, anomalies, or sudden changes that could indicate downstream slope instability. -Regular Inspections: Trained personnel visually inspect the downstream slope for signs of cracking, erosion, vegetation changes, or unusual surface features.	- A comprehensive stability assessment has been carried out for the Stage 3 embankment in accordance with industry standards (Stage 3 Design Report). - The stability assessments adopt conservative loading conditions, including elevated phreatic surface levels and pore water conditions (Stage 3 Design Report). - The embankment is designed in compliance with industry standards and provides for adequate freeboard (Stage 3 Design Report).	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications - Install survey monuments on the embankment and downstream benches and implement a routine monitoring plan to track embankment deformations and for early identification of excessive movements. - Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment that allows early detection and mitigation of the risk of slope instability - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Maintain, exercise and review a site specific water management plan.	- Geotechnical parameters for the rockfill are based on conservative assumptions. Laboratory testing has not been carried out - Site investigations of the Stage 3 foundation have been limited to test pitting. No rock coring/strength testing has been conducted.	Credible	A detailed slope stability assessment was carried out during the design. The stability assessment considered various scenarios. The results of the stability analysis indicate that the achieved FoS exceed ANCOLD Guidelines. The minimum computed FoS along the upstream face is 2.34 at the end of filling. It is considered that the probability of slope instability occuring is non-negligible, due to unidentified weakness, incorrect materials characterisation, unforeseen loading conditions, and/or poor construction. Therefore, this PFM is assessed to be Credible and included in the risk assessment process.
7	DR TSF-Drg S-SS-7	Slope Stability	Overtopping due to instability of the downstream slope resulting from failure of the seepage collection system	Drainage and Seepage Collection System	Normal, Flood, Earthquake	Failure of the seepage collection system occurs due to blockage from fine materials or blockage of the downstream outlet. Pore water pressure develops within the embankment. The effective stress reduces within the embankment. A deep-seated sliding occurs, causing loss of freeboard and the release of storage containment. Erosion develops into full breach formation.	Downstream slide	Loss of freeboard and breach	Full Dam Breach	Yes	Yes	Yes	- Routine inspections of the seepage collection system, noting seepage rates, colour of seepage, and clarity of seepage. - Routine review of the seepage water pump-back rates from the Seepage Collection Pond to assess for trends, anomalies, or sudden changes that could indicate blockage of the seepage collection system.	- A comprehensive stability assessment has been carried out for the Stage 3 embankment in accordance with industry standards (Stage 3 Design Report). - The stability assessments adopt conservative loading conditions, including elevated phreatic surface levels and pore water conditions (Stage 3 Design Report). - The embankment is designed in compliance with industry standards and provides for adequate freeboard (Stage 3 Design Report). - The embankment is to be constructed with free-draining rockfill, which prevents the development of an elevated phreatic surface within the embankment (Stage 3 Design Report/Technical Specifications) - Seepage collection system is designed to appropriate filter design criteria to prevent blockages/migration of fines (Stage 3 Design Report)	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications - Install survey monuments on the embankment and downstream benches and implement a routine monitoring plan to track embankment deformations and for early identification of excessive movements. - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment that allows early detection of increased seepage rates and mitigation of the risk of failure of the seepage collection system - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Maintain, exercise and review a site specific water management plan.	- The buried seepage collection system prevents easy access/maintenance in the case of blockage from fines	Not Credible	The embankment is constructed from free-draining rockfill. In the case of a blocked/failed seepage collection system, seepage will begin emanating at the toe of the embankment, however due to the free-draining nature a steady state phreatic surface is not expected to develop. . Additionally, the slope stability assessments indicate that even if an elevated phreatic surface were to develop within the embankment (i.e. "liner leak" case), it would have negligible impact on the critical factor of safety. The stability of the embankment is not considered to be sensitive to the performance of the seepage collection system Therefore, this PFM is assessed to be Not Credible.
8	DR TSF-Emb-SS-8	Slope Stability	Overtopping due to instability of the upstream slope causing slumping and loss of freeboard	Main Embankment	Normal, Flood, Earthquake	Reservoir level rises during flood events, or water sits against the embankment during normal operating conditions. Pore water pressure develops within the embankment material underlaying the liner due to the leak from damged liner or failure of seams. The effective stress reduces within the underlaying material. A shallow slide could occur, causing loss of freeboard and the release of storage containment.	Upstream slide	Loss of freeboard and uncontrolled release	Partial Dam Breach	Yes	Yes	Yes	-Visible pond develops and is established for a period of time. Regularly collected data from instrumentation and monitoring systems should be analysed for trends, anomalies, or sudden changes that could indicate downstream slope instability. -Regular Inspections: Trained personnel visually inspect the downstream slope for signs of cracking, erosion, vegetation changes, or unusual surface features.	- A comprehensive stability assessment has been carried out for the Stage 3 embankment in accordance with industry standards (Stage 3 Design Report). - The stability assessments adopt conservative loading conditions, including elevated phreatic surface levels and pore water conditions (Stage 3 Design Report). - The embankment is designed in compliance with industry standards and provides for adequate freeboard (Stage 3 Design Report).	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications - Install survey monuments on the embankment and downstream benches and implement a routine monitoring plan to track embankment deformations and for early identification of excessive movements. - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment that allows early detection and mitigation of the risk of slope instability - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Maintain, exercise and review a site specific water management plan.	- Geotechnical parameters for the rockfill are based on conservative assumptions. Laboratory testing has not been carried out - Site investigations of the Stage 3 foundation have been limited to test pitting. No rock coring/strength testing has been conducted.	Not Credible	A detailed slope stability assessment was carried out during the design. The stability assessment considered various scenarios. The results of the stability analysis indicate that the achieved FoS exceed ANCOLD Guidelines. The minimum computed FoS along the upstream face is 1.62 at the end of construction. However, the critical slip surface represents a shallow failure which will not result in a catastrophic release of containment downstream. A negligible consequence is expected. Therefore, this PFM is excluded from the risk assessments due to the negligible consequences.
9	DR TSF-Emb-BGM-9	Slope Stability	BGM Liner Failure Leading to Seepage and Instability of the Upstream Slope	Main Embankment	Normal, Flood, Earthquake	BGM Liner can fail due to Seam Failure, Puncture or Tear, Aging, UV exposure (if not covered), chemical degradation, or low interface shear strength between the BGM liner and the support layer, leading to slippage or wrinkling. Localised leakage through the damaged BGM liner allows water infiltration into the support layer and saturates the support material resulting in loss of strength and causing slumping and US slope instability. The loss of freeboard may result in the uncontrolled release of containment.	Upstream slide	Loss of freeboard and uncontrolled release	Partial Dam Breach	Yes	Yes	Yes	-Visible pond develops and is established for a period of time. Regularly collected data from instrumentation and monitoring systems should be analysed for trends, anomalies, or sudden changes that could indicate downstream slope instability. -Regular Inspections: Trained personnel visually inspect the downstream slope for signs of cracking, erosion, vegetation changes, or unusual surface features. -Regular Inspections: Trained personnel visually inspect the exposed BGM liner for defects, punctures, seam failure etc.	- A comprehensive stability assessment has been carried out for the Stage 3 embankment in accordance with industry standards (Stage 3 Design Report). - The stability assessments adopt conservative loading conditions, including elevated phreatic surface levels and pore water conditions (Stage 3 Design Report). - The embankment is designed in compliance with industry standards and provides for adequate freeboard (Stage 3 Design Report).	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment and BGM liner is constructed to the design specifications - Install survey monuments on the embankment and downstream benches and implement a routine monitoring plan to track embankment deformations and for early identification of excessive movements. - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankmentand BGM liner that allows early detection and mitigation of liner failure and slope instability - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.	- Defects of the BGM liner below the tailings/water surface are difficult to detect from visual inspections	Not Credible	A detailed slope stability assessment was carried out during the design. The stability assessment considered various scenarios. The results of the stability analysis indicate that the achieved FoS exceed ANCOLD Guidelines. The minimum computed FoS along the upstream face is 1.62 at the end of construction. However, the critical slip surface represents a shallow failure which will not result in a catastrophic release of containment downstream. A negligible consequence is expected. Therefore, this PFM is excluded from the risk assessments due to the negligible consequences.
18	DR TSF-Emb-SS-18	Slope Stability	Overtopping due to instability of the downstream slope resulting from failure of Return Water System component	Main Embankment	Flood, Normal	Return Water System functionality could be compromised due to the inadequate design or the failure of components (intake, pipe and outlet) resulting in restricted hydraulic capacity or partial/full blockage. This can happen during normal operation or flood events, resulting in elevating the ponded water against the embankment causing elevated phreatic surface levels in the embankment.	Downstream slide	Loss of freeboard and breach	Full Dam Breach	Yes	Yes	Yes	Routine inspection of the Return Water System Storm data and flood warning monitoring from Bureau of meteorology	- A comprehensive stability assessment has been carried out for the Stage 3 embankment in accordance with industry standards (Stage 3 Design Report). - The stability assessments adopt conservative loading conditions, including elevated phreatic surface levels and pore water conditions (Stage 3 Design Report)	- Maintain the reservoir level below the MRL and manage the pond to prevent elevated storage levels (in accordance with Operations Manual) - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the RWS that allows early detection and mitigation of the risk of RWS failure - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Maintain, exercise and review a site specific water management plan.	- Failure of the RWS may result in elevated decant pond levels	Not Credible	Failure of the RWS system may result in the decant pond rising, thus applying additional hydrostatic pressures to the embankment. However, slope stability assessments have been carried out assuming a reservoir level coincident with the embankment crest. The slope stability assessments show that the reservoir level has negligible impact on the Factor of Safety of the downstream slope. Therefore, a failure of the RWS resulting in an elevated decant pond level is not considered to be a credible initiator/trigger for slope instability. This PFM is therefore assessed to be Not Credible.

Internal Erosion (IE)																		
15	DR TSF-Emb-IE-15	Internal Erosion	Internal erosion of the embankment	Main Embankment	Normal, Flood, Earthquake	In the upper part of the embankment, defects may be present due to the weather conditions and the rainfall cycles, causing desiccation cracking near the crest level. Cracking might also form due to the earthquake (the depth of cracking is below the FSL). Defects may also be present resulting from poorly compacted or highly permeable materials through the embankment. In the middle and lower part of the embankment, transverse cracking may be formed through the embankment due to the differential settlement or the presence of a poorly compacted or high permeability layer through the embankment. The water levels rise on the crest during the flood event and, or in normal operation, sit against the embankment long enough to seep into the tailings and embankment, establish a strong hydraulic gradient through the crack, and initiate internal erosion. The materials hold the crack. There is no filter material downstream of Zone 3A material, and the probability of continuing erosion is 1. The erosion continues, leading to the crest's collapse and freeboard loss. The intervention is not possible due to the extreme weather conditions, difficulty with access and time needed to respond. The embankment will breach due to gross enlargement of the pipe, slope instability of downstream slope, unravelling of the downstream toe or overtopping due to the formation of a sinkhole.	Excessive seepage from embankment	Full Breach of the dam	Full Dam Breach	Yes	Yes	Yes	- Observation of increased seepage out of the downstream face of the embankment or in the foundation. This may be by visual observation, or by seepage measurement, or more sophisticated methods such as thermal monitoring of the foundation or the downstream slope. - Measured higher pore pressures in the foundation and/or embankment. - Settlements, deformation and cracking in the embankment or area downstream of the dam.	- The embankment is designed to be constructed from free-draining rockfill material, with two filter zones to prevent the migration of fine particles (Stage 3 Design Report and Technical Specifications) - The filter zones have been designed in accordance with industry standards (Stage 3 Design Report) - The design includes a BGM liner along the entire upstream face of the embankment (Stage 3 Design Drawings and Technical Specifications) - The embankment materials (coarse rockfill) would require a sufficiently high flow velocity in order to dislodge and transport these particles, unlikely to be observed from seepage flows (Engineering judgement)	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment and BGM liner is constructed to the design specifications - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and BGM liner that allows early detection and mitigation of excessive seepage; defects within the embankment and BGM liner; and trends of vertical and lateral movement within the crest - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.	- No piezometers or pore pressure monitoring instrumentation within the embankment - Defects within the BGM liner will be difficult to repair - Stage 3 Seepage Collection System is to be buried beneath a capping layer - inspection of the clarity and flow rates of seepage waters is difficult	Not Credible	PFM initiation and progression requirements: In order for piping to initiate, it requires a concentrated seepage connected to a water source, with a sufficiently high hydraulic gradient to initiate internal erosion through the embankment. The flow velocities within the embankment should be high enough to dislodge and transport fine particles in the embankment. In addition, a high hydraulic gradient is required to contribute to suffusion, which removes fine particles from a soil matrix due to seepage flow in the raised embankments. The decant pond is located against the embankment, so the water source is always present. However, a BGM Liner is installed along the entire upstream face which produces a water-tight seal. In the case of any defects within the liner, filter layers prevents the migration of tailings particles. As documented in Stage 1 and 2 detailed design report, the Zone 2C material is designed to act as a filter to the Zone 2A and 2B when Zone 2C comprises a D15F not greater than 5 mm. The PSD documented in the Stage 2 construction report confirms adequate QA/QC to meet the criteria. It is expected that the construction of Stage 3 adopts the same specifications with the same level of QA/QC. Furthermore, for any defects below the tailings deposit, the probability of progression will consider the presence of tailings on the upstream side of the defects. There is a high probability that the crack-filling action will stop erosion, and the tailings will restrict the flow in the developing pipe. As a result, the potential for embankment breach and loss of containment is anticipated to be negligible for defects below the tailings deposit. Considering the existing control measures, this failure mode is assessed to be Not credible.
16	DR TSF-Emb-IE-16	Internal Erosion	Internal erosion of the embankment into the foundation or at embankment foundation contact	Main Embankment	Normal, Flood	Defects through the embankment material are in contact with the foundation defects forming a seepage path. Defects may exist in the upstream face due to differential settlement, long-term aging, UV Degradation or Thermal Expansion and Contraction. The water levels rise in the dam during the flood event and, or in normal operation, sit against the embankment long enough to seep into cracks or create seepage paths, establish a strong hydraulic gradient through the defects, and initiate internal erosion. Internal erosion initiates at the contact between the embankment and foundation due to seepage through the embankment eroding material into the foundation or seepage in the foundation at the embankment contact, eroding the embankment material. The erosion process continues if the exit is unfiltered or inadequately filtered. The process will progress if the material is able to hold a crack. The intervention may fail due to late detection or access issues where the defects are at foundation contact. The embankment will breach due to gross enlargement of the pipe, slope instability of the downstream slope, unravelling of the downstream face or overtopping due to the formation of a sinkhole.	Excessive seepage from the embankment/ foundation contact	Full Breach of the dam	Full Dam Breach	Yes	Yes	Yes	- Observation of increased seepage out of the downstream face of the embankment or in the foundation. This may be by visual observation, or by seepage measurement, or more sophisticated methods such as thermal monitoring of the foundation or the downstream slope. - Routine inspections of the seepage collection system, noting seepage rates, colour of seepage, and clarity of seepage. - Settlements, deformation and cracking in the embankment or area downstream of the dam.	- Full-time construction supervision during Stage 2 construction ensuring adequate foundation preparation (Stage 2 Construction Report) - Tailings deposition has been ongoing since 2017. It is likely that any defects present within the foundation (which aligns with a defect in the embankment/BGM Liner) will now have been filled and sealed with tailings (Engineering judgement).	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment, BGM liner, and foundation preparation is constructed to the design specifications - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and BGM liner that allows early detection and mitigation of excessive seepage; defects within the embankment and BGM liner; and trends of vertical and lateral movement within the crest - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.		Not Credible	As documented in the design and construction reports for Stage 1&2, Zone 2B can not be eroded into Zone 2A due to the much coarser material particle size. This PFM is assessing the potential erosion of Zone 2A into the rock foundation. The existing embankment is constructed on rock foundations. Type 2 Foundation preparation was conducted in areas of exposed rock foundations within the downstream of the concrete plinth. Type A2 foundation preparation consisted of the removal of all loose soil and rock by machine excavation and were moistened with water prior to material placement and compaction. During overall embankment foundation preparation it was observed that the foundation had very few open joints. No Open joints were recorded in Type 2 foundation preparation area to allow for erosion of the embankment through the foundation. Tailings have been deposited since construction began in 2017. Therefore, in the unlikely event that a defect in the embankment aligns with a joint in the foundation rock, it is expected that these joints have now been filled with tailings. Similarly, if a gap initially existed at the embankment-foundation contact, it is likely sealed by tailings deposition over time. The same condition is expected for extended foundation in abutments. Considering the existing control measures, this failure mode is assessed as not credible.
17	DR TSF-Emb-IE-17	Internal Erosion	Internal erosion through the soil/rock foundation	Main Embankment	Normal, Flood	Initiation and progression of internal erosion in embankment soil foundation may occur by concentrated leak, backward erosion or suffusion. Excessive seepage or water flow through an erodible element within the dam foundation. This could be a continuous (from upstream to downstream) crack in the plastic material forming the foundation or a loose layer in the coarse material forming the foundation. The low plasticity soil particles are detached when the seepage exits to the free unfiltered ground surface downstream. The seepage flow carries the detached particles, and the process gradually works towards the upstream side of the foundation until a continuous pipe is formed. The erosion process continues if the exit is unfiltered or inadequately filtered. The process will progress until the material is able to hold a crack. The intervention may fail due to late detection or access issues where the defects are in the foundation. The embankment will breach due to gross enlargement of the pipe, slope instability of downstream slope, unravelling of the downstream face or overtopping due to the formation of a sinkhole.	Excessive seepage from the foundation contact	Full Breach of the dam	Full Dam Breach	No	Yes	Yes	- Observation of increased seepage out of the downstream face of the embankment or in the foundation. This may be by visual observation, or by seepage measurement, or more sophisticated methods such as thermal monitoring of the foundation or the downstream slope. - Routine inspections of the seepage collection system, noting seepage rates, colour of seepage, and clarity of seepage. - Settlements, deformation and cracking in the embankment or area downstream of the dam.	- Full-time construction supervision during Stage 2 construction ensuring adequate foundation preparation (Stage 2 Construction Report) - Installation of a fully intercepting foundation grout curtain for Stage 2 (Stage 2 Construction Report) - Design for fully intercepting foundation grout curtain for Stage 3 (Stage 3 Design Report) - Stage 3 construction will require the treatment of all exposed open joints in the foundation and abutments (Stage 3 Technical Specifications)	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment, BGM liner, and foundation preparation is constructed to the design specifications - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and BGM liner that allows early detection and mitigation of excessive seepage; defects within the embankment and BGM liner; and trends of vertical and lateral movement within the crest - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.		Not Credible	The embankment is constructed on rock foundations. Foundation preparation involved the stripping and removal of all alluvial and colluvial materials until exposing weathered quartzite rock. A fully intercepting grout curtain has been installed along the upstream toe of the Stage 1 and 2 embankment at varying depths. The requirements for the foundation grouting was determined based on water testing at each grout hole prior to grouting works. The grout curtain was installed to depths up to approximately 12 m, depending on grouting requirements as determined from the water pressure testing. The Stage 3 design also nominates a fully intercepting grout curtain for the extents of the Stage 3 raise. Similiarly to the Stage 1 and 2 construction, the plinth trench is proposed to be terminated on moderately to slightly weathered rock. This structure effectively extends the cut-off at upstream. Therefore, the probability of a continuous defect existing in the foundation from the upstream to the downstream side is negligible. It is therefore considered that the probability of initiation of erosion in the rock foundation is negligible and thus this PFM is not credible.
25	DR TSF-Emb-SS-25	Internal Erosion	Internal erosion along a buried conduit	Main Embankment	Normal, Flood	Internal erosion initiates along a poorly compacted or high permeability zone around a buried conduit through the foundation. The poorly compacted or high permeability zone creates preferential paths for water to flow. Water tends to follow these paths, moving along the zone rather than permeating through the surrounding, denser soil. As water flows through the poorly compacted or high permeability zone, it exerts hydraulic forces on the soil particles. These forces can cause the initiation of erosion, where soil particles are dislodged and carried away by the flowing water. The erosion process continues if the filter diaphragm is not provided at the exit. The process will progress if the material is able to hold a crack. The intervention may fail due to late detection or access. The internal erosion weakens the overall stability of the embankment, potentially leading to embankment settlement, sinkholes, or even catastrophic failure if not addressed.	Excessive seepage at conduit exit	Full Breach of the dam	Full Dam Breach	Yes	Yes	Yes	Visual Inspection: Cracks: Look for cracks on the dam crest, slopes, and downstream toe. Significant cracking can indicate internal movement and potential instability. Deformation: Observe for any bulging, tilting, or settlement of the dam crest. Seepage: Increased seepage or leakage from the dam can indicate internal damage to water flow paths. Instrumentation Monitoring: Survey monuments: Track vertical settlements of the dam crest to assess overall stability.	- No buried conduits are present within the structure.			Not Credible	No buried conduits are present within the structure. Therefore this PFM is assessed as Not Credible.
Liquefaction (LIQ)																		
13	DR TSF-Emb-LIQ-13	Liquefaction	Embankment Breach due to flow liquefaction or foundation liquefaction	Main Embankment	Earthquake	The embankment material may be susceptible to liquefaction or may be founded on saturated granular soil which is susceptible to liquefaction in seismic events. Liquefaction is triggered in the embankment material or saturated granular soil foundation in seismic events or in static loading reducing the effective stress of the soil. The loss of strength in the foundation soil can result in embankment deformation causing slumping and loss of freeboard. The deformation surpasses the available freeboard resulting in loss of containment. Intervention prove ineffective due to the abrupt and unpredictable nature of this failure mode. Embankment breaches primarily caused by overtopping.	Embankment breach or Loss of FB	Embankment breach or overtopped	Full Dam Breach	Yes	Yes	Yes	- Field observations- detecting surface disturbances, signs of ground movements like lateral spreading, fissures, or depressions near the dam toe or downstream areas, changes in seepage pattern, turbidity, and discoloured seepage. Pre and post-earthquake survey to detect changes in dam geometry, indicating potential settlements or deformations due to liquefaction. - Post earthquake geotechnical site investigations - Post-earthquake inspection and review the monitoring data	- Technical specifications require adequate foundation preparation including stripping of all alluvial and colluvial materials until exposing weathered quartzite rock. - The embankment rockfill and rock foundations have been judged to not be susceptible to liquefaction (Stage 3 Design Report) - The Stage 3 embankment is designed to be constructed using downstream construction methods; thus the stability of the embankment is not sensitive to the state of the tailings (i.e. liquefied or not) (Stage 3 Design Report)	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for routine and post-earthquake inspections, surveillance and maintenance of the embankment - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.		Not Credible	The embankment materials comprise competent rockfill which are not considered susceptible to liquefaction. Foundation preparation involved the stripping and removal of all alluvial and colluvial materials until exposing weathered quartzite rock. The rock foundation is not considered susceptible to liquefaction. Therefore, this PFM is assessed to be Not Credible.
14	DR TSF-Emb-OT-14	Liquefaction	Embankment Breach due to overtopping by liquefied tailings	Main Embankment	Earthquake/ Normal	The tailing material may be susceptible to liquefaction. Liquefaction is triggered in the embankment material seismic events or in static loading reducing the effective stress of the tailings causing slumping, loss of freeboard and embankment overtopping. Intervention prove ineffective due to the abrupt and unpredictable nature of this failure mode. Embankment breaches primarily caused by overtopping.	Embankment breach or Loss of FB	Embankment breach or overtopped	Full Dam Breach	Yes	Yes	Yes	Post-earthquake inspection and survey to detect changes in tailings deposited indicating deformations due to liquefaction.	- The Stage 3 ultimate tailings beach is designed to have no deposited tailings above the spillway invert (Stage 3 Design Drawings).	- Conduct quarterly LiDAR surveys to confirm the tailings beach development is within design expectations - Routinely review the production forecast estimates to identify whether the forecasts exceed the design tailings storage volume - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the tailings beach - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.		Not Credible	The final Stage 3 design tailings beach does not involve any proportion of tailings deposited above the Stage 3 spillway invert. If liquefaction were to occur, it would be expected that the tailings would remobilise to a flat (or near flat) beach slope. Given the negligible volume of tailings above the spillway invert prior to liquefaction, it would be expect that the entire tailings beach would flatten and remain below the spillway invert post-liquefaction. Therefore, no release of tailings into the downstream environment would be expected. Therefore, this PFM is assessed to be Not Credible.
Other Failure Modes																		
10	DR TSF-Emb-BGM-10	Uncontrolled Release	BGM Liner Failure Leading to Excessive Seepage and Loss of Water Containment	Main Embankment	Normal, Flood, Earthquake	BGM Liner can fail due to Seam Failure, Puncture or Tear, Aging, UV exposure (if not covered), chemical degradation, or low interface shear strength between the BGM liner and the support layer, leading to slippage or wrinkling. Continued leaking through the damaged BGM liner can cause a sustained and uncontrolled loss of the stored water. Structural failure of the embankment may not eventuate however a complete loss of stored water is possible.	Uncontrolled release	Erosion of downstream slope	Environmental Spill	No	Yes	Yes	- Construction control during installation of BGM liner with appropriate QA/QC - Regular Inspections: Trained personnel visually inspect the exposed BGM liner for defects - Regular Inspections: Trained personnel visually inspect the downstream slope for signs of excessive seepage -Regular Inspections: Trained personnel visually inspect the exposed BGM liner for defects, punctures, seam failure etc.	- BGM liner designed to industry standards and supplier requirements (Stage 3 Design Report) - No permanent populations located within the potential seepage path	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment and BGM liner is constructed to the design specifications - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankmentand BGM liner that allows early detection and mitigation of liner failure and excessive seepage - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.	- Defects of the BGM liner below the tailings/water surface are difficult to detect from visual inspections	Not Credible	The presence of defects presenting within the BGM Liner is credible due to either poor construction practices; improper maintenance; manufacturing defects; and/or degradation. Once defects are present below the water surface, repairs are difficult. However, life safety consequences are considered to be negligible owing to the fact that there are no permanent populations within the seepage path and that the rate of seepage is expected to be slow. Therefore, this PFM is assessed to be Credible but excluded from the Risk Assessment process in consideration of the negligible life safety consequences.
19	DR TSF-Emb-IE-19	Fire Damage	Fire damage to BGM Liner	Main Embankment	Normal	Vegetation establishes along the abutments which catch on fire due to extreme heat or vandalism. The fire transitions to the BGM liner, causing damage to the liner and loss of function of the BGM liner as a water containing component. Water flows through the embankment, initiating erosion of the rockfill. The erosion continues, leading to the crest's collapse and freeboard loss. The intervention is not possible due to fire risk, extreme weather conditions, and difficulty with access and time needed to respond. The embankment will breach due to gross enlargement of the pipe, slope instability of downstream slope, unravelling of the downstream toe or overtopping due to the formation of a sinkhole.	Excessive seepage from embankment	Full Breach of the dam	Full Dam Breach	Yes	Yes	Yes	- Observation of vegetation establishment along abutments and adjacent to the concrete canvas. -Regular Inspections: Trained personnel visually inspect the exposed BGM liner for defects, punctures, seam failure etc.	- The design prescribes the installation of Concrete Canvas at the abutments to protect against bushfire damage	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the Concrete Canvas and BGM liner is constructed to the design specifications - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance to detect for the establishment of vegetation along the abutments and ensuring a "fire break" remains in place, adjacent to the Concrete Canvas, along the abuments. - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.	- BGM Liner is susceptible to fire damage	Not Credible	A Concrete Canvas has been installed at the abutments to provide bushfire protection to the underlying BGM Liner for Stage 2. Concrete Canvas is also proposed for the Stage 3 Raise. The embankment and abutments are routinely monitored for the establishment of vegetation along the abutments and adjacent to the Concrete Canvas. Operations Plan requires that all shrubs and trees with a trunk base diameter of greater than 50 mm are cut at the base and removed. The probability of vegetation establishing along the abutment edges to a size in which they produce a risk of fire to the BGM Liner is negligible. This PFM is therefore assessed to be Not Credible.
20	DR TSF-Emb-SE-20	Surface Erosion	Overtopping due to slope instability caused by the formation of erosion gullies from surface water runoff	Main Embankment	Flood	The failure pathway begins with the occurrence of intense surface water runoff, often due to heavy rainfall. The runoff concentrates in specific areas on the embankment dam, leading to the formation of erosion gullies. These gullies typically develop along the slope of the dam. Over time, the concentrated flow of water erodes the downstream face, creating gullies that cut into the embankment slope. The gullies increase in size and depth as erosion continues. The erosion gullies undermine the stability of the embankment by removing material and creating voids beneath the surface. This undermines the structural integrity of the dam. As erosion progresses the embankment slope becomes steeper leading to slope failures along the embankment. Intervention is ineffective due to the poor maintenance practice. Embankment breaches primarily caused by slope instability leading to overtopping.	Downstream slide	Loss of freeboard and breach	Full Dam Breach	Yes	Yes	Yes	Erosion gullies, changes in slope characteristics, and signs of instability can be detected during the routine and annual inspections	- The Stage 3 embankment is designed to be constructed with rockfill materials which are less susceptible to surface erosion (Engineering judgement) - The Stage 3 emergency spillway outlet is located away from the embankment toe. Any spillway discharge is channeled via the existing natural drainage channels. No embankments nor engineered structures are within the flowpath.	- Implement a quality assurance plan which includes full-time construction supervision by a suitably qualified geotechnical engineer - Implement appropriate QA/QC procedures to ensure that the embankment is constructed to the design specifications - Perform hydrological studies to assess the volume and velocity of surface water runoff, identifying areas prone to erosion and potential gully formation. - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the embankment and decant pond that allows early detection of seepage and surface runoff erosion, the formation of erosion gullies, changes in slope characteristics, and signs of instability along the embankment downstream face - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Construct the embankment with free draining coarse rockfill, which adds erosion resistance to the downstream face (Engineering judgement)	- No scour/erodibility assessment of the embankment has been conducted	Not Credible	The embankment is to be constructed with rockfill material that is less susceptible to surface erosion. The formation of erosion gullies to the point in which slope instability occurs would require a sustained and unremediated development of erosion gullies. The formation of erosion gullies would be identified during routine inspections and remediated by replacement with new rockfill. Any embankment instability as a result of the steepening of the downstream face is likely to result in localised slip surfaces to form rather than large-scale global failure. The risk of erosion gullies developing to the point of causing global embankment failure is therefore considered negligible in consideration of the embankment width; routine inspection practices; embankment materials being less susceptible to erosion; and high global stability factors of safety. As a result, this PFM is considered not credible.
21	DR TSF-TD S-OP-21	Operational	Failure of Tailing Delivery System	Tailing Delivery System	Flood, Normal	Components of the Tailing Delivery System could fail due to inadequacy in structural design, construction technique or operation	Loss of Functionality	Operation Failure	Operation Failure	No	No	Yes	Routine inspection	- Operation Maintenance and Surveillance Plan which stipulates the routine inspection of tailings delivery system (Operations Plan) - Spill containment dams are positioned at appropriate locations along the tailings pipeline route (Operations Plan)	- Conduct a comprehensive condition assessment and hydraulic capacity assessment of the Tailings Delivery System - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress.		Not Credible	The structural failure of the Tailing Delivery System components would not be expected to cause failure of the embankment. However, it has operational risk implications.
24	DR TSF-Drg S-OP-24	Operational	Failure of Seepage Collection System Pump	Drainage and Seepage Collection System	Flood, Normal	The Seepage Collection System pumping infrastructure could fail due to inadequacy in structural design, construction technique or operation. The Seepage Collection System could back up and result in seepage via the embankment toe.	Loss of Functionality	Operation Failure	Operation Failure	No	No	Yes	Routine inspection Monitoring of pump data	- Operation Maintenance and Surveillance Plan which stipulates the routine inspection of tailings delivery system (Operations Plan) - Spill containment dams are positioned at appropriate locations along the tailings pipeline route (Operations Plan)	- Conduct a comprehensive condition assessment and hydraulic capacity assessment of the Seepage Collection System - Develop an Operation Maintenance and Surveillance Plan (OMSP) to describe the requirements for inspection, surveillance and maintenance of the Seepage Collection System and associated pumping infrastructure - Develop Emergency Plan and TARPs to document the procedures in the event that the Failure Mode is in progress. - Store backup and contingency pump infrastructure on site for prompt replacement/repair	- A systematic root cause analysis addressing potential failures in the electrical and mechanical components of the structure has not yet been undertaken, nor has a reliability assessment	Not Credible	The structural failure of the Seepage Collection System pumping infrastructure and components would not be expected to cause failure of the embankment. However, it has operational and environmental risk implications.

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APPENDIX H – CERTIFICATION STATEMENT

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Our Ref: 250542-R04

6 February 2026

Form of certification (consequence assessment and design plan)

Name of Registered Professional Engineer providing certification:

Dale Murray Ross

Address of Registered Professional Engineer providing certification:

ATC Williams
222 Beach Rd, Mordialloc 3195

Statement of relevant experience

I hereby state that I am a Registered Professional Engineer of Queensland and meet the requirements of the definition of 'suitably qualified and experienced person'.

Statement of certification

All relevant material relied upon by me, including subsidiary certifications of specialist components, where required by the environmental authority, is provided in the attached report *Dugald River Mine – Tailings Storage Facility – Stage 3 Raise Detailed Design Report, Ref: 250542-R04 (Rev 0)* dated 6 February 2026.

I hereby certify that the design plan (and appended consequence assessment) entitled *Dugald River Mine – Tailings Storage Facility – Stage 3 Raise Detailed Design Report, Ref: 250542-R04 (Rev 0)* and dated 6 February 2026:

- Provides an assessment of the consequence category of the Dugald River Mine Stage 3 Tailings Storage Facility in accordance with the *Manual* published by the administering authority (ESR/2016/1993 Version 5.04);
- The design has been prepared in accordance with good engineering practice and the design/dam is also consistent with the standards required for structures of the assessed consequence category as set out in the *Manual* published by the administering authority (ESR/2016/1993 Version 5.04); and
- Provided the structure is constructed or modified (in consultation with the designer) in the manner specified and the facility is operated and maintained as recommended, the dam/structure/facility is capable of delivering the performance stated in the attached report so as to be compliant with relevant conditions of the environmental authority.

I Dale Murray Ross, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under section 480 of the *Environmental Protection Act 1994* to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

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Signed:

Dale Murray Ross, RPEQ No. 34596

Date: 6/2/2026

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Appendix E: TSF Conceptual Closure Design Report

REPORT

MMG DUGALD RIVER PTY LTD
ABN: 19 083 405 556

MMG Dugald River Mine
Tailings Storage Facility
Conceptual Closure Design Report

240189-R01-rev1
APRIL 2025

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Document Control

Project Name:	MMG Dugald River Mine
Document Title:	Tailings Storage Facility – Conceptual Closure Design Report
File Location:	P:\Dugald\240189 Dugald TSF Conceptual Closure Design\Documents\R01 - Conceptual Closure Design Report\Text\rev1\240189-R01-rev1.docx
Document Number:	240189-R01-rev1.docx

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
0	Draft Issue	10/04/25	NK, MS	PG
1	Final	17/04/25	NK, MS	PG

Issue Register

Distribution List	Date
MMG Dugald River Mine	17/04/25

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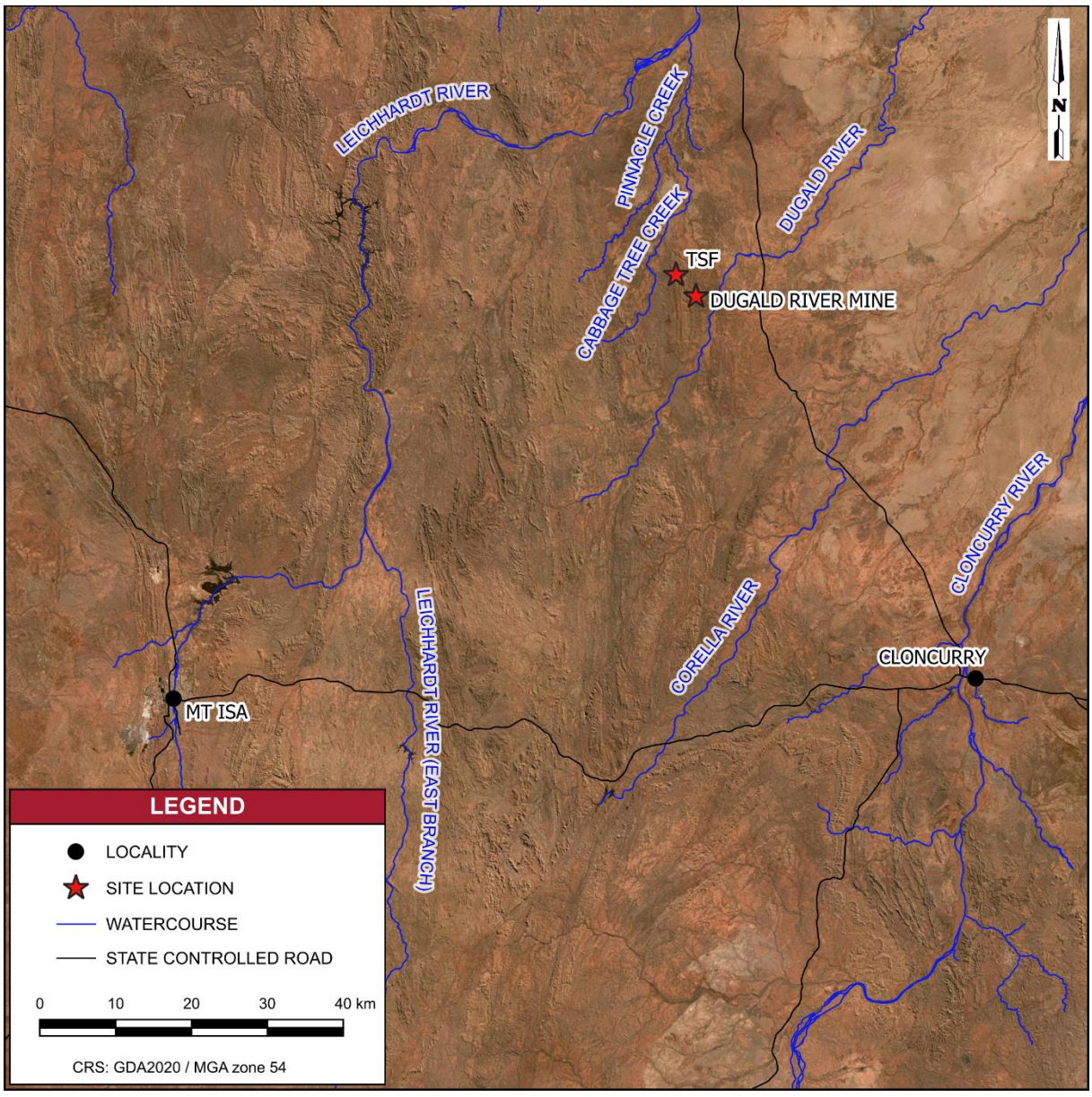
1 INTRODUCTION

1.1 MMG Dugald River Mine

MMG Dugald River Pty Ltd (MMG) is an underground lead and zinc mining operation, located approximately 60 kilometres (km) northwest of Cloncurry in North West Queensland as shown in **DIAGRAM 1**. It is owned and operated by MMG, a wholly owned subsidiary of MMG Australia Limited.

Dugald River Mine (DRM) is authorised by the Department of Environment, Tourism, Science and Innovation (DETSI) under Environmental Authority (EA) EPML00731213 and resides on 40 Mining Leases (ML) and one Mineral Development Lease (MDL).

DIAGRAM 1: SITE LOCATION



1.2 Tailings Storage Facility

DRM operates a Tailings Storage Facility (TSF) located in the Knapdale Range valley and is formed by a cross-valley embankment that dams a creek line. Tailings discharge occurs at the northern and southern ends of the valley with the low point maintained in the centre of the valley. The TSF is used to contain both process tailings and mine-affected water.

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The TSF embankment is a 37 metre (m) high, zoned, granular and rockfill embankment, with an impermeable bituminous geomembrane (BGM) liner fitted on the upstream face. An emergency spillway is excavated into the northern abutment.

1.3 Scope

MMG proposes to increase the capacity of the TSF by raising the crest height of the main embankment (the Stage 3 embankment raise design concept) **[1]**. This constitutes a major amendment of the EA, triggering the requirements for updated Progressive Rehabilitation and Closure Plan (PRCP) and PRCP Schedule.

ATC Williams Pty Ltd (ATCW) has been engaged by MMG to develop a conceptual closure design for the TSF. The conceptual closure design includes the cover system design, landform design, and erosion modelling. Landform Evolution Modelling (LEM) has been excluded at this stage of work. The conceptual closure design must be consistent with the approved PRCP **[2]**, and meet the minimum information requirements in the PRCP Guideline **[3]**. The information requirements in the PRCP Guideline are listed in **TABLE 1** with references provided to the relevant sections of this report in meeting these requirements.

TABLE 1 - PRCP GUIDELINE INFORMATION REQUIREMENTS

INFORMATION REQUIREMENT	REPORT REFERENCE
The cover system design should include: • Identification and specification of the objectives of the cover system	**SECTION 6.1.2** identifies the cover system objectives for the TSF.
• A detailed description of the design including the thickness of each layer.	**SECTION 6.1.4** provides a description of the cover system design for the TSF.
• A detailed description of construction methodology including any proposed staging of the cover system.	**SECTION 8.2** outlines the construction aspects including high level construction methodology being part of future works.
• A quantitative assessment that identifies the location and quantity of proposed capping material available on site.	**SECTION 6.2** provides a material balance for the available proposed capping materials.
• Proposed quality assurance / quality control (QA/QC) for the construction of the cover system including the timely implementation of corrective actions where deviations from the design are identified.	**SECTION 8.2** outlines the QA/QC for the construction of the cover system being part of future works.
The final landform design must include: • Three-dimensional design plans of the final landform.	**SECTION 7.5** outlines the conceptual final landform geometry.
• Method for determining landform design.	**SECTION 7.4** and **7.5** outline the conceptual final landform design.
• Modelling predicting the long-term stability of the final landform design.	**SECTION 7.1** outlines the erosion modelling undertaken for the proposed final landform.
• Method of construction.	**SECTION 8.2** outlines the construction methodology in the Forward Works.
• QA/QQC requirements.	**SECTION 8.2** outlines the Quality Assurance/ Quality Control in the Forward Works.

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INFORMATION REQUIREMENT	REPORT REFERENCE
• Trial methodology to verify the predicted success of the final landform design.	**SECTION 8.2** outlines the trial methodology in the Forward Works.
• Limitations and assumptions of the landform design.	**SECTION 6.3.1** outlines the assumptions and limitations associated with cover system modelling using the SEEP/W package. **SECTION 7.1.1** outlines the assumptions and limitations associated with erosion modelling using the WEPP model.

2 LEGAL AND OTHER REQUIREMENTS

2.1 Environmental Authority

DRM operates EA EPML00731213 and resides on 40 ML's and one MDL. Several conditions of EA EPML00731213 are relevant to the rehabilitation and closure of the TSF (I13, I14, I15, I16, I17, I18, I19, I20, I21). These conditions are:

- Condition I13 requires that land disturbed by mining must be rehabilitated in accordance with *Schedule I – Table 1,* which has been reproduced, as it relates to the TSF, in **TABLE 2**.
- Conditions I15 to I17 require the commencement of monitoring of cover system trials, which were undertaken by SGM Environmental Pty Ltd (SGME) (**SECTION 6.1.1.2**).
- Conditions I19 to I21 include requirements for the development and implementation of a rehabilitation monitoring program.

TABLE 2 - EA REHABILITATION OBJECTIVE

Domain	Mine Feature	Rehabilitation Goal	Rehabilitation Objective	Indicators
TSF	TSF and Seepage Collection Pond	Self, non-polluting, stable and self-sustaining. (All land subject to the mining activity must be rehabilitated to meet the requirements of the administering authorities Guide Rehabilitation requirements for Mining Projects).	Class 5 Native Habitat	Compliance with condition I19 and the Post Mine Land Use Plan.
	Topsoil Stockpiles – TSF			
	TSF Pipelines and Roads			

2.2 Progressive Rehabilitation and Closure Plan

The *Environmental Protection Act 1994* (EP Act) requires that all areas disturbed within the relevant mining tenure must be rehabilitated to a Post Mining Land Use (PMLU) or managed as a Non-Use Management Area (NUMA). The PRCP schedule identifies the PMLUs and any NUMAs. The PRCP schedule also includes a table of milestones and any conditions imposed by the administering authority.

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2.2.1 Closure Objectives and Post Mining Land Use

The approved PMLU for the TSF and associated pipelines and seepage collection pond is native ecosystem **[2]**. A PMLU of native ecosystem is consistent with the rehabilitation objective defined in *Schedule I - Table 1* of the EA.

A PMLU must be rehabilitated to stable condition in accordance with the definition given in Section 111A of the EP Act.

> *"Land is in stable condition if:*
>
> *a) the land is safe and structurally stable; and*
> *b) there is no environmental harm being caused by anything on or in the land; and*
> *c) the land can sustain a post-mining land use."*

Section 3.5.4 of the PRCP states that the rehabilitation of the TSF must achieve the following objectives:

- Control and minimise the transport of oxidation products within the tailings;
- Be capable of supporting vegetation; and
- Be resistant to erosion by wind and / or rainfall runoff.

2.2.2 Completion Criteria

The completion criteria for measuring whether the PMLU has been successfully achieved are outlined in the approved PRCP. The completion criteria for the PMLU will be used as milestone criteria for the final milestone in the PRCP Schedule, which shows achievement of the PMLU to a stable condition at surrender.

The rehabilitation milestones and milestone criteria that are relevant to the closure design for Rehabilitation Area 6 (RA6) (i.e. the TSF) are presented in **TABLE 3**.

TABLE 3 – RA6 REHABILITATION MILESTONES AND MILESTONE CRITERIA [2]

REHABILITATION MILESTONE	MILESTONE CRITERIA
RM7 – Landform development and reshaping	a) The construction of the cover system / cap has been certified by an appropriately qualified person as being consistent with the cover design. b) QAQC testing is completed post construction at a rate of at least 1 sample per ha and confirms depth of layers and permeability is to specified designs and no PAF material is present within the cover system. c) Primary monitoring locations have been established in representative locations recommended as an outcome of the trial mentioned in Condition PRCP5(e) and include: I. an automated meteorological station that records the following: rainfall (tipping bucket), i. evaporation, ii. relative humidity, iii. wind strength, iv. wind direction, and v. air temperature. II. piezometers within the tailings and capillary break layer, III. automated in situ water content and suction sensors in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals (except in the capillary break), IV. temperature sensor in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals, V. a lysimeter.

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REHABILITATION MILESTONE	MILESTONE CRITERIA
	d) Secondary monitoring locations have been established in representative locations recommended as an outcome of the trial mentioned in Condition PRCP5(e) and include in each layer of the cover system and in the tailings below the cover system: I. piezometers within the tailings and capillary break layer, II. automated in situ water content sensors in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals (except in the capillary break). e) Temperature sensor in each layer of the cover system and in the tailings below the cover system that records data at 30 minute intervals. All sensors are calibrated to each material type using the manufacturers specifications. f) Lysimeters and associated drainage collection and monitoring system are installed in at least 3 locations that are recommended as an outcome of the trial mentioned in Condition PRCP5(e). g) Sediment capture flumes have been installed and calibrated at the base of the TSF embankment. h) All monitoring equipment has been installed and calibrated by an appropriately qualified person. i) Slopes of TSF top to have a grade of 1% with slope lengths of ~2000m at the southern end of the TSF, and 1150m at the northern end. j) Certification by an AQP that landform has been constructed according to the design and has achieved an acceptable factor of safety. k) Main TSF embankment formed as a broad spillway rock chute with slopes of 15% with a slope length of ~230 m. l) TSF is assessed as geotechnically stable by a suitably qualified geotechnical engineer. m) Features such as large woody debris or boulders are present to provide suitable habitat for the Purple Neck Rock Wallaby. n) TSF surface has been shaped to prevent ponding and concentration of surface water flow. o) Spillway is designed and constructed to support peak flood flow velocity. p) An average erosion rate <0.2m. q) Installation of erosion and sediment control structures that comply with International Erosion Control Association (IECA).
RM9 – Surface preparation	a) Deep ripping of compacted surfaces, at least 300mm into soil profile, where required and avoiding habitat features associated with RM3 and RM8. b) An assessment of the need for soil amelioration undertaken and soil ameliorants such as fertiliser, gypsum and/or organic matter have been applied at rates determined by an appropriately qualified person. c) Topsoil placement of a minimum 0.2 m

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REHABILITATION MILESTONE	MILESTONE CRITERIA
RM10 – Revegetation (native ecosystem)	a) Seeding rate of 4 – 10 kg/ha is applied. b) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2 and 1.7.7 on RA1 including *Eucalyptus leucophloia, Corymbia terminalis, Corymbia capricornia* with a groundcover of *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus,Themeda triandra, Triodia pungens*. c) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2 and 1.7.7 on RA6 including *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus,Themeda triandra, Triodia pungens*. d) Direct seeding species mix is endemic to Regional Ecosystem 1.11.2a/1.7.7a and RE1.11.3a/1.3.13a on RA7, including the terrestrial species of *Eucalyptus leucophloia, Corymbia terminalis* and *Corymbia capricornia* with a groundcover of *Aristida latifolia, Eriachne obtusa,Sporobolus australasicus, Themeda triandra* and *Triodia pungens*. e) Direct seeding species mix on RA7 including riparian species of *Eucalyptus camaldulensis, Corymbia capricornia, Sporobolus australasicus, Melaleuca species, Lophostemon* species and other suitable wetland groundcover species in riparian vegetation zones. f) Deep rooting vegetation such as Eucalyptus Spp not present on RA6. g) Groundcover >50%.
RM12 – Achievement of surface requirements (native ecosystem)	For all areas: a) Weed species in densities less than 10% total coverage. b) Average erosion rate of <5 t/ha/y. c) Vegetation cover 70%, d) Species used in revegetation in RM10 remain present and showing evidence of natural recruitment. e) Surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly to moderately disturbed). f) Stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low. g) Quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA. h) Soil testing indicates the following parameters are met: I. Rootzone EC 6 as measured at any part of the root zone, II. Exchangeable Sodium Percentage (ESP%) i i) Continuous recording demonstrates seepage volume is decreasing. j) Seepage is collected and disposed of at an appropriately licensed facility. k) In-situ permeability and surface infiltration are not significantly decreasing compared with initial rates based on statistical analysis.

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REHABILITATION MILESTONE	MILESTONE CRITERIA
RM14 – Achievement of post-mining land use to a stable condition (native ecosystem)	For all areas: a) Vegetation cover exceeds 70% of the surface area. b) All species used in RM10 show natural recruitment. c) Weed species in densities less than 10% total coverage. d) Native fauna observed, or indicators of these species have been recorded. e) There is no evidence of seepage occurring within the mining tenure. f) Certification from an REPQ that the domain has achieved stable condition. g) Certification from an AQP that the landform achieved a factor of safety 1.5. h) All results from surface water quality measured at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken on an event basis1 complies with ANZECC/ARMCANZ (2000) Table 3.4.1 for 95% protection level and Table 3.3.4 values for aquatic ecosystems (slightly disturbed) for a minimum of 5 consecutive years. [Sites of tributaries of Dugald River sample daily for the first two days when stream flows commence. If flows persist, sample weekly until flow ceases. Dugald River Sites sample Dugald River sites daily while flows are present downstream of the mine and daily for one week after cessation of flows in the tributaries downstream of the mine. Sample monthly if flows are present in Dugald River during the wet season. Cabbage Tree Creek sites Sample CT3 08, CC 05 and CC 06 daily when flows are present at CT3 08 and sample CC 05 and CC 06 daily for two days after flows at CT3 08 cease. Sample CC-05 and CC-06 weekly if flows are present.] i) All results from stream sediment quality at downstream monitoring sites (CT3-08 (MS2), CC-05, CC-15, MS8 (SN-15), SC-29 (MS5), SN-05 (MS8 REF), SN-08 (MS5 Ref) and DR-18) undertaken twice a year (at end of wet season and end of dry season) complies with ANZECC/ARMCANZ (2000) Interim Sediment Quality Guidelines – low for a minimum of 5 consecutive years. j) All results from quarterly groundwater monitoring at MB5, MB6, MB9S and MB9D demonstrate groundwater quality complies with groundwater trigger limits nominated in Schedule C – Table 8 of the EA for a minimum of 5 consecutive years. k) Soil testing undertaken at yearly intervals indicates the following parameters are met: I. Rootzone EC 6 as measured at any part of the root zone, III. Exchangeable Sodium Percentage (ESP%) n) No evidence of erosion classified as ‘moderate’ or 'severe'. q) No evidence of salt rise through the cover system of the TSF. r) In-situ permeability and surface infiltration are not significantly decreasing compared with initial rates based on statistical analysis. s) Results of monitoring gathered from primary and secondary monitoring stations established in RM7 demonstrate the following has been maintained for a minimum of 10 years: I. Hydraulic conductivity of the cover system is less than 1 x 10-8 m/s for at least 10 years,

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REHABILITATION MILESTONE	MILESTONE CRITERIA
	II. Net percolation through the cover into the tailings has been reduced to <5% of rainfall for least 10 years as measured by primary and secondary monitoring locations and lysimeters. III. Water content of the reduced permeability layer is maintained above 85% over a 10 year period, IV. Temperature within the tailings has not increased over a 10 year period, V. Volumetric water content of tailings does not respond to rainfall events.

2.3 Governance

The Conceptual Closure Design developed is based on industry best practice and follows relevant industry guidance. While compliance with industry guidelines is not directly addressed and assessed, specific sections relevant to the closure technical designs of TSFs are followed. This includes relevant sections from:

- Global Industry Standard on Tailings Management
- International Council on Mining and Metals Tailings Management: Good Practice Guide
- International Council on Mining and Metals Integrated Mine Closure: Good Practice Guide

Other design reports and the broader Closure Planning for the Dugald River Mine will address other aspects of the relevant guidelines.

3 SITE SETTING/CONDITIONS

3.1 Climate

3.1.1 SILO Data

Climate data from 1970 until 2024 were sourced from Queensland Government Scientific Information for Land Owners (SILO) for the site location **[4]**. The year range selected covers decadal changes including extended periods of hotter, wetter, cooler and drier weather. BoM station 29127 MOUNT ISA AERO is the closest recording station, and is located about 85 km south west of the site. SILO data were used in preference to the BoM station to provide a more accurate data set.

The site is within the Hot (Winter Drought) Grassland area based on the Köppen climate classification. Median monthly rainfall and temperature for the period of January 1970 to December 2024 is depicted in **GRAPH 1** below and show the winter drought extends from April to September with effectively 0 mm rainfall received in these months. The mean maximum monthly evaporation for the reporting period is 228.9 mm in December, and the mean minimum monthly evaporation is 109.2 mm in June. The evaporation exceeds rainfall in every month showing a strong moisture deficit in most years. The median maximum daily temperature for the reporting period is 37.7°C in December, and the median minimum daily temperature is 8.2°C in July showing wide extremes of temperature over the year are common.

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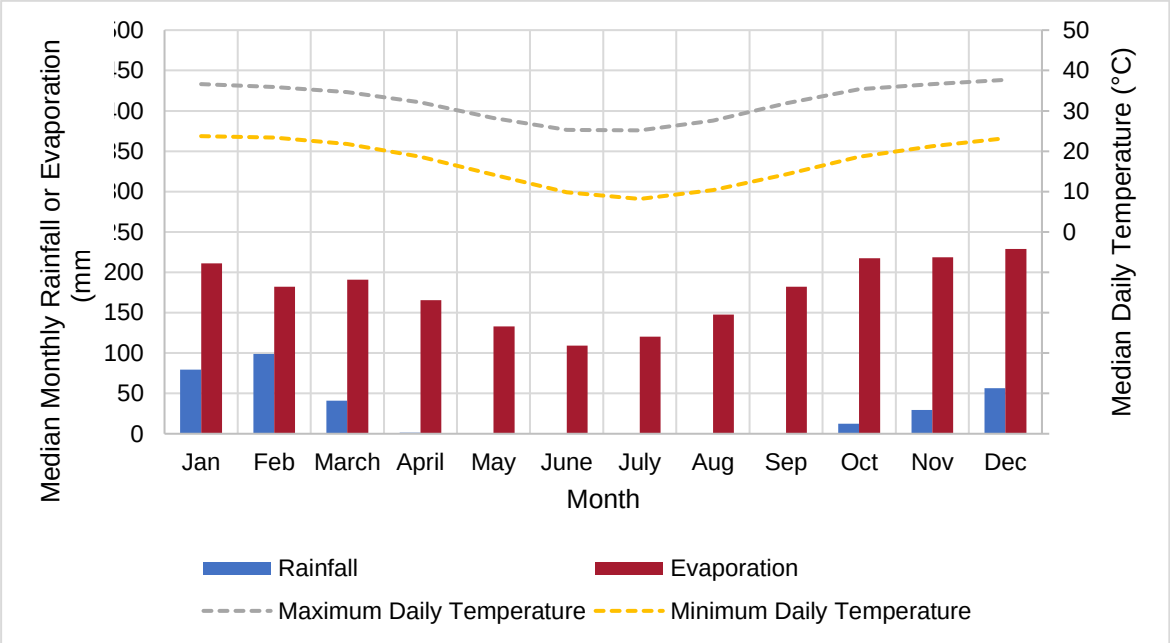
GRAPH 1: MONTHLY CLIMATE DATA



3.1.2 Long Term Projections

Climate projections data have been generated using 28 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) global climate models (GCMs) and four Representative Concentration Pathways (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5), which define a range of possible future climates. While more recent climate projects are available in the IPCC's Sixth Assessment Report (AR6), the AR5 data were available at the time of the Forage climate projections report development **[5]**. The median values for the historical data (1957-2022) and climate projections for 2030, 2050 and 2070 are presented in **TABLE 4**.

TABLE 4: PROJECTED ANNUAL CLIMATE SUMMARY

Climate Variable (Median Annual)	Historical 1957-2022	Projection 2030	Projection 2050	Projection 2070
Rainfall (mm)	460.7	453.8	447.6	443.2
Evaporation (mm)	2,996.1	3,228.0	3,362.3	3,469.1
Mean Temperature (°C)	25.7	26.8	27.5	28.0
Maximum Temperature (°C)	32.8	33.8	34.5	35.0
Minimum Temperature (°C)	18.6	19.7	20.4	21.0

Source: FORAGE Report: Regional Climate Projections Lot on Plan: 92SP303378,036AP23793 **[5]**

Median annual rainfall is expected to decrease in 2030, 2050 and 2070, while median annual evaporation and temperature is expected to increase. Notwithstanding, the State of the Climate 2022 biennial report and IPCC's AR6 predicts greater variability and intensity in rainfall, more extreme weather events such as heat waves, droughts and floods **[6]**, **[8]**.

While climate change projections indicate greater variability and increase in rainfall intensity and frequency, leading to higher runoff volumes, these factors primarily influence surface water

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management rather than cover system performance. While surface water management is a primary concern, extended dry periods can lead to reduced net infiltration rates due to changing precipitation patterns. This can impact vegetation coverage. To account for potential impacted vegetation coverage, one of the WEPP modelling scenarios had 0% vegetation cover as a worst case (see **SECTION 7.1.1.6**).

3.2 Regional Surface Water

The main mine area is situated on gently sloping plains in central western Queensland, approximately 3 km west of the Dugald River, shown on **MAP 1**. The Dugald River flows in a northerly direction past the site.

The TSF is located in the adjacent catchment, approximately 3 km east of Cabbage Tree Creek, as shown on **MAP 1**. Cabbage Tree Creek is located in the Leichardt River Basin, which discharges north to the Gulf of Carpentaria. The TSF is located on an unnamed tributary of Cabbage Tree Creek, which is referred to as the 'TSF Trib'. The location of Cabbage Tree Creek and TSF Trib are depicted on **MAP 1**.

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP Water and Wetland Biodiversity) has scheduled Environmental Values (EV's) and Water Quality Objectives (WQO's) for surface water and groundwater.

The TSF is required to meet the conditions of the EA. WQOs for the Cabbage Tree Creek are listed in *Section C* (reproduced in **TABLE 3**) of the EA and must be monitored at the locations and frequency mentioned.

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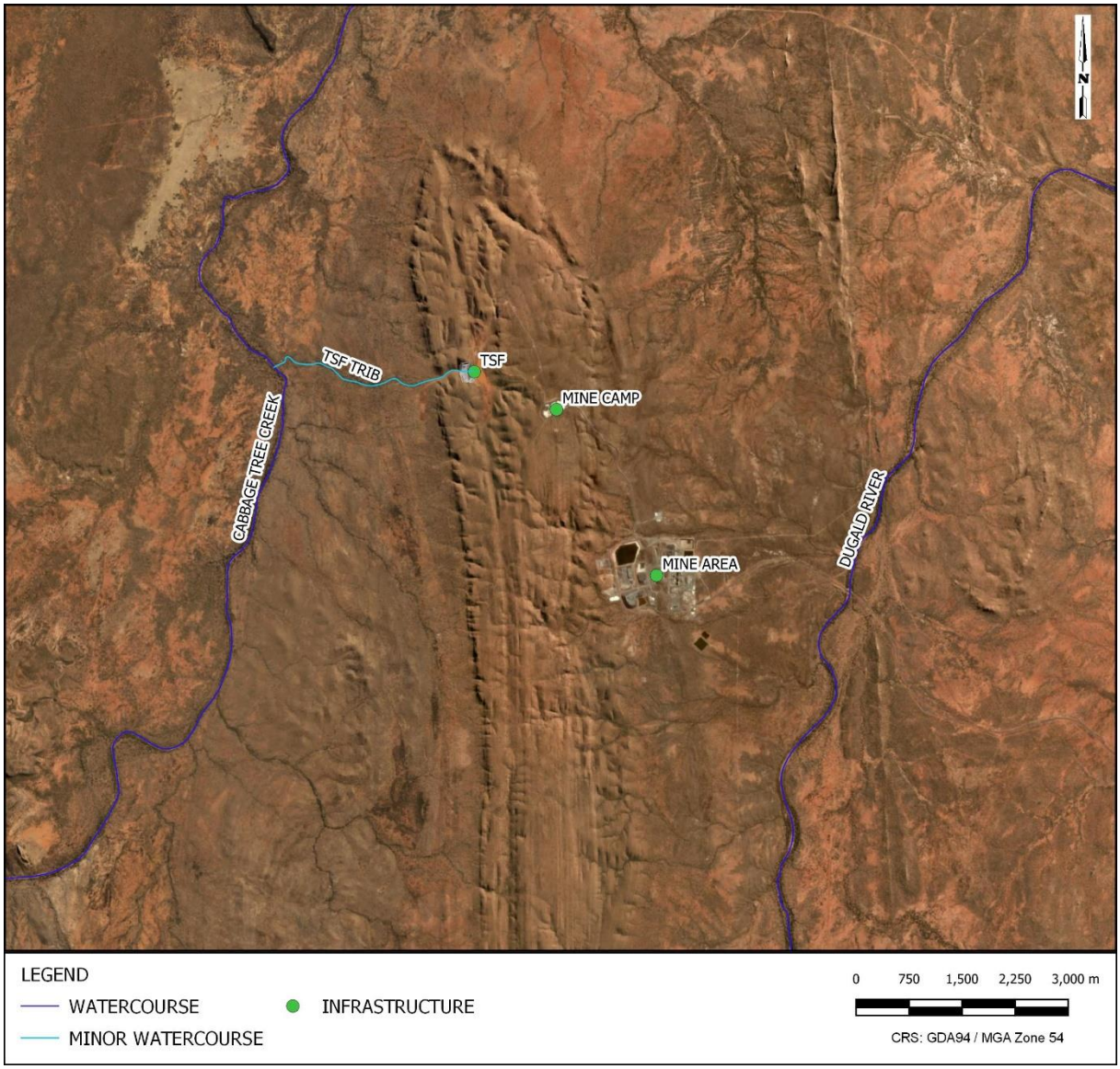
MAP 1: LOCAL WATERCOURSES



3.3 Regional Groundwater

An assessment of the hydrogeology of the Dugald River site and the groundwater aspects of the proposed mine development are outlined in **[17]**. The following is a summary:

- There are no significant aquifers within the Knapdale Quartzite. The mylonitic fault which separates the quartzite from the Corella Formation to the east is considered to form a low permeability groundwater disconnect.
- Minor perched zones occur in the upper 10 m of the quartzite formation where unloading fractures occur. However, due to the nature of the quartzite formation, the groundwater exists only locally in the fissures within the rock mass. Below this depth, the formation is massive and unfractured.
- As with the Knapdale Range, the utilisation of groundwater within the Cabbage Tree Creek catchment area to the west has been very limited. However, the lack of production bores or wells in the area suggests it is a poor groundwater resource.

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3.4 Regional Geology

The Dugald River mine site is located within the Mary Kathleen Zone of the Eastern Foldbelt of the Mt Isa Inlier, on Proterozoic sandstone, siltstone and quartzite. Based on the BMR Quamby Sheet 6957, 1980 Regional Geology Sheet, the 14 km long, 3 km wide Knapdale Range consists of Knapdale Quartzite of the Mount Albert Group, which overlie the Corella Formation calc-silicates. Separating the quartzite from the Corella Formation is a low angle, mylonitic thrust fault.

The quartzite is a massive formation of medium-grained, pink-grey metamorphosed sandstone, striking predominantly north-south with a dip of foliation angle in the range 60 to 80 degrees to the west. No known faults are running through the valley.

3.5 Soil Types

Map units in the Atlas of Australian Soils represent soil landscapes, which encompass the spatial distribution of soils with similar characteristics and formed under similar environmental conditions. There are three distinctive soil groups present in proximity of the DRM site:

- Mo34: Red smooth-ped earths. Gently undulating lands with some areas of stronger relief & occasional low hills.
- Bz19: Siliceous sands. High sandstone plateaux with prominent cliffs & steep rocky slopes much dissected at the margins.
- Fa38: Earthy loams. Moderately to strongly undulating lands with occasional low hills.

The Australian Soil Classification (ASC) order shows soils are typically classed as:

- Rudosol: Shallow, stony soils with little more than some minor organic matter accumulation on the surface and weathered parent material.
- Kandosol: Sandy to loamy-surface soil, grading to porous sandy-clay subsoils with low fertility and poor water-holding capacity.
- Vertosol: Clay soils with shrink-swell properties that cause deep and wide cracking on drying. Very high-soil fertility and large water-holding capacity.

3.6 Regional Ecosystem

3.6.1 Vegetation

The vegetation endemic to the region has a regional ecosystem code of RE 1.11.2a/1.7.7a and RE 1.11.3a/1.3.13a **[22]**. Descriptions of individual regional ecosystems and vegetation communities are shown in **TABLE 5 [23]**.

TABLE 5: REGIONAL ECOSYSTEM CODE DESCRIPTIONS

RE code	Description
1.11.2a	*Eucalpyptus leucophloia* often with *Corymbia spp*., *Terminalia aridicola* and *E. leucophylla* low open woodland
1.7.7a	*Corymbia capricornia* low open woodland on silcrete
1.11.3a	*Eucalyptus leucophylla* low open woodland often with Cory*mbia terminalis, C. aparrerinja* and *E. leucophloia*
1.3.13a	*Eucalyptus leucophylla* and/or *Corymbia terminalis* woodland on levees and minor drainage lines

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As per the rehabilitation milestones and milestone criteria, presented in **TABLE 3**, deep rooting vegetation such as Eucalyptus spp. is not to be present on the TSF.

3.6.2 Fauna

The rehabilitation milestones and milestone criteria, presented in **TABLE 3**, mentions the milestone criteria of features such as large woody debris or boulders be present to provide suitable habitat for the Purple Neck Rock Wallaby.

4 HISTORIC MATERIAL CHARACTERISATION

4.1 Tailings

As discussed in the Cover Options Memo **[9]**, a review of existing tailings geochemistry completed by Environmental Geochemistry International Pty Ltd (EGi) was undertaken to inform performance objectives of the cover system. EGI completed static and kinetic analysis of a tailings solids sample **[10]**, and in 2024, ATCW undertook an updated geochemical review of the sampling **[11]**.

Based on the outcomes of these studies, tailings have the potential to leach metal and metalloids and are considered Potentially Acid Forming (PAF). They contain a high sulphide content, mainly comprised of pyrite (or pyrrhotite) as well as some sphalerite and galena not recovered during processing. The net acid producing potential (NAPP) of the tailings represent a high capacity for acid generation if the tailings were to be exposed to atmospheric conditions within the TSF. It is also highlighted that the tailings possess some buffering capacity, and as such, current contaminant concentrations (in seepage or supernatant) may not be representative of long term conditions.

With respect to metals, zinc, manganese, lead, and cadmium were typically one or two orders of magnitude higher than the corresponding metal concentrations reported for the tailings liquor and thereby represent significant mobilisation from the solid phase as a consequence of sulphide oxidation and the initial acidification of the tailings.

4.1.1 Geochemical

In 2009, Environmental Geochemistry International Pty Ltd (EGi) completed static and kinetic analysis of a tailings solids sample **[10]**:

- The static geochemical analysis found that the tailings solids sample had a total sulfur content of 7.9% with high sulfide content and was strongly acid generating with low to moderate acid neutralising capacity (ANC) (54 kg H_2SO_4/t). Based on the NAPP (86 kg H_2SO_4/t) and NAG pH (140 kg H_2SO_4/t) test results, the tailings solids sample was classified as Potentially Acid Forming (PAF).
- The tailings liquor had an initial pH 7.3 and was slightly saline (767 µS/cm). Under leach column testing, the tailings solids acidified to around pH 3.5 within the first few months of leaching nd salinity increased to moderate levels (1000-2500 µS/cm). Over the course of the 52 week column leach test program, the concentration of sulfate in leachate ranged from 1,640 to 5,720 milligrams per litre (mg/L). In addition to sulfate, the leachate had high rates of release of zinc (13 to 75 mg/L), manganese (7 to 95 mg/L), lead (0.25 to 1.4 mg/L), and cadmium (0.12 to 0.55 mg/L).

In accordance with condition H1 (d) of the EA, DRM undertakes a program of progressive sampling and characterisation to identify acid producing potential and metal concentrations of tailings. In 2024, ATCW undertook an updated geochemical review of the sampling **[11]**. The median values for NAPP, ANC and MPA were 231 kg H_2SO_4/t, 51 kg H_2SO_4/t, and 285 kg H_2SO_4/t, respectively. The median concentrations of total zinc and total lead were 13,800 mg/kg and 3,610 mg/kg, while the median total sulfur content was 9%. Therefore, tailings at DRM are classified as PAF with ANC, and metal(loid) leaching, and require careful management at closure.

4.1.2 Physical

Other available physical characterisation results for the tailings sample as reported in **[12], [15] [16]** and **[20]**. The results are summarised in **TABLE 6** and **TABLE 7**.

Particle size distribution analysis found the tailings consisted largely of silt with smaller amounts of fine and clay. The tailings are non-plastic and do not show shrink-swell potential. Overall, the tailings are classified as a low plasticity silt with extremely low saturated hydraulic conductivity.

TABLE 6: TAILINGS PSD'S [20]

Sieve Analysis		Hydrometer	
Size (mm)	% Passing	Size (mm)	% Passing
100	-	-	-
75	-	-	-
53	-	0.0288	52.2
37.5	-	0.0212	45.6
26.5	-	0.0147	40
19	-	0.0112	33.6
13.2	-	0.0082	26.4
9.5	-	0.006	20.2
6.7	-	0.0043	15.2
4.75	-	0.003	12
2.36	-	0.0023	10.1
1.18	100	0.0014	6.6
0.6	99.9	0.0009	5.3
0.425	99.7	-	-
0.3	99.7	-	-
0.15	99.3	-	-
0.075	91.8	-	-
0.038	68.5	-	-

TABLE 7: TAILINGS PHYSICAL CHARACTERISTICS [12]

Analysis	Tailings Result
Unified Soil Classification	Low Plasticity Silt
Particle Density	2.96 t/m^3
Maximum dry density	1.63 t/m^3
Optimum Moisture Content	20% grav.
Liquid Limit	21%
Plasticity Index	6%

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Analysis	Tailings Result
Saturated Hydraulic Conductivity	3 x 10^{-8} m/s to 2 x 10^{-7} m/s

4.2 Borrow Area Cover System Materials

4.2.1 Chemical

Three samples of stockpiled topsoil were collected by DRM **[16]**, and were found to have similar chemical properties to pre-disturbance soils with low to moderately low soil fertility. The stockpiled topsoil was moderately alkaline (pH 8.2 to 8.3), extremely saline (electrical conductivity (EC) (1:5) 1.1 to 1.5 dS/m), non-sodic (ESP <6%), low cation exchange capacity (CEC) (8.1 to 9.2 meq/100g) and very low total nitrogen levels (350 to 470 mg/kg).

The Emerson aggregate test classified the stockpiled topsoil samples as either Class 4 or Class 8. Class 4 indicates the topsoil will readily slake but with a low risk of dispersion. Class 8 indicates that the topsoil will not readily slake with a negligible risk of dispersion. Therefore, the stockpiled topsoil samples were considered non-dispersive with a low potential to erode.

4.2.2 Physical

ATCW undertook a Geotechnical Investigation in November 2013, to investigate the nature and depth of near-surface soils for use as granular and low permeability construction materials, within proposed borrow areas **[19]**. A summary of these laboratory results are presented in **TABLE 8**.

The soil is predominantly gravel, with typically > 50% gravel and then an approximately even split between sand and fines. The soil as a low plasticity index indicating a rapid change from plastic to liquid states upon wetting. The permeability ranged four orders of magnitude between the two composite samples and it is unclear form the PSDs why the range was so large.

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TABLE 8: ATCW 2013 GEOTECHNICAL INVESTIGATION – BORROW AREA – LABORATORY TEST RESULTS (TABLE 9) [19]

Sample Details		Description	Classification (USCS)	Moisture Content (%)	Atterberg Limits		Particle Size Distribution [1]			Standard Compaction		Permeability [2] (m/sec)
Test Pit	Depth (m)				LL (%)	PI (%)	% Fines	% Sand	% Gravel	MDD (t/m^3)	OMC (%)	
TB2	0.2 - 0.6	Clayey GRAVEL with sand	GC	4.3	25	10	19	22	57			
TB3	0.7 - 0.9	Poorly graded GRAVEL with silty clay	GP-GC	2.8	21	7	10	10	64			
TB4	0.6 - 0.8	Poorly graded GRAVEL with silt and sand	GP-GM	3.0	19	2	11	15	49			
TB6	0.5 - 0.7	Poorly graded GRAVEL with silt and sand	GP-GM	2.3	21	1	10	16	55			
TB8	0.5 - 0.8	Silty GRAVEL with sand	GM	2.8	18	0	19	17	58			
TB9	0.4 - 0.6	Poorly graded GRAVEL with silt and cobbles	GP-GM	2.6	18	2	6	6	48			
TB11	0.4 - 0.6	Silty SAND	SM	4.5	19	4	48	48	5			
TB13	0.8 - 1.1	Poorly graded GRAVEL with silt and sand	GP-GM	2.2	18	1	11	15	72			
TB23	0.4 - 0.7	Poorly graded GRAVEL with clay	GP-GC	3.3	22	9	11	10	79			
TT8	1.0 – 1.5	Silty GRAVEL	GM	0.6	20	3	18	13	65			
TT10	0.2 - 0.4	Silty GRAVEL with sand	GM	3.8	19	1	16	30	51			
TT14	0.2 - 0.7	Silty GRAVEL with sand	GM	3.3	20	1	33	18	49			
TT15	1.3 - 1.6	Silty clayey GRAVEL	GC-GM	0.7	22	6	18	12	66			
TT15	2.0 – 2.5	Clayey GRAVEL	GC	6.3	27	13	15	12	63			
TT16	0.5 - 0.8	Poorly graded GRAVEL with clay	GP-GC	5.0	21	8	12	11	69			
TP7-EF	0.4 - 0.7	Silty GRAVEL with sand	GM	2.6	18	1	29	23	34			
TR2 RC	0.4 - 0.7	Silty clayey GRAVEL with sand	GC-GM	4.2	21	5	21	37	39			
MIX 1	-	Combined Sample – TB2, TB3, TT10, TT15 (2.0-2.5)					14	17	67	2.01	9.5	3 E-09
MIX 2	-	Combined Sample – TB4, TB6, TB8, TT14					16	15	54			2 E-05

Notes: 1. Fines (Particle Size < 0.075mm), Sand (0.075mm< Particle Size < 2.36mm), Gravel (2.36mm < Particle Size < 63mm)

2. Permeability tests conducted at ~93% MDD and OMC

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5 2024 GEOTECHNICAL INVESTIGATION – MATERIAL CHARACTERISATION

As discussed in the Cover Options Memo **[9]**, in 2024, a borrow investigation was undertaken to characterise site soils, as outlined in “TSF Cover Soils Geotechnical Investigation” **[19]**. The purpose of the investigation was to determine the presence and boundaries of suitable cover material for the TSF within the soil profiles.

The investigation was located to the west of the TSF and comprised excavating 22 test pits to refusal, using a 20 tonne Caterpillar excavator. Samples from the test pits were taken for laboratory testing. A summary of key observations from the investigation are summarised as follows:

- Generally surface soils range from 0.5 m to 1.6 m in depth. Below surface soils, weathered rock was encountered.
- Soils were consistently a sandy gravel, expected to have reasonably high permeability if placed with low compaction.
- No material with a high fines content was identified except in two test pits (TP10 and TP11).
- The depth of topsoil was limited (typically less than 100 mm).

A summary of these laboratory results is presented in **TABLE 9**.

5.1 Summary of Test Results

The stratigraphy encountered consisted of Silty, Sandy Gravel, with refusal depths ranging from 0.5 m to 2 m. No groundwater was encountered during the investigation.

From the 22 test pits excavated, seven samples of subsoil were selected for subsequent laboratory testing. Laboratory test certificates are in ATCW 2025 GI **[13]**, and summarised in **TABLE 9**. The Soil Water Characteristic Curve (SWCC) testing is ongoing and was not available at the time of writing this report.

Most of the analyses undertaken do not support large particle sizes and as such, oversize particles were removed prior to testing. In the case of TP03, TP17 and TP19, the gravel content was around 80% and it was determined that representative tests for compaction, permeability and soil water characteristics curves could not be obtained once the gravel portion was removed. These tests were therefore abandoned on TP03, TP17 and TP19 samples.

Key observations from the investigation are summarised as follows:

- The depth of topsoil is limited and generally ranges from 0.1 m to 0.2 m, with an increased depth (0.4 m) found at TP12.
- Material below the topsoil was relatively consistent across the site, comprising Silty, Sandy GRAVEL. The proportion of gravel is high, in some locations accounting for more than 80% of soil matrix (TP03, TP17, and TP19).
- Refusal occurred consistently at relatively shallow depths. Up to 2 m of subsoils were encountered at some locations, however generally depths were around 1 m or less.

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TABLE 9: ATCW 2024 GEOTECHNICAL INVESTIGATION – BORROW AREA – LABORATORY TEST RESULTS

Sample Details		Emersion Class	Atterberg Limits				Particle Size Distribution [1]			Standard Compaction		Permeability [2] (m/sec)
Test Pit	Depth Sampled (m)		LL (%)	PL (%)	PI (%)	LS (%)	% Fines	% Sand	% Gravel	MDD (t/m^3)	OMC (%)	
TP03	0.1 - 0.9	3	25	13	12	4.5	10	11	79			
TP08	0.1 - 1.0	3	25	15	10	4.5	8	12	80	2.04	8.5	1.26×10^{-5}
TP10	0.6 - 1.4	3	32	17	15	6	69	11	20	1.91	11.0	2.38×10^{-9}
TP11	0.9 - 1.4	5	30	16	14	4.5	59	21	20	1.88	12	1.42×10^{-9}
TP17	0 - 0.6	3	19	16	3	3	9	11	80			
TP19	0 - 0.8	3	22	17	5	1.5	6	11	83			
TP22	0.3 - 0.6	3	23	12	11	4.5	18	20	62	1.97	10	1.30×10^{-5}

Notes: 1. Fines (Particle Size < 0.075mm), Sand (0.075mm> Particle Size < 2.36mm), Gravel (2.36mm > Particle Size < 63mm)

2. Permeability tests conducted at ~95% MDD and OMC.

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5.2 Interpretation of results

A more extensive investigation could identify additional material (both in quantity or type, e.g. clays) however based on available information and past studies, surface soils are relatively consistent across the site. Outcomes from the 2024 investigation are consistent with historical investigations (which were undertaken to identify suitable material for embankment construction). On this basis, the outcomes of the 2024 investigation (and considering past investigations) have been used to inform the cover system options as follows:

- The most abundant material comprised the Silty, Sandy Gravel. This material possesses a relatively high permeability (around $1x10^{-5}$m/s) and low fines content (generally <10%). Based on the permeability and particle size distribution of this material, it would generally be suitable for the Infiltration Storage Layer (ISL) of the cover system.
- Some topsoil is available although the depths encountered are generally around 100 mm. The shallow depth of topsoil will mean that a large borrow area would be required to win sufficient material to include in the cover system (recognising also the borrow area needs to be rehabilitated). If insufficient topsoil is available onsite, ameliorants may need to be added to the subsoil to improve conditions for plant growth and reduce erosion potential.
- The quantity of clay available on site is very limited and was only encountered at two TP locations. Based on the limited area investigated, and review of historical investigations (refer **SECTION 4.2**), it may be difficult to source sufficient material to construct a Reduced Permeability Layer (RPL) using materials onsite. In the absence of suitable site materials for an RPL, a geomembrane (eg. HDPE liner, geosynthetic clay liner, etc) may be required.
- The majority of site soils have moderate potential for dispersion (Emerson Class 3). The dispersion potential of the site soils will need to be managed both on the TSF and in the operation and rehabilitation of the borrows area. management of dispersive soils would be detailed in the sediment and erosion control plan, to be developed prior to construction. The dispersion potential of site soils highlights the importance of establishing vegetation on the rehabilitated TSF post closure.
- The limited depth of soils will mean that the borrow will be large. Optimising cover system thickness will be critical to ensuring that the cover thickness is minimised as much as possible, to limit the volume of material required for closure.

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6 COVER SYSTEM CONCEPTUAL DESIGN

This section provides details on the conceptual cover system design for the TSF, further details can be found in the Cover Options Memo **[9]** and the Conceptual Cover System Modelling Results Memo **[21]**.

6.1 Basis of Design

As outlined in **SECTION 2**, the PRCP schedule outlines the rehabilitation and management milestones for DRM, including a final site design map, PMLUs, NUMAs, and milestones. An appropriate cover system needs to be developed to successfully achieve the completion criteria outlined in the PRCP Schedule.

6.1.1 Previous Cover System Conceptual Design

6.1.1.1 2015 ATCW

In 2015, ATCW designed a conceptual cover system for the TSF **[15]**. The conceptual cover system design as reported in the PRCP is a single capillary break cover and includes the following layers, in sequence from the surface:

- **Topsoil (0.1-0.2m)** – soil stripped from within the impoundment area at the time of construction will be placed on top of the cover system. Good quality topsoil within the TSF impoundment areas is scarce and therefore is unlikely to be sufficient to cover the entire surface. Topsoil will need to be spread thinly and in patches depending on the quantities available.
- **Waste Rock Cover (1m)** – A low water flux cover system will be constructed over the sealing layer consisting of a non-acid forming waste rock layer. Waste rock will be loosely paddock dumped over the sealing layer and then roughly smoothed out with a dozer to encourage infiltration without pooling.
- **Sealing Layer (0.5m)** – low permeability compacted earth fill constructed above the capillary break layer to limit water infiltration. This material may need to be sourced from either the non-acid forming weathered waste rock dumps or general earth fill borrow pits located within the project boundaries.
- **Capillary Break (0.3m)** – mainly coarse, non-acid forming waste rock placed directly over the tailings. The purpose of this layer is to prevent the rise of salts from the underlying tailings to the sealing layer above.

6.1.1.2 Column Cover System Trials

SGME developed and instrumented column cover system trials as required by conditions I15 to I17 of the EA **[16]**. Following the completion of the column cover system trials, data was used to semi-calibrate a cover system model. Based on the outcome of the trials, SGME recommended cover option 1 and 2 as the preferred conceptual cover options.

Option 1 comprises:

- A 0.4 m Capillary Break (CB) layer of gap-graded NAF waste rock above the tailings; and
- A 0.5 m Reduced Permeability Layer (RPL) of borrow subsoil above the CB layer; and
- A 1 m Infiltration Storage Layer (ISL) of borrow subsoil above the RPL; and
- A 0.2 m topsoil layer above the ISL.

Option 2, which includes a double CB layer, comprises:

- A 0.3 m CB layer of gap-graded NAF waste rock above the tailings;
- A 0.5 m RPL of borrow subsoil above the CB layer;
- A 0.3 m CB layer of gap-graded NAF waste rock above the RPL;

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- A 1 m ISL of borrow subsoil above the CB layer; and
- A 0.2 m topsoil layer above the ISL.

SGME stated that the necessity of the RPL cannot be confirmed or rejected and recommended that additional trials are undertaken, which adopt NAF waste rock in place of the borrow subsoil (in the RPL and ISL), as either of these materials may be used in the final cover system for the TSF.

The semi-calibrated modelling suggested that option 1 and 2 would reduce net percolation to less than 10% of cumulative annual rainfall.

6.1.2 Cover System Objectives

Potential cover system options have been developed based on the inferred geochemical characterisation of the tailings and the availability of cover materials. As outlined in **SECTION 4.1**, significant risk with respect to acid mine drainage (AMD) and neutral mine drainage (NMD) exist from the tailings. The cover system is therefore required to:

- Minimise infiltration to the maximum extent, such that seepage from the TSF is minimised.
- Minimise capillary rise from the tailings into the cover system, thereby contaminating the cover soils.
- Be physically stable
- Be chemically stable
- Be able to sustain agreed Post-Mining Land Use (PMLU) of native vegetation **[2]**.

The tailings have the potential to (refer **SECTION 4.1.1**):

- Leach metal and metalloids and are PAF (i.e., potential to produce AMD); and
- Generate acidic conditions and oxidise soon after discharge into the TSF; and
- Develop a hard pan on the surface soon after deposition resulting in tailings below approximately 0.5 m BGL remaining fresh and unoxidized indefinitely after deposition **[16]**.

Therefore, the PAF tailings require careful management to minimise the risk of environmental harm into the receiving environment from AMD. The cover system is required to limit rainfall infiltration into the tailings to prevent seepage, and mobilisation of oxidation production from the PAF tailings that may form AMD impacting surface water.

Section 3.5.4 of the PRCP states that the rehabilitation of the TSF must achieve the following objectives:

- Control and minimise the transport of oxidation products within the tailings;
- Be capable of supporting vegetation; and
- Be resistant to erosion by wind and / or rainfall runoff.

6.1.3 Potential Risks

Cover systems must be appropriate for the type of waste and reflect a risk-based approach and evaluate the potential long-term impacts of tailings on the receiving environment.

Key risks identified for the long-term storage of tailings include:

- Tailings are PAF with a high sulphide content, and thus have the capacity to generate significant acidity if exposed to atmospheric conditions.
- Tailings material is unlikely to establish and sustain vegetation. This results in reduced vegetation cover, reduced plant health, disruption of ecosystem processes, poor visual appeal, failure to meet agreed PMLU.
- Tailings material is prone to wind erosion if not suitable covered, resulting in smothering of vegetation.
- Tailings material is prone to water erosion if not suitable covered, resulting in excessive downstream sedimentation.

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- Mobilisation of metals and/or metalloids and salts, resulting in surface salts from evaporation of near surface infiltration, and increased solute load to the receiving environment.
- Reduced groundwater quality.
- Consolidation and settlement of tailings can alter the final landform drainage patterns.

6.1.4 Cover System Configurations

A number of potential cover systems have been identified and are proposed to be modelled to assess their relative performance regarding net percolation and determine which option(s) would meet the closure objectives.

The International Network for Acid Prevention's (INAP's) Global Acid Rock Drainage Guide (GARD Guide) **[18]** suggests that a store and release cover system is the most suitable for the climate. However, based on the geotechnical assessments (**SECTION 5**), the availability of soil materials is limited, particularly for topsoil and the reduced permeability layer (RPL). Past cover investigations have nominated a 0.2 m topsoil layer which could be reduced to 0.15 m thick. Modelling has maintained a 0.2 m thick layer to maintain the current cover assumptions and changing this thickness in an uncalibrated water balance model would not alter the interpretation of the modelling results. The volume of clay available on site is also limited, so, a geosynthetic liner (e.g. GCL or HDPE) may be required and will be assessed as potential cover system options.

To address capillary rise, a capillary break will likely be required, dependant on the outcomes of cover system modelling. A capillary break layer would comprise a clean, gravel aggregate product either manufactured on site or imported from a quarry. Recognising the quantity required and cost associated with manufacturing or importing gravel, a geomembrane (e.g. HDPE) would prevent capillary rise and will therefore also be assessed. It is highlighted that a GCL would limit capillary rise but does not prevent the upward movement of salts or other contaminants form the tailings.

The PRCP Schedule references the high risk cover design, specified in the ERC calculator. The hydraulic modelling in this report has focused on alternate designs to inform what other cover systems may be suitable for the DRM site. These cover systems are shown in **TABLE 10** and summarised as follows:

Cover 1: Store and release cover (SAR) system that comprises topsoil, Infiltration Storage Layer (ISL), and Reduced Permeability Layer (RPL). This option is generally consistent with the cover system recommended by the GARD guide, although as previously noted, limited material has been identified on-site which would meet the requirements of a low-permeability layer.

Cover 2: Single capillary break (CAP) cover system (PRCP). Cover 2 adopts a similar profile to Cover 1, however also incorporates a capillary break. A capillary break may be required to decrease capillary rise of contaminants and salts from the tailings material into the cover . Cover 2 also comprises a RPL which requires sourcing adequate material on site.

Cover 3: Cover 3 adopts a similar profile to Cover 2, with the topsoil and ISL, however includes a Geosynthetic Clay Liner (GCL) as the RPL in replacement for a clay soil. This is in recognition that clay may be difficult to source on site. Cover 3 also includes a capillary break as the GCL does not prevent capillary rise.

Cover 4: Cover 4 includes the same topsoil and ISL layer but incudes an HDPE liner as a replacement for the RPL, which would prevent infiltration and capillary rise. The clay RPL and capillary break have therefore been omitted for Cover 4.

It is noted that the thickness of layers in **TABLE 10** are based on similar project experience and would be refined and optimised at subsequent design stages when actual material properties are available.

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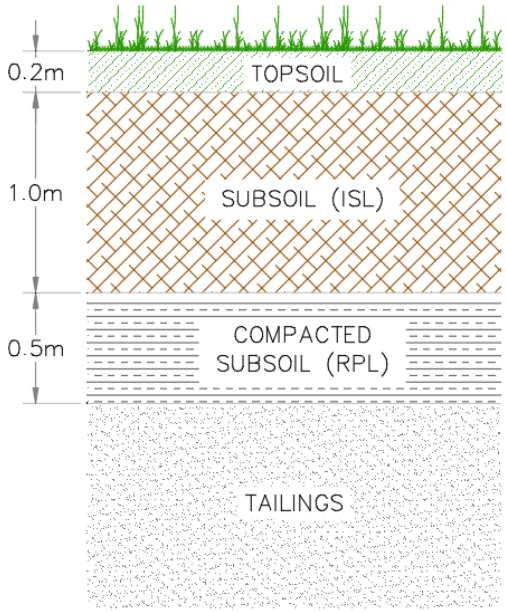
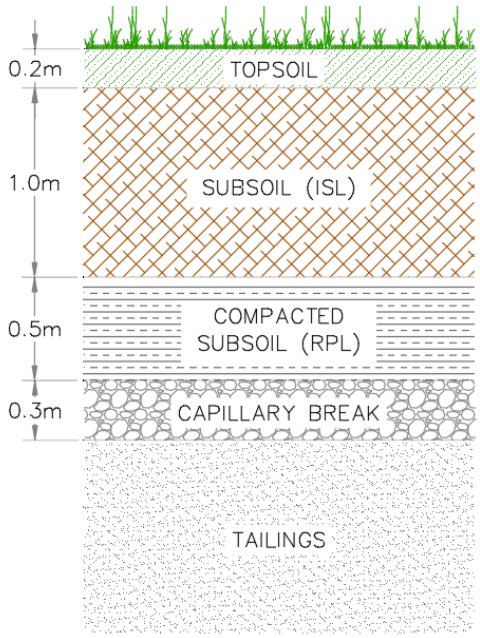
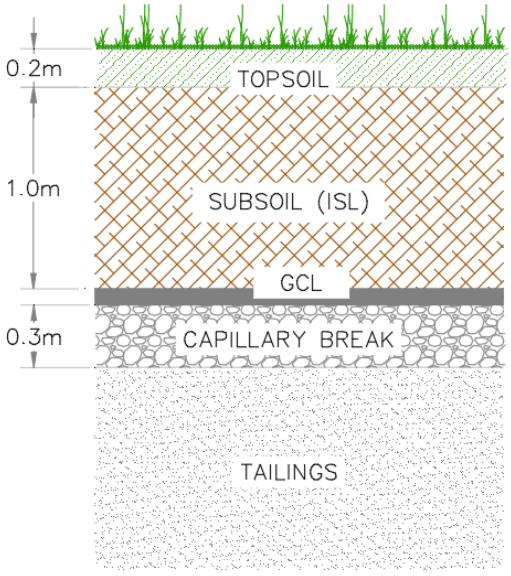
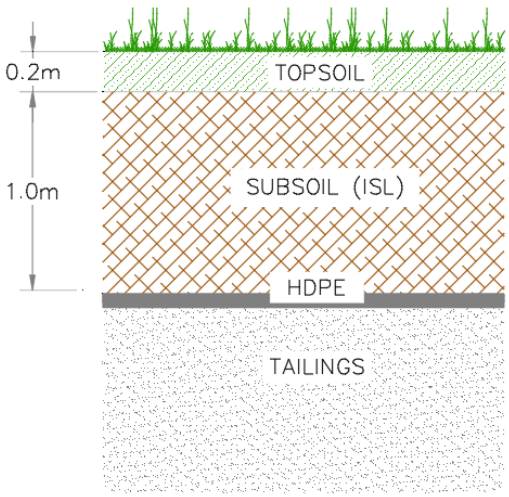
TABLE 10: COVER SYSTEM CONFIGURATIONS

COVER 1: STORE & RELEASE	COVER 2: CAPILLARY BREAK (PRCP)
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL)	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL) • 0.3 m Capillary Break
	
COVER 3: GCL	**COVER 4: HDPE**
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • GCL • 0.3 m Capillary Break	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • HDPE
	

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A description of key cover elements is provided in **TABLE 11**.

TABLE 11: FUNCTION OF COVER LAYERS

Layer	Abbreviation	Purpose	Source and Description
Topsoil	Topsoil	Support vegetation and minimise runoff and erosion.	Borrow area, to be located adjacent to the TSF.
Infiltration Storage Layer	ISL	Store moisture to support vegetation growth and limit downward flux into the tailings.	This material would be sourced from a borrow located near the TSF, and comprise the subsoil, being the material immediately beneath the topsoil and above the weathered rock.
Reduced Permeability Layer	RPL	Limit flux through the cover system into the tailings.	Provide a barrier beneath the ISL to reduce percolation into the underlying tailings material and PAF waste rock when the overlying storage capacity is exceeded.
Capillary Break Layer	CB	Disrupt the upward and downward movement of water (and hence salt) through capillary action by providing a change in pore size distribution.	To comprise a clean gravel product. A manufactured material, sourced from a licenced quarry or crushed and screened NAF waste rock.
Geomembrane (GCL/HDPE)	GM	Low permeability barrier, to be used in the absence of an RPL, if required.	Geosynthetic clay liner (GCL) is a sodium-bentonite clay sandwiched between non-woven geotextile and forms a very low permeability barrier to water but is susceptible to structural changes from high calcium content. High density polyethylene (HDPE) or Linear Low Density Polyethylene (LLDPE) are thermoplastic polymer sheets that form an impermeable barrier to water and many contaminants. Purchased from specialised supply companies and installed by qualified installers.

6.2 Material Requirements

As discussed in the Cover Options Memo **[9]**, material quantities for each of the cover systems identified are summarised in **TABLE 12**. Assumptions made in developing the material quantities are as follows:

- Quantities are based on the conceptual final surface developed by ATCW **[24]**.

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- No bulking factors have been included, all material quantities for earthen materials are as placed
- 10% wastage has been included for the GCL and HDPE materials
- Finalisation of material quantities is subject to cover system modelling as discussed in **SECTION 6.3**.

TABLE 12: COVER SYSTEM CONFIGURATIONS

Layer	Description	Thickness (m)	Units	Material Quantities Required			
				Cover 1 Store and Release	Cover 2 Capillary Break	Cover 3 GCL	Cover 4 HDPE
Topsoil	Haul from borrow area, place and spread without compaction.	0.2	m³	170,200	170,200	170,200	170,200
Infiltration Storage Layer	Haul from borrow area, place and spread without compaction.	1	m³	851,000	851,000	851,000	851,000
Reduced Permeability Layer	Haul from borrow area, place, moisture condition and compact to specified density	0.5	m³	425,500	425,500		
Capillary Break	Source, spread to specified thickness	0.3	m³		255,300	255,300	
GCL	Source and install in accordance with manufactures guidelines	NA	m²			936,100	
HDPE	to be installed by licenced lining contractor.	NA	m²				936,100
Notes: No bulking factors have been applied. All quantities are as placed. Thickness of each layer is subject to finalisation of cover system modelling. 10% wastage included in estimate for GCL and HDPE.							

6.3 Cover System Modelling

Modelling was undertaken with SEEP/W. Modelling was undertaken using a one-dimensional column through the proposed cover system profile and extending 5 m into the tailings profile.

6.3.1 Method

6.3.1.1 Model Geometry

The SEEP/W model comprises a one-dimensional column, comprised of 5 m of tailings overlain by the cover system. While the depth of tailings exceeds 5 m, climatic forcing is generally limited to the top few metres of the modelled profile.

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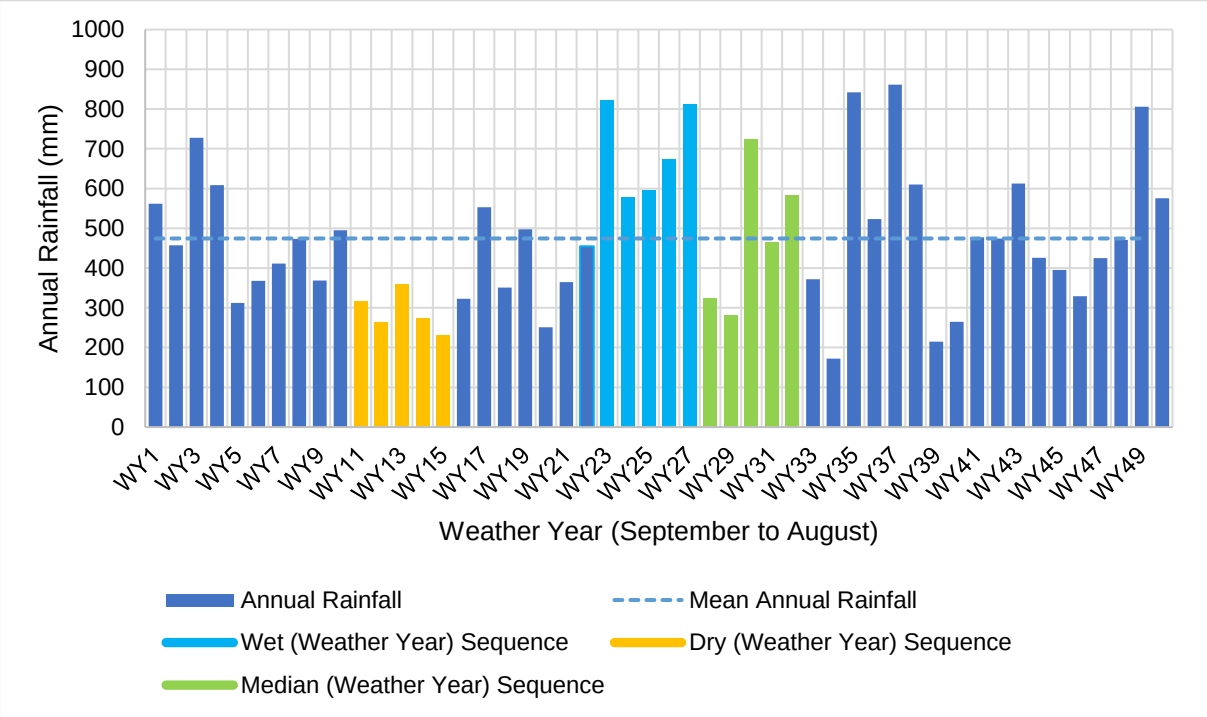
6.3.1.2 Climate Data

For water balance, the data are aggregated based on a weather year, i.e. from the start of the wet to the end of the dry. Defining the weather year in this way assists in correlating the rainfall received to any percolation which may be delayed, in some cases by months. According to the SILO data discussed in **SECTION 3.1.1**, August has the lowest rainfall, whereas September can be more variable due to an earlier break in the seasons. Thus, September was chosen as the start month of the Weather Year (WY).

Rainfall for the weather years from September 1974 to August 2024 is depicted in **GRAPH 2** below. The mean rainfall was 474.4 mm, the maximum rainfall of 861.7 mm occurred in WY37 (2010/2011) whilst the minimum rainfall of 171.8 mm occurred three years earlier in WY34 (2007/2008). Successive wet or dry years can have a major impact on the percolation and the capillary rise from the tailings. The driest five years occurred from WY11-WY15 (1984/1985 to 1988/1989), and the wettest period was from WY23-WY27 (1996/1997 to 2000/2001) as indicted, respectively, by the yellow and blue shading in **GRAPH 2**.

GRAPH 2: ANNUAL RAINFALL



6.3.1.3 Boundary Conditions

The model boundary conditions are outlined as follows:

Climatic Conditions:	Applied to the surface of the cover system as detailed in **SECTION 6.3.1.2**.
Initial Gradient (Free Drainage):	Applied at the base of the model to allow seepage from the model. Seepage rates are calculated assuming the downward flux is equal to the hydraulic conductivity at that point.
Vegetation:	Applied assuming native vegetation, which is discussed further in **SECTION 6.3.1.5**.

Initial moisture content and pore water pressures were defined as an initial water head located 1 m below the tailings surface.

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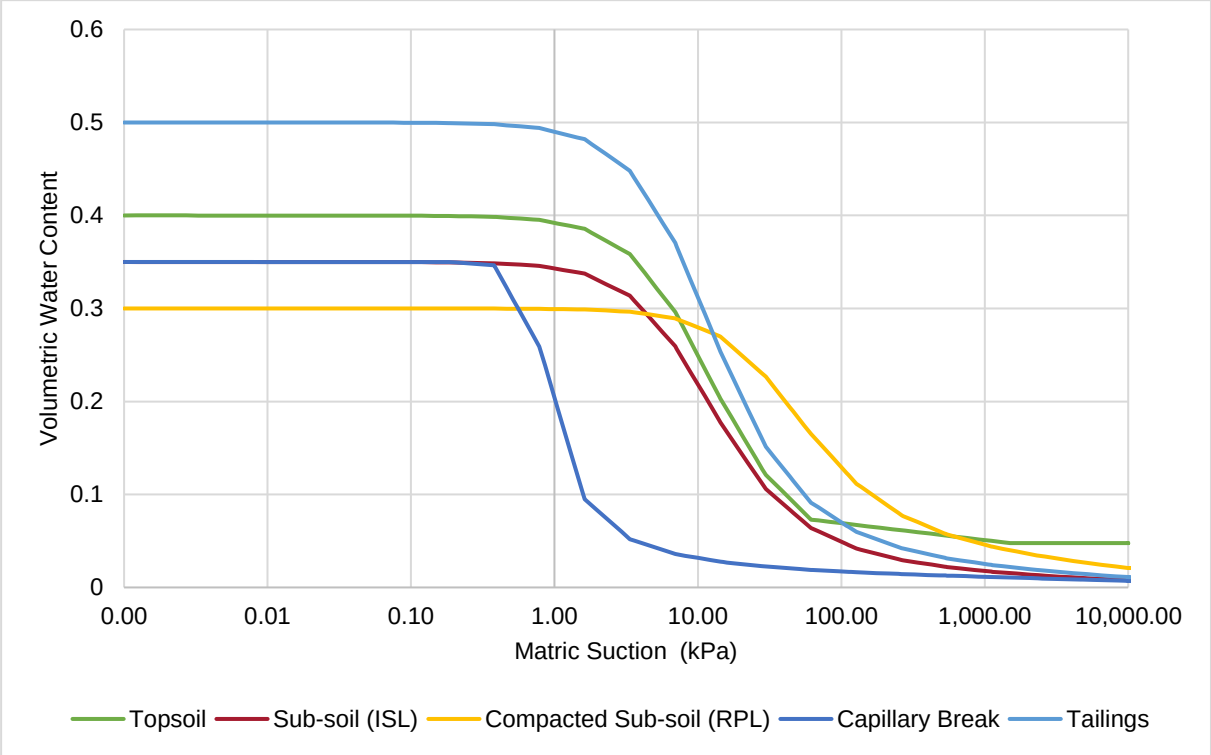
6.3.1.4 Material Properties

The 2025 laboratory SWCC testing results were not available at the time of conducting the SEEP/W modelling. As a result, the default SWCCs were adopted in the SEEP/W, with adjustments made according to previous geotechnical investigations and test pit information. Adopted SWCC's are shown in **GRAPH 3**.

GRAPH 3: SOIL WATER CHARACTERISTIC CURVES



The hydraulic conductivity curves were estimated using SEEP/W's inbuilt Fredlund-Xing-Huang model, as shown in **GRAPH 4**. The model inputs are the SWCCs and saturated hydraulic conductivity, as shown in **TABLE 13**.

TABLE 13: SATURATED HYDRAULIC CONDUCTIVITY

LAYER	SATURATED HYDRAULIC CONDUCTIVITY (m/s)
Topsoil	1×10^{-5}
ISL (sub-soil)	1×10^{-5}
RPL (compacted sub-soil)	1×10^{-9}
Capillary Break	1×10^{-3}
GCL	1×10^{-13}
HDPE	1×10^{-18}
Tailings	1×10^{-7}

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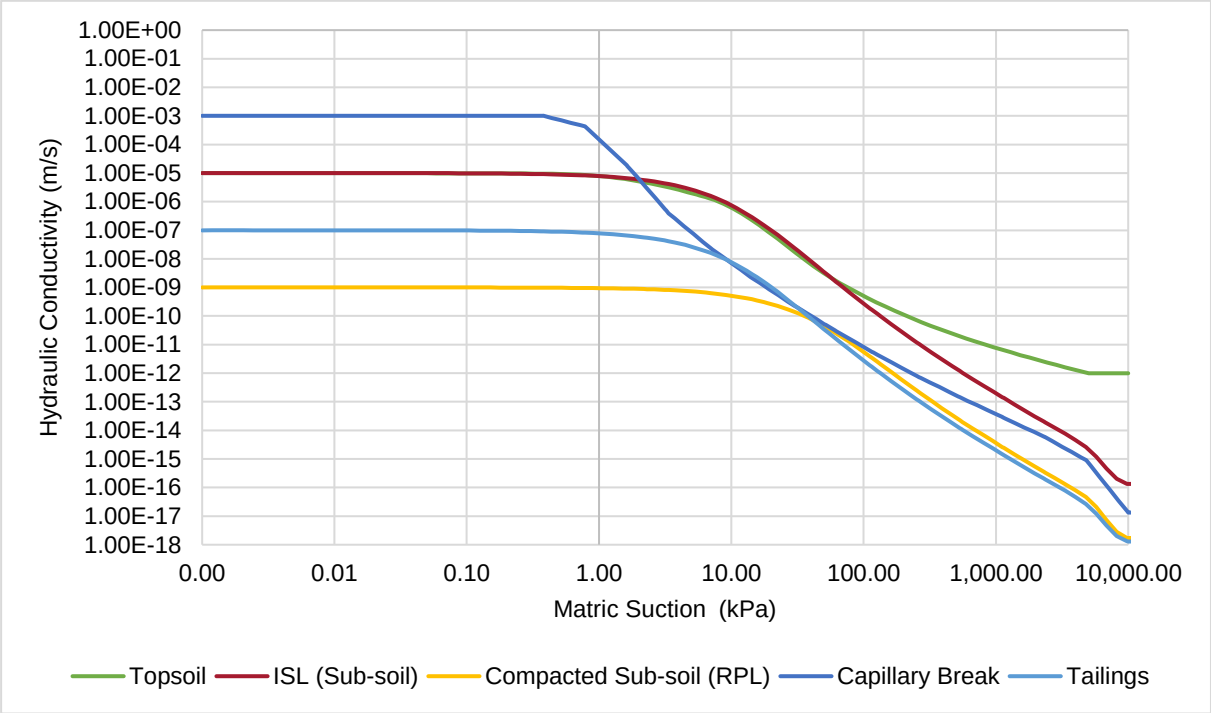
GRAPH 4: HYDRAULIC CONDUCTIVITY FUNCTION



6.3.1.5 Vegetation Model Scenarios

As discussed in the Conceptual Cover Modelling Results Memo **[21]**, vegetation inputs to SEEP/W comprise leaf area index, plant moisture limiting function, normalised root density and cover soil fraction. Vegetation parameters are highly variable depending on species and environmental factors such as rainfall. Vegetation parameters input into the model represent the PMLU of native vegetation in the area, described as low open woodland **[23]** (as discussed in **SECTION 3.6.1**), however do not include any response to environmental factors. Vegetation parameters are outlined in the Conceptual Cover Modelling Results Memo **[21]**.

6.3.1.6 Model Limitations

The cover system model has been developed using empirical formulas and material parameters obtained in laboratory testing, i.e. it has not been calibrated against field data. An uncalibrated model can have an error up to an order of magnitude due to the variability between laboratory and longer-term field obtained values. The primary function of the current, uncalibrated cover system model is to compare cover system options and configurations. It is not intended to accurately predict the performance of each cover system but assess relative performance of the cover system options.

6.3.2 Results and Discussion

6.3.2.1 Overview and Terminology

As discussed in the Conceptual Cover Modelling Results Memo **[21]**, the performance of each cover system has been assessed against the closure criteria discussed in **SECTION 2.2**. The terminology used is summarised as follows:

Water Balance

The water balance shows the balance of moisture within the modelled profile. Results which form part of the water balance are:

Rainfall:	Rainfall depth occurring for the modelled period.

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Runoff:	Rainfall runoff that does not infiltrate into the cover system that reports as surface water runoff off the TSF. It is noted that as the model is one-dimensional, no run on is considered, with rainfall reporting as runoff leaving the model domain.
Evaporation:	Moisture lost from the surface of the soil due to climate.
Transpiration	Transpiration is the water that a plant extracts from the soil through it roots and then expels into the air through aerial parts, such as leaves, stems and flowers.
Flux:	Moisture flux indicates the direction and rate of movement of moisture within and through the cover system profile. Negative flux rates indicate downward movement of moisture (e.g. rainfall infiltrating into the soil or percolation out of the soil and into the tailings) whilst positive flux rates are upward (e.g. evaporation or evapotranspiration to the atmosphere or capillary rise at the tailings and cover interface).
Percolation:	The volume of water moving out of the cover system profile and into the underlying tailings (Noting capillary rise is not deducted from these values).

Volumetric Water Content and Degree of Saturation

The volumetric water content (VWC) is calculated on a daily basis to account for the redistribution of the net infiltration through the soil profile which can then potentially enter the underlying tailings. The plant available water content (PAWC) is typically calculated as the difference between field capacity (nominally 33 kPa) and permanent wilting point (nominally 1,500 kPa). If drier than the wilting point, the matric suction no longer allows for uptake of moisture by plants.

Degree of Saturation provides the same chart to the VWC with the difference of the Y axis displaying the ratio of saturation from the predicted moisture content (0.03 to 0.5) to saturated (1) (refer **GRAPH 11**).

6.3.2.2 Water Balance

50 YEAR MODELLED – WATER BALANCE

Graphs depicting the cumulative WY water balance for the 50-year modelled duration are provided in **GRAPH 5** to **GRAPH 8**. A summary of the water balance for the 50 year modelled duration is provided in **TABLE 14** and **TABLE 15**.

Model results indicate runoff accounts for less than 1% of the rainfall volume on an average annual basis. Runoff was mainly predicted to occur in WY35 with runoff reported on 30 January (45.2 mm runoff from 84.2 mm rainfall) and 9-11 February (127 mm runoff from 170.6 mm rainfall). The runoff was in response to a very wet January which resulted in near saturated conditions in the topsoil and ISL. The simplification used by one-dimensional water balance models does not allow for accurate runoff prediction and hence only extreme events are likely to trigger runoff.

The remaining rainfall infiltrates into upper layers of the cover system and is subsequently lost through evaporation and transpiration, which typically represents more than 17% and 81%, respectively, of the rainfall volume. Importantly, NP met the performance criteria for all model scenarios to less than 1 mm/yr, limiting the percolation into the underlying tailings material for all cover system options.

The performance of the cover systems is predicted to achieve the performance objectives described in **SECTION 2.2**. Objectives achieved include minimising infiltration, minimising capillary rise, and being able to sustain agreed PMLU of native vegetation. The similarity between cover system performance is a result of the constant vegetation parameters and the moisture remaining predominantly in the ISL.

TABLE 14: MEAN ANNUAL WATER BALANCE

Cover	Mean Annual Water Balance				
	Rainfall (mm/yr)	Runoff (mm/yr and % of Rainfall)	Evaporation (mm/yr and % of Rainfall)	Transpiration (mm/yr and % of Rainfall)	NP (mm/yr and % of Rainfall)
CAP	472.7	2.6 (0.5%)	83.8 (17.7%)	386.4 (81.7%)	0.6 (0.1%)
SAR	472.7	2.6 (0.5%)	83.8 (17.7%)	386.6 (81.7%)	0.7 (0.2%)
GCL	472.7	3.5 (0.7%)	85.9 (18.2%)	383.5 (81.1%)	0.0 (0.0%)
HDPE	472.7	3.5 (0.7%)	85.9 (18.2%)	382.4 (80.9%)	0.0 (0.0%)

Note: Minor errors in the water balance are related to changes in soil moisture storage and model calculation errors.

WETTEST, MEDIAN AND DRIEST WEATHER YEAR – WATER BALANCE

Analysis of the percolation reported in the wettest and driest years can assist in understanding the variability of the predictions and whether percolation is likely to exceed the performance criteria. The wettest weather year was WY37, which shows that < 5 mm/yr percolation is predicted to occur from the CAP and SAR cover systems (**TABLE 15**). For median and drier years and for all years for the GCL and HDPE, it was predicted that no percolation would occur. Given the low rainfall and high evaporation rates, this is not unexpected.

TABLE 15: PERCOLATION IN WETTEST AND DRIEST YEARS

	Wettest Weather Year (WY37)		Median Weather Year (WY42)		Driest Weather Year (WY34)	
	Rainfall (mm/yr)	Percolation (mm/yr and % of Rainfall)	Rainfall (mm/yr)	Percolation (mm/yr and % of Rainfall)	Rainfall (mm/yr)	Percolation (mm/yr and % of Rainfall)
CAP	861.7	2.6 (0.3%)	474.4	0.0 (0.0%)	171.8	0.0 (0.0%)
SAR	861.7	4.3 (0.5%)	474.4	0.0 (0.0%)	171.8	0.0 (0.0%)
GCL	861.7	0.0 (0.0%)	474.4	0.0 (0.0%)	171.8	0.0 (0.0%)
HDPE	861.7	0.0 (0.0%)	474.4	0.0 (0.0%)	171.8	0.0 (0.0%)

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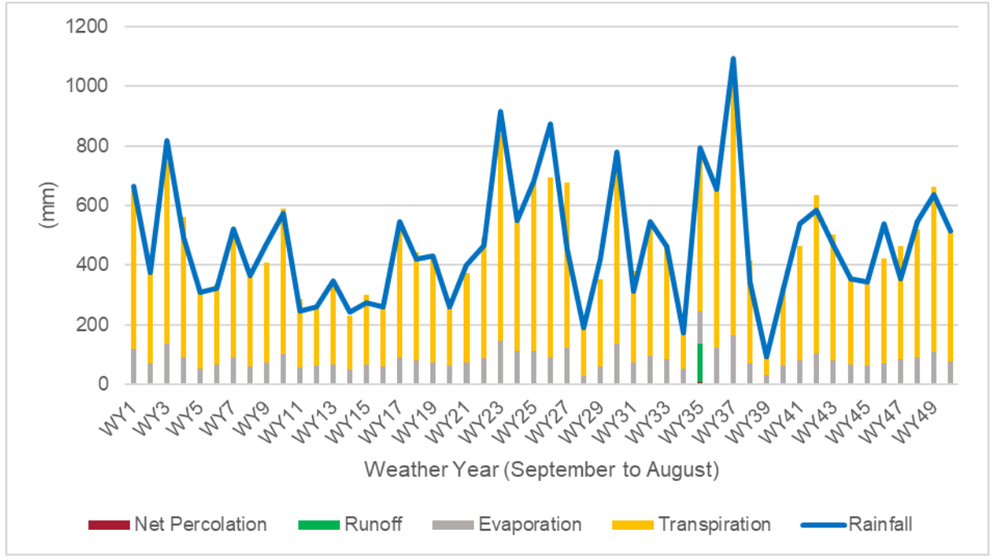
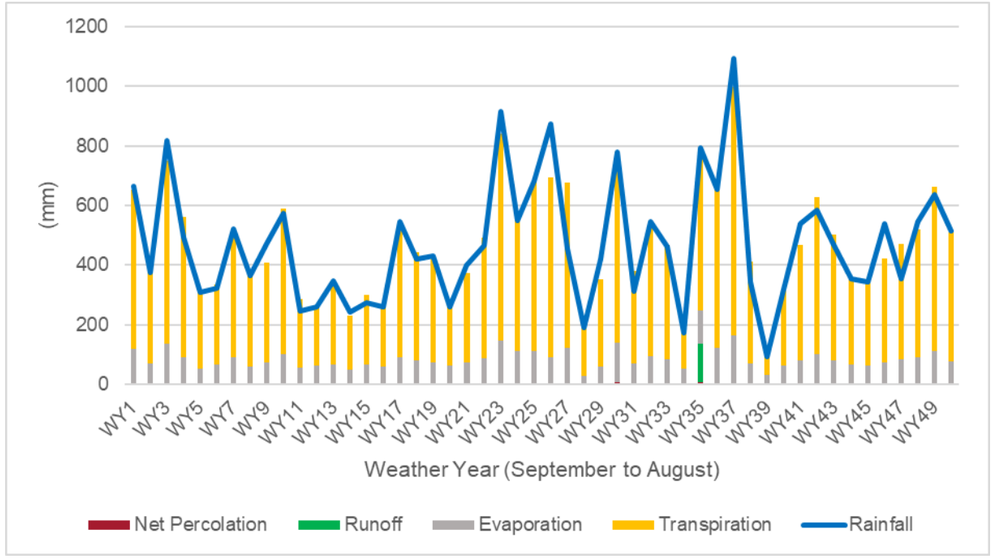
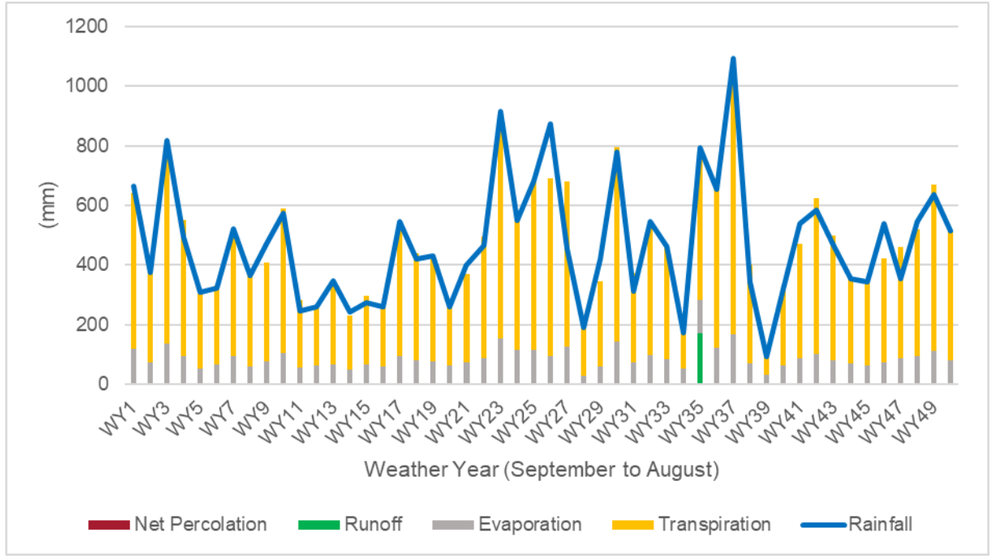
GRAPH 5: CAP COVER WATER BALANCE



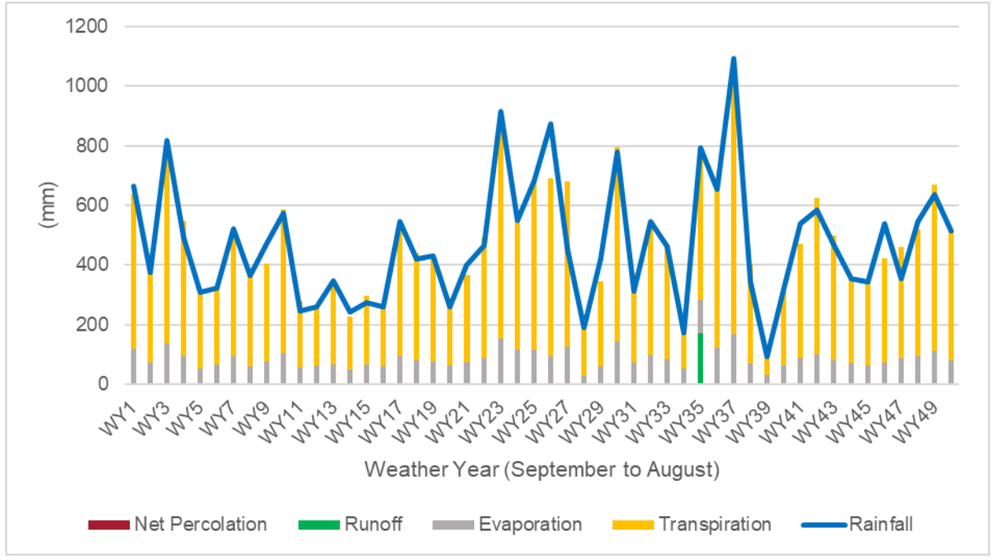
GRAPH 6: SAR COVER WATER BALANCE



GRAPH 7: GCL COVER WATER BALANCE



GRAPH 8: HDPE COVER WATER BALANCE



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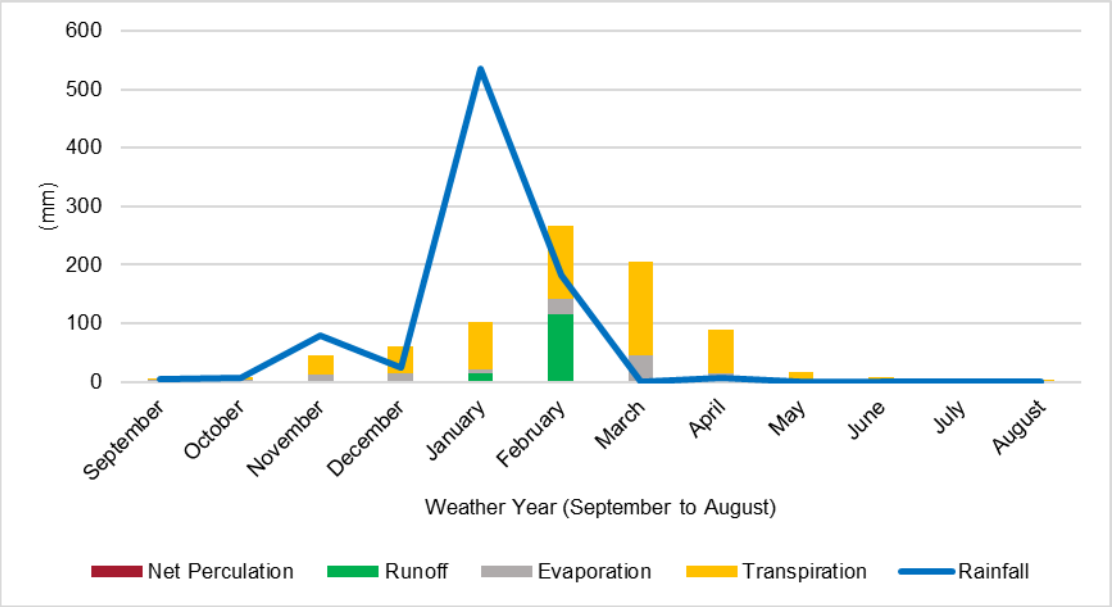
6.3.2.3 Weather Events of Note

Selected weather years were analysed to better understand the performance of the cover system in different weather scenarios.

a) WY35 had the highest Percolation, despite also having the highest Runoff (**GRAPH 9**)

Weather Year 35 had the second highest rainfall (842 mm) and was predicted to result in 8.8 mm percolation for the SAR cover, equating to 1% of the rainfall for that WY. This is likely due to high rain falling consistently throughout January, as well as two consecutive days of high rainfall in first half of February. Longer duration rainfall will keep the soil saturated to a point where evaporation and transpiration will not be able to dry out the soil, and thus percolation can occur.

GRAPH 9: WY 35 – HIGHEST PERCOLATION AND HIGHEST RUNOFF



b) WY 37 had the highest rainfall but not the highest NP (**GRAPH 10**)

Weather Year 37 had the highest rainfall of 861.7 mm, but only 0.46% of the rainfall reported as percolation in the SAR cover. This is likely due to the rainfall being spread out over the summer wet season allowing the vegetation to take up all the infiltrating rainfall and not allow percolation to occur.

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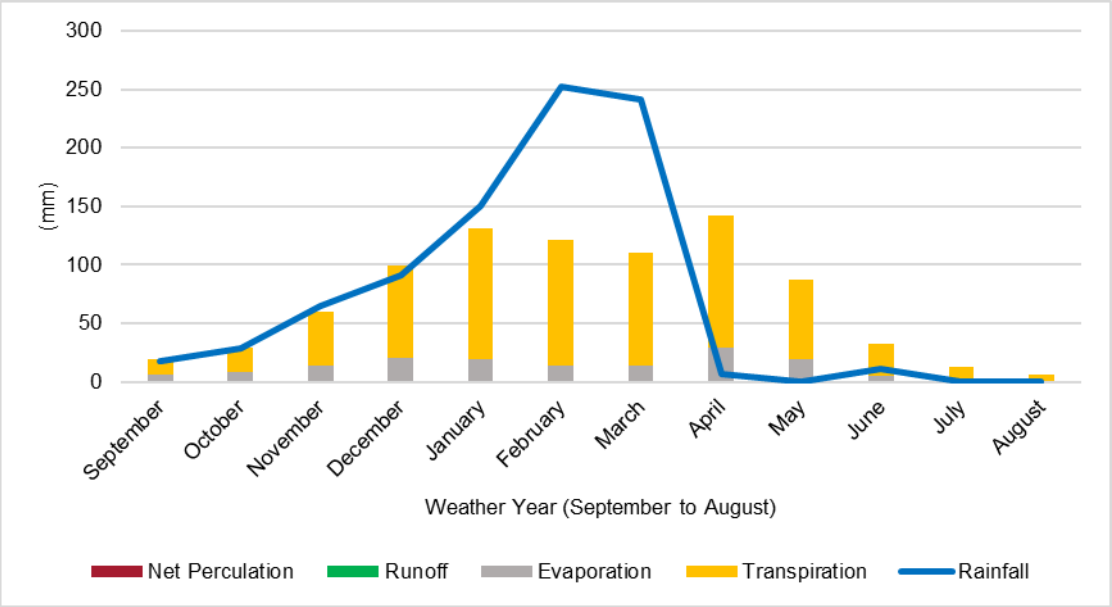
GRAPH 10: WY 37 – HIGHEST RAINFALL BUT NOT HIGHEST PERCOLATION



6.3.2.4 Degree of Saturation

As discussed in the Conceptual Cover Modelling Results Memo **[21]**, saturation in the topsoil and upper layers of the ISL is highly variable, with increased water saturation after rainfall events, followed by rapid drying due to evapotranspiration. At greater depths within in the ISL, increases in saturation are observed only following large rainfall events, indicating a significant rainfall depth is required for infiltration deep into the cover system profile. The tailings moisture content steadily decreases through the modelling period for all scenarios except the store and release cover where occasional increases in moisture content are observed. As the lower boundary of the model is free-draining, the decrease for most scenarios is due to downward movement of moisture through the tailings and not upward movement via capillary rise.

GRAPH 11 to **GRAPH 14** depicts a range of saturation within the cover system as a response to rainfall events, for the 5 wettest weather years (WY23 to WY27).

Some key observations for all cover systems are:

- The degree of saturation increases after rainfall events.
- The ISL varies greatly with rainfall, and loses the moisture slowly over the following months, thus is storing and releasing water and working as intended. The ISL is typically dry at the beginning of the following weather year showing that the soil storage capacity is near its maximum and able to store the following years rainfall.
- The RPL varies less than the ISL due to the higher clay content and low rainfall environment. Very little is transmitted through the RPL and hence it is performing as required.

The degree of saturation in the CAP and SAR cover systems shows water moves predominantly in the topsoil and ISL but also moves into the RPL. In the CAP profile the moisture accumulates in the RPL because of the capillary break, as expected. The increased moisture in the RPL also results in sustained moisture in the topsoil and ISL compared with the SAR cover, where the moisture percolates into the tailings in these very wet conditions. The SAR cover system performs similarly to the CAP cover system, except the decreased permeability results in no percolation into the tailings. In the HDPE cover system, the moisture rapidly moves through the profile and accumulates above the HDPE (i.e. 0.01 m above the tailings) but does not enter the tailings. Moisture which accumulates above the low permeability layers can potential move laterally but is also likely to be used by the plants.

Overall, there is a net deficit of rainfall which will require plants to have drought tolerance to be able to survive during the dry season and lower rainfall years. The use of endemic native species will improve the potential for successful vegetation survival and establishment.

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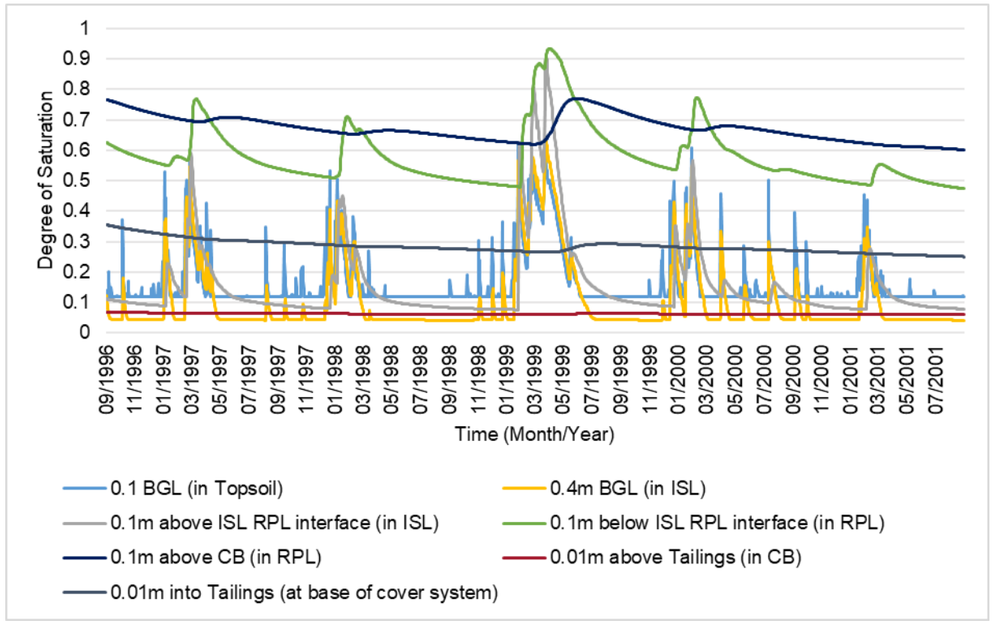
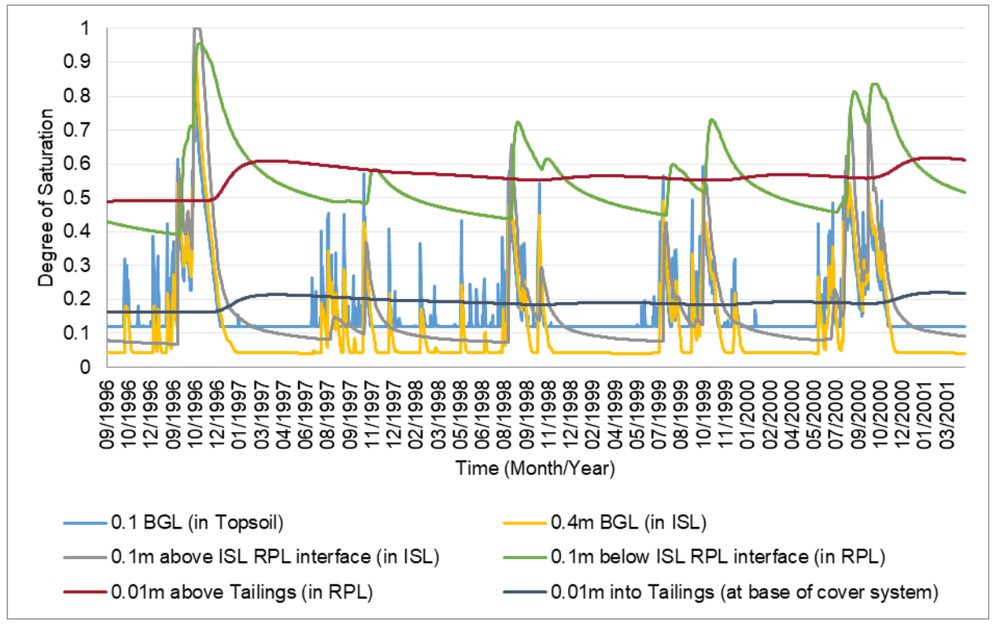
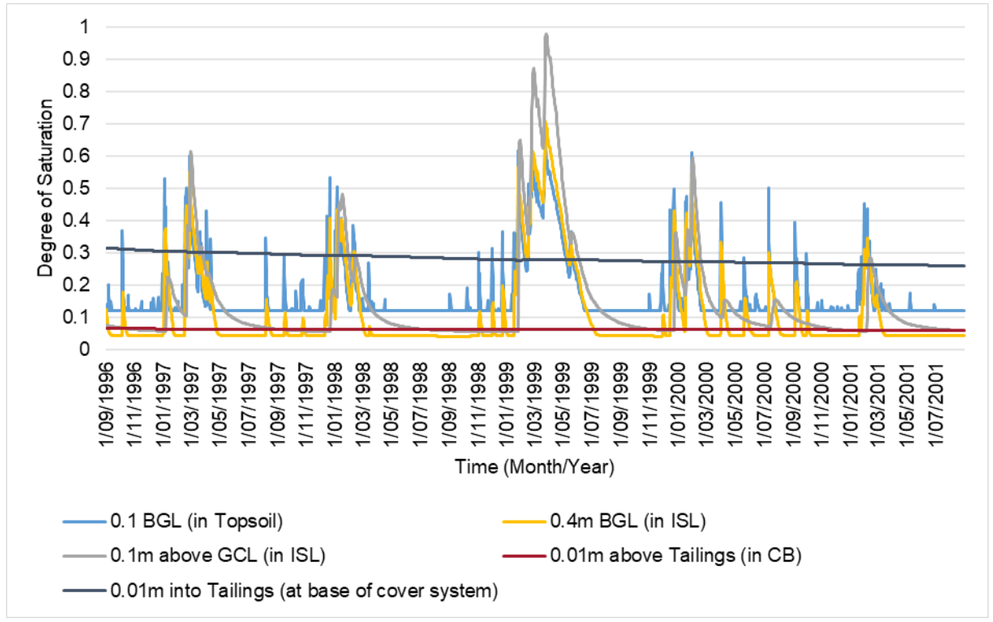
GRAPH 11: CAP COVER – DEGREE OF SATURATION



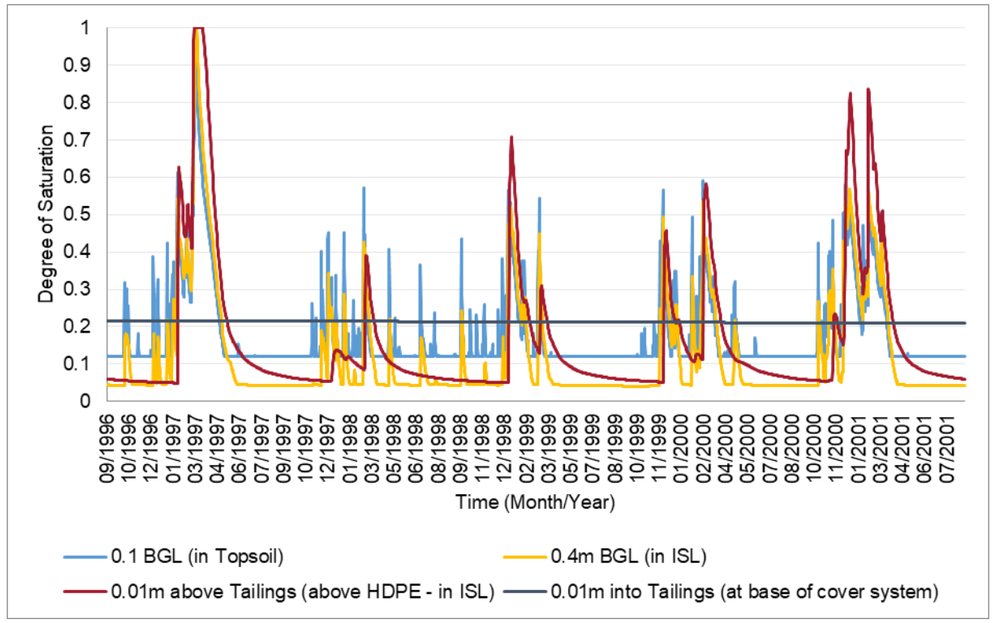
GRAPH 12: SAR COVER – DEGREE OF SATURATION



GRAPH 13: GCL COVER – DEGREE OF SATURATION



GRAPH 14: HDPE COVER – DEGREE OF SATURATION



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6.3.2.5 Net Percolation

Net Percolation (NP) into the tailings, 0.01 m below the interface of the cover system and the tailings, is close to zero (refer to **TABLE 16** and **GRAPH 15**).

The modelling NP results indicate downward percolation is an order of magnitude higher in the SAR and CAP cover systems, though all are relatively small flux into the tailings. Capillary rise (+ve flux) is predicted for all cover designs except for the HDPE. The capillary rise is small but is greater than the percolation (-ve flux) which suggests salts may move into the cover soil and are likely to accumulate (**GRAPH 15**).

TABLE 16: PERCOLATION STATISTICS

Cover	Percolation Statistics									
	Mean (mm/yr)		Median (mm/yr)		90th percentile (mm/yr)		Maximum (mm/yr)		No. events >5% of Rainfall	
	+ve	-ve	+ve	-ve	+ve	-ve	+ve	-ve	+ve	-ve
CAP	1.1	0.6	0.9	0.0	2.3	2.2	3.6	5.1	17	12
SAR	1.5	0.8	1.3	0.0	3.2	2.8	5.4	8.0	53	14
GCL	1.0	0.0	1.0	0.0	1.4	0.0	1.8	0.0	0	0
HDPE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0	0

Overall, the net percolation represents a small proportion of the rainfall received. However, it must be remembered that these results are predicted from an uncalibrated model and the actual percolation in the field may be an order of magnitude lower or higher than predicted by the model. For the negligible net percolation predicted for the HDPE cover system, this potential error would still result in very small amounts of net percolation. For the higher net percolation predicted for the SAR, CAP and GCL cover systems, this range of accuracy may result in more significant percolation into the tailings and/or capillary rise.

Investigation of the variability of the annual percolation can indicate the likelihood of the cover systems achieving the performance requirements. **TABLE 16** shows that for the CAP and SAR cover, the negative median results are much lower than the mean, indicating that the results are skewed. The 90th percentile of the positive and negative percolation is lower than the maximum results, indicating that the high percolation events are not overly common over the 50 year modelling period. The number of events that exceed 5% of the rainfall are higher in the CAP and SAR covers. However, considering the modelling period of 50 years (18,260 days), 53 events only account for 0.3% over the 50 year modelling period. There are no events that exceed 5% of the rainfall in the GCL or HDPE covers.

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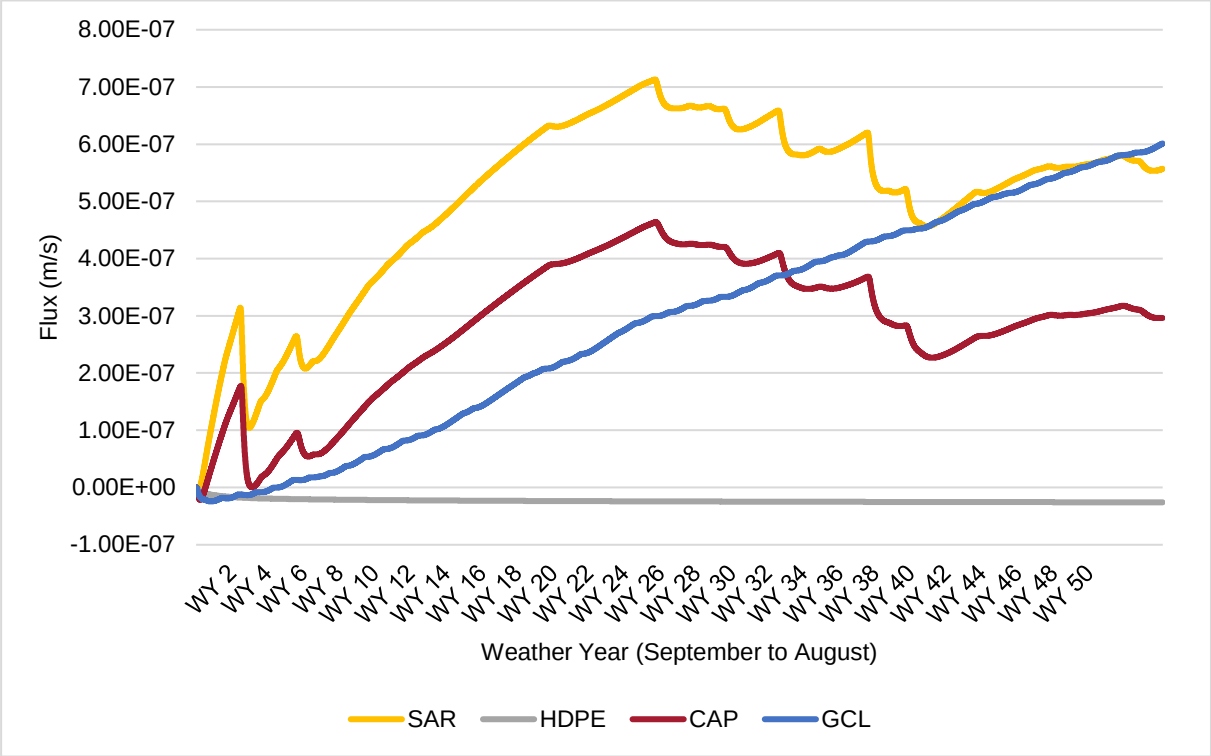
GRAPH 15: CUMULATIVE PERCOLATION AT TOP OF TAILINGS (0.01M BELOW COVER/TAILINGS INTERFACE)



The percolation at the tailings interface, for the SAR, CAP, and GCL covers, is net upwards, as shown in **Graph 15**. This means that salts from the tailings may move into the cover system. At a point in the cover profile the upward movement in dry years will be balanced by the downward movement in wet years. This is the depth at which salts from the tailing can rise to and accumulate. This is important to know for the plants and potential environmental impact. If that point is within about 50 cm below ground level (BGL), there may be a problem with plant growth, and if that point is within about 20 cm BGL, it may result in an environmental problem.

The cumulative flux for the SAR cover is show in **GRAPH 16**. For the SAR, CAP, and GCL covers, there is a net downward flux to 0.9 m bgl, and at 1.0 m BGL it switches to a net upward flux. This indicates that salts from the tailings may accumulate around 0.9 – 1 m depth over the longer term. On an annual basis, the salt may rise higher but wetter years will leach the salt back through the profile. Regardless, salts accumulating at 1 m depth are unlikely to significantly impact native vegetation.

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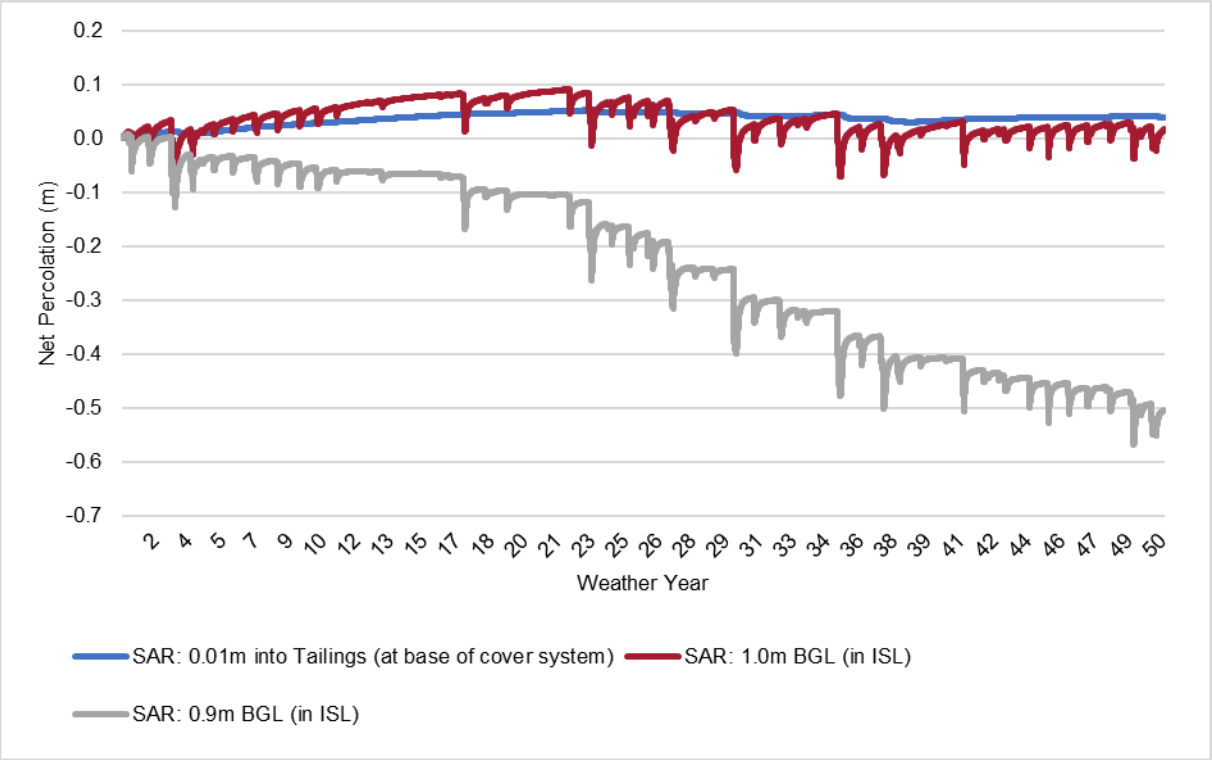
GRAPH 16: SAR - CUMULATIVE NET PERCOLATION



None of the cover systems modelled have a flux rate more than 1 x 10-8 m/s, thus satisfying the completion criteria described in **SECTION 2.2.2**.

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7 LANDFORM CONCEPTUAL DESIGN

This section provides details on the erosion modelling of the conceptual final landform for the TSF, further details can be found in the Erosion Modelling Memo **[25]**.

7.1 Erosion Modelling

Average annual erosion rates for the final landform were estimated using the Water Erosion Prediction Project (WEPP) model. The purpose of WEPP modelling is to estimate the net soil loss for rehabilitated areas. Results are considered conceptual and used to demonstrate the typical surface water controls required to prevent problematic erosion.

7.1.1 Method

7.1.1.1 Target Erosion Rate

The primary objectives for the TSF closure landform with respect to erosion are to:

- Avoid erosion which would impact the performance of the cover system (i.e. through reducing thickness of the cover system and impacting cover system performance).
- Prevent exposure of the underlying tailings.
- Ensure long-term erosional stability of the landform.

The key driver for preventing erosion will be to establish and maintain vegetation over the rehabilitated landform. For the purpose of this assessment, a target soil loss rate of 5 t/ha/yr has been assigned as the maximum average soil loss rate for all years of modelling **[1]**.

7.1.1.2 Model Duration

A model duration of 50 years was adopted as it is considered to be an appropriate model duration to determine average erosion rates. The 50-year period adopted includes years of high and low rainfall, allowing assessment of loss rates for varying climatic conditions.

Vegetation is assumed to be established at the beginning of the model start time. Temporary erosion control structures would be in place until sufficient ground cover was established and are established by a construction and rehabilitation works completion date. Vegetation coverage is discussed in **SECTION 7.1.1.6**.

7.1.1.3 Geometry

The geometry for the model was adopted from the concept TSF Closure Landform Design **[24]**, undertaken by ATCW. As outlined in that report, generally, the final tailings beach slopes are 1.5% for first 500 m (top 1/3 of beach), 1% for second 500 m (middle 1/3 of beach) and 0.67% for remaining slopes (bottom 1/3 of beach).

WEPP recommends that flow path lengths do not exceed 100 m **[26]**, with potential to overestimate the erosion rates for slope lengths that exceed this distance. For the purpose of the model, a flow path length of 500 m at 1.5% was adopted. This flow path is conservative recognising the following:

- WEPP states that erosion is likely to be overestimated for slope lengths greater than 100 m, therefore results are likely conservative.
- The maximum flow path length is limited to around 500 m by surface water drains as discussed in **SECTION 7.3**.

7.1.1.4 Climate Data

A 50 year synthetic climate file was generated using the CLIGEN stochastic weather generator. Fifty years (1975 to 2024) of patched daily temperature (maximum and minimum) and rainfall data was imported into CLIGEN.

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7.1.1.5 Soil Input Parameters

WEPP modelling was undertaken prior to receiving the entirety of laboratory results from the 2024 borrow source investigation **[12]**. In the absence of laboratory test data from the borrow source investigation, material parameters were informed by historical investigation for the TSF embankment **[19]** and experience with similar sites. Visually, materials from the previous investigation and the samples obtained from the 2024 **[12]** investigation were similar. Additionally, laboratory results obtained following completion of the modelling, and prior to writing this report, further demonstrated consistency. The permeability results were within the same order of magnitude and PSD results were very similar to the Mix 1 from **[19]** used as the topsoil material.

The soil input parameters adopted in the WEPP model for the TSF beach slope are summarised in **TABLE 17**.

TABLE 17: WEPP MODEL SOIL INPUT PARAMETERS

Parameter	Topsoil	Subsoil (ISL)
Clay (%)	14	33
Sand (%)	17	18
Rock (%)	69	49
Organic Matter (%)	1.1	0.5
Cation Exchange Capacity (meq/100g)	10	10

7.1.1.6 Vegetation

The PMLU for the site is native ecosystem, which will support a range of native grasses and shrubs (refer **SECTION 3.6**).

The approved PRCP rehabilitation objective for vegetation is to achieve a ground cover 70%. Three vegetation scenarios were used in the WEPP model: no vegetation (0 %) (worst case), 30%, and 70% ground cover. Static vegetation cover was adopted for all scenarios (i.e., vegetation does not grow or die off over the course of the simulation), aligning with the performance criteria, noting that static vegetation cover may not represent site conditions (e.g., seasonal dieback and extended wet or dry seasons).

It is highlighted that plant parameters are influenced by a wide range of factors including climate conditions, plant species and conditions. No plant specific inputs for the particular species discussed in **SECTION 3.6** were available, and as such, values were adopted based on similar project experience.

7.1.1.7 Model Limitations

The following limitations are noted:

- The WEPP model results are based on static (no change in vegetation cover over time) or no vegetation cover as stated in the modelling assumptions. No allowance has been made for seasonal dieback and increased soil loss rates as a result of rainfall after a dry period with reduced vegetation cover.
- The WEPP model results are based on a simplified cross section geometry (e.g. 500 m slope at 1.5 %). Localised erosion rates are likely to occur which exceed the average annual soil loss rates presented, which represent the annual average soil loss rates for the entire slope length.

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- Some material parameters used are not based on site specific data, as described in **SECTION 7.1.1.5**. Variation to soil properties would impact the WEPP model outcomes (percentages of clay, sand and rock, organic matter and cation exchange capacity).

7.1.2 Results and Discussion

The primary output from WEPP is the estimated soil loss rate expressed in tonnes per hectare per year (t/ha/yr). The milestone criteria outlined in the approved PRCP is to achieve an average soil loss rate of less than 5 t/ha/yr. The average annual soil loss rates predicted by the WEPP model are summarised in **TABLE 18**.

Results indicated that for the TSF beach slope, with 70% vegetation cover, the soil loss rates were 1.11 t/ha/yr, which is less than a quarter of the target soil loss rate. At 30% cover, the soil loss rates were 3.89 t/ha/yr, which still achieves the target loss rate. At the worst case scenario of 0% cover, the soil loss rates were 12.7 t/ha/yr, which does not achieve the target soil loss rate.

Results indicate while acceptable erosion rates can be achieved with proposed final landform, vegetation will be critical to successful rehabilitation.

TABLE 18: TSF BEACH SLOPE AVERAGE ANNUAL SOIL LOSS

PRCP Target Average Annual Soil Loss (t/ha/yr)	WEPP Modelling Result Average Annual Soil Loss (t/ha/yr)		
70% Vegetation Cover	70 % Vegetation Cover	30 % Vegetation Cover	0 % No Vegetation Cover
<5	1.11	3.89	12.70

7.2 TSF Embankment

Rehabilitation of the embankment will comprise flattening the batter from 1.5H:1V to 6.5H:1V, undertaken by pushing excess fill material from the crest of the embankment to fill the downstream toe of the embankment.

The embankment rockfill, as discussed in the Erosion Modelling Memo **[25]**, will not be subject to the same erosive mechanisms as soils on the rehabilitated tailings beach, where low flow rate have the potential to detach soil particles over long time periods, gradually eroding the cover system. The critical design aspect for the embankment rock fill is to ensure for extreme rainfall events, that the rockfill is coarse enough to resist displacement caused by the flow over the embankment.

A hydraulic assessment has been undertaken by ATCW **[28]**, which indicates flow velocity on the embankment would range from 1.5 m/s at the crest to 2.1 m/s at the toe of the embankment. Recommended D50 rock sizing for this range of flow velocities range from 150 mm to 300 mm. Careful consideration during earthworks would be required to preferentially place the larger particles towards the base of the embankment, where flow velocities are higher.

7.3 Surface Water Management Considerations

Erosion modelling indicated very low erosion rates on the TSF. However, the external catchment to the TSF has multiple, natural gullies reporting to the TSF. Natural gullies would introduce concentrated flows to the rehabilitated tailings surface, likely to cause localised erosion and scour. To reduce the risk of erosion and scour, a network of surface channels is proposed to convey flows from the upstream catchments to the discharge outlet structure.

The proposed conceptual general arrangement for the final drainage of the TSF is shown in **DIAGRAM 2**. The conceptual drainage channels shown are intended to allow for the capture of runoff from upstream external catchment sources, rather than incidental rainfall on the TSF itself. The TSF closure surface was modelled to incorporate the shedding surface to convey runoff from the upstream connected catchments towards the repurposed Stage 2 emergency spillway **[28]**. As part of detailed

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design, the surface will be modelled with the conceptual drainage channels to ensure there is no ponding on the TSF surface post closure to reduce the potential for seepage in channels with low to no longitudinal grade.

The channel dimensions are to maintain low velocity by maximising channel width (compared to depth). The channel is to be rock lined with a geotextile underlay, as shown in **DIAGRAM 3**. The drains will be designed to convey peak flows to a suitable design event.

DIAGRAM 2: CONCEPTUAL SURFACE WATER DRAINAGE

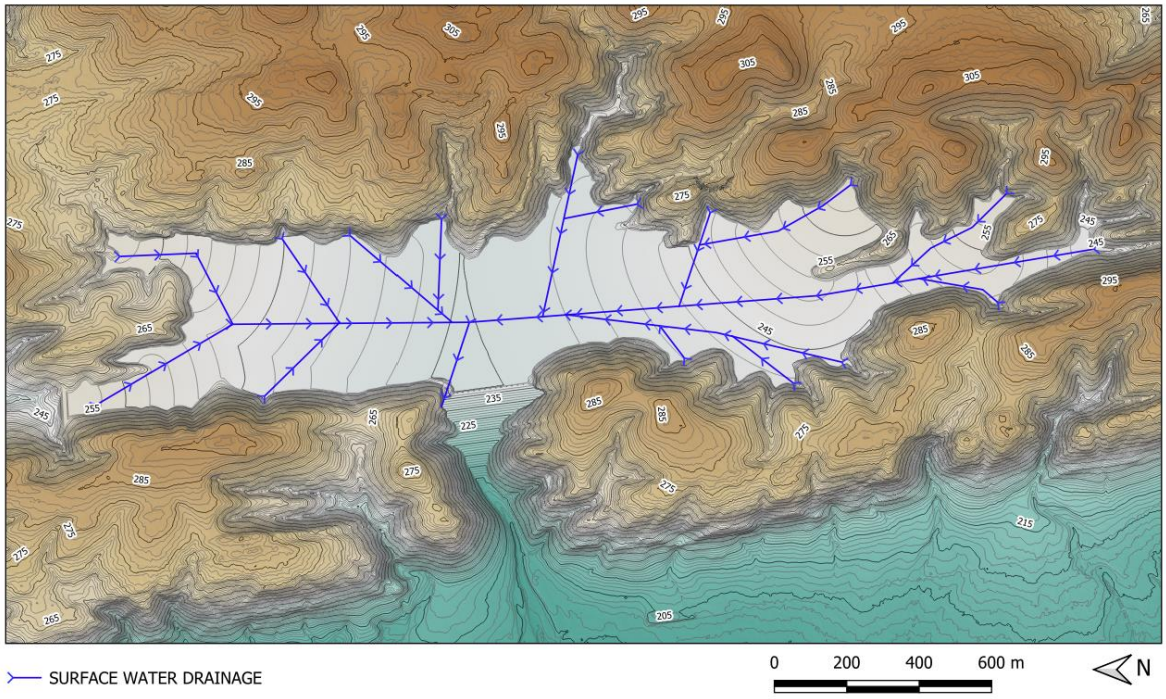
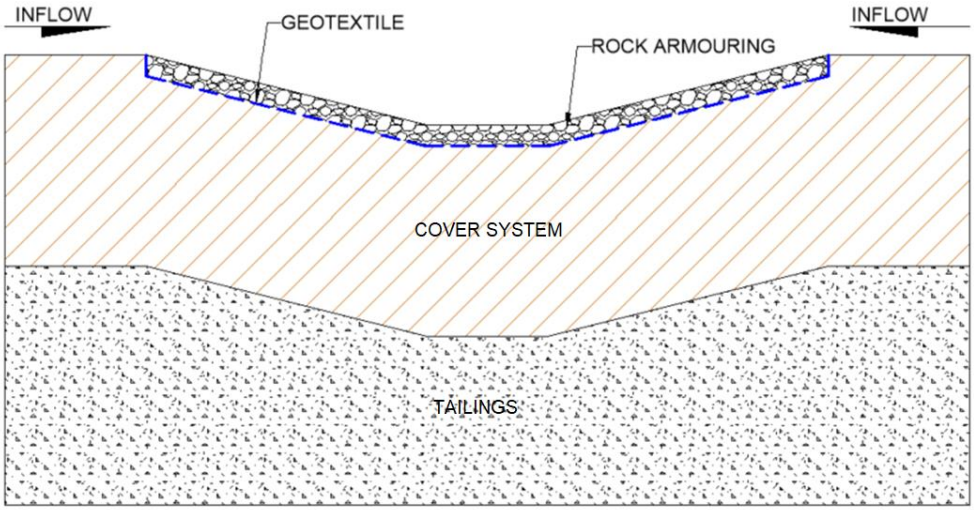


DIAGRAM 3: DRAIN CONCEPT SECTION



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7.3.1 Water Inventory Management at Closure

A concept level water management strategy was developed for site closure **[29]**. This assumes the removal of all major water infrastructure, the naturalisation of existing drainage, and reconnection with downstream watercourses at closure.

In order to achieve the removal of major water infrastructure the stored water inventory must be disposed of with some water inventory pumped to the TSF (enabling subsequent decommissioning of the storages). The total volume of water in the TSF at closure would be in the order of 2,750 ML.

Considering the large catchment area reporting to the TSF (338 ha) and the likely significant volume of water stored at closure, it is considered unlikely that the TSF would dry out without some form of intervention.

For this concept level assessment, enhanced evaporation was adopted. This was based on cost, simplicity, and absence of residual impacts.

Modelling showed that enhanced evaporation, using mechanical evaporators, would be an effective way of removing water from the TSF. A range of water throughput rates were tested, and a throughput rate of 600 m^3/hr and evaporative efficiency of 30% was adopted for modelling. This provided a water loss rate of 180 m^3/hr, allowing the TSF to dry out within 2.5 years.

If this timeframe is considered too long the capacity/number of the evaporators could be increased. Alternatively, the evaporators could be installed prior to closure, to shorten the timeframe between closure and placement of cover materials on the TSF.

7.4 Geotechnical Considerations

The flattened closure embankment of the batter slope to 6.5H:1V will stabilise the TSF embankment in the long-term as well as prevent water ponding and being stored within the TSF. The closure landform is designed to allow for stormwater to self-shed in a controlled manner towards the outlet channel and therefore, no water storage capacity has been allowed within the TSF final landform.

A detailed stability analysis will need to be performed as part of detail design of the TSF closure profile.

7.5 Conceptual Final Landform Geometry

To allow for a self-shedding closure landform whilst also minimising erosion (refer erosion results in **SECTION 7.1.2),** the final tailing beach slopes are proposed as follows: 1.5% for first 500m (top 1/3 of beach), 1% for second 500m (middle 1/3 of beach) and 0.67% for remaining slopes (bottom 1/3 of beach) **[24].**

A three-dimensional diagram of the final landform and sections are shown in **DIAGRAM 4** and **DIAGRAM 5**.

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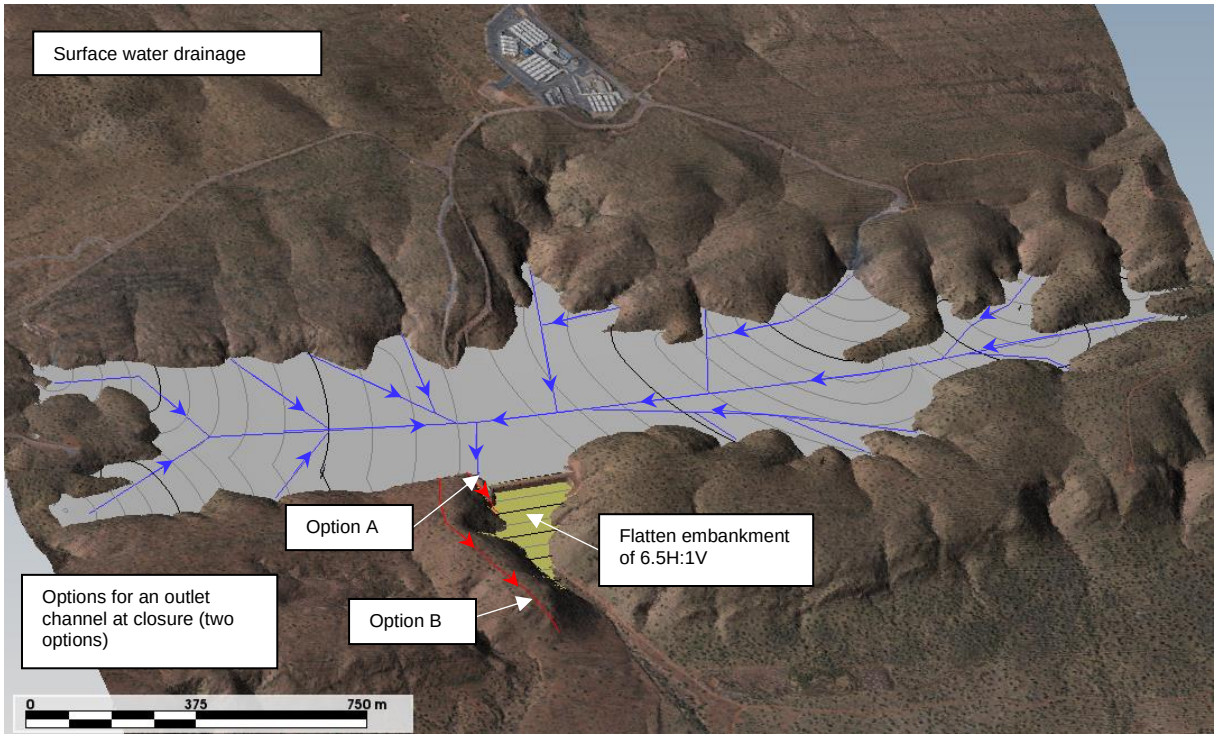
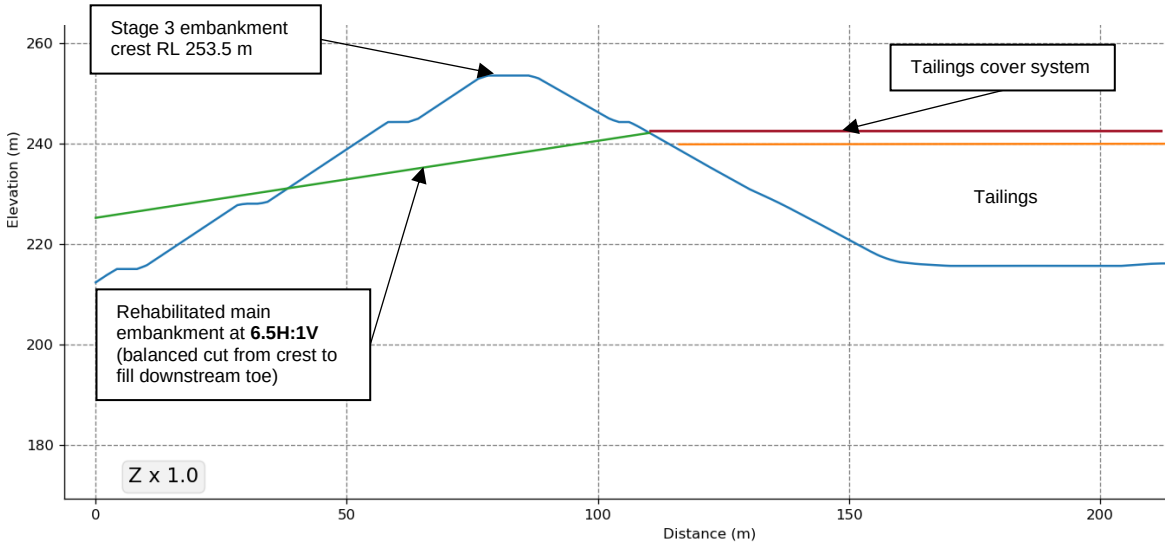
DIAGRAM 4: TSF CLOSURE LANDFORM – PLAN



Two (2) options for the location of the outlet channel are presented in **DIAGRAM 4**.

- Option A involves reinstating and widening the current Stage 2 spillway. However, impacts of the outlet flow on the flatten embankment will require further study.
- Option B, located slightly north of the embankment will require significant cut volumes of approximately 2.9 Mm^3 (This cut volume may change depending on the base width of the outlet channel).

DIAGRAM 5: EMBANKMENT AT CLOSURE - SECTION



It is worth noting that the final Stage 3 tailings surface will require significant reshaping to achieve the above-mentioned concept final tailings surface, approximately 1.7 Mm^3 of cut and 1.9 Mm^3 of fill

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volumes **[24]**. It is therefore critical to allow for further optioneering of the conceptual final tailings surface with considerations of:

- Optimisation of the tailings deposition strategy such as locations of spigot, frequency of deposition and location of the ponded water, especially 5-10 years before closure.
- Progressively rehabilitating the TSF (including removal of ponded water) before closure to reduce catchment size and increasing efficiency when capping during closure, also noted in the 'Closure dewatering strategy' memorandum **[29]**. Considerations for reducing the operating pond and design storage allowance (DSA) volume, and a trial plot can also be investigated as part of this work.
- Alternate steeper final tailings surface which will include analysis of erosion, surface water flow and stability of rehabilitated embankment.

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8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Without an appropriate cover system, Dugald River tailings have the potential to generate acid mine drainage and/or neutral mine drainage following closure of the facility. Key objectives of the cover system are therefore to limit infiltration of meteorological and surface water through the cover system into the tailings and to prevent capillary rise of tailings pore water into the vegetation-supporting layers of the cover system.

DRM is in a hot, dry climate with mean annual rainfall < 500 mm and summer temperatures often over 40 °C. The climate is highly variable with annual rainfall reported over 1000 mm and temperatures dropping to < 5 °C. These extremes require the cover to provide a robust solution to controlling moisture movement into and out of the tailings.

A general observation from the geotechnical investigation was that the *in situ* depth and available quantity of surface soils is limited. Based on this outcome, it will be critical to reduce the quantity of cover soils required, while still meeting the closure requirements. Currently, a nominal topsoil depth of 0.2 m for all cover systems has been included, consistent with the current PRCP **[2]**. Recognising that natural topsoil depths are <0.1 m, sourcing a sufficient quantity to rehabilitate the TSF will require a very large borrow area. Reducing the topsoil depth from 0.2 m to 0.1 m in the numerical mode is unlikely to show a material difference in modelling results. The reduction should be assessed by a Certified Professional Soil Scientist to determine likely impacts to vegetation and recommend potential mitigation measures to adequately support vegetation establishment.

Based on the outcomes of the geotechnical investigation **[12]**, availability of low-permeability materials on site appears limited. A low permeability layer is typically included in the cover system profile to reduce percolation into the tailings. In the absence of low-permeability materials in sufficient quantity, a geosynthetic liner (e.g. GCL or HDPE) can be used instead. A geomembrane (such as HDPE) can also be used to prevent capillary rise instead of a capillary break (which is created from coarse screened rock). Recognising the quantity required and cost associated with manufacturing or importing gravel, a geomembrane (e.g. HDPE or LLDPE) may provide a more cost-effective solution. It is highlighted that a GCL would limit but not prevent capillary rise.

The water balance model for the different cover scenarios has assumed that the topsoil and ISL are the same for all systems and that the vegetation remains constant. This assumption results in the model predicting similar runoff and transpiration for all cover systems. Regardless, there are potentially significant differences in the percolation between the cover systems. The HDPE cover is likely to significantly reduce percolation into the tailings to near 0 mm/yr and prevent capillary rise from the tailings into the soil. In contrast, the SAR cover allowed the highest percolation into the tailings and also allowed capillary rise from the tailings into the soil. Based on the modelling undertaken, all the cover system options meet the required performance criteria for Net Percolation (<5% of rainfall) on a weather year basis, but the CAP and SAR covers have specific rainfall events where NP is above 5% of rainfall, but NP remains under 5% for the weather year overall. only the GCL and HDPE cover systems reduced the percolation to < 5% of rainfall for all modelled years and all cover systems reduced the flux into the tailings to < 1×10^{-8} m/s.

Over the longer term, the net percolation predicted from the CAP, SAR and GCL covers was upward suggesting it is likely that the movement of salt into the soil profile in drier years would accumulate in the soil and the percolation in wet years may not be sufficient to leach the salt back into the tailings. Modelling indicated that salts from the tailings may accumulate around 0.9 – 1 m depth over the longer term. At this depth, most endemic species have exclusion mechanisms in their roots to reduce salt uptake; however the salt concentration is not known and some impact to vegetation, such as a reduction in coverage, may still result.

Modelling indicated the cover systems significantly reduce the potential for percolation of rainfall into the tailings. The largest loss of rainfall is via evapotranspiration, with transpiration by plants needed to remove moisture stored in the soil profile during wetter years. The HDPE cover reduced percolation and prevented the upward movement of water and salts from tailings. For the SAR, CAP and GCL covers, there are increased uncertainty as their performance is more reliant on natural material properties. As such, there is increased potential for higher percolation than predicted and for a net upward movement of salt into the profile. Noting the limitations of the numerical modelling approach, further assessments would need to be undertaken to more accurately quantify cover system performance, increase confidence in the chosen approach, and manage identified risks.

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The WEPP erosion modelling conducted for the rehabilitated tailings surface provides important insights into the long-term stability and sustainability of the final landform. A 50-year model duration was adopted, which captures high and low rainfall periods and allows sufficient time for initial erosional features to develop. The modelling was based on a conservative flow path length of 500 m at a 1.5% slope, recognising that WEPP tends to overestimate erosion for slope lengths greater than 100 m.

The key findings from the WEPP modelling include:

- The conceptual closure design can achieve long-term stability, with average annual soil loss rates estimated to be within acceptable limits for scenarios with at least 30% vegetation cover.
- Identified limitations highlight the need for further detailed design and site-specific data collection to refine the erosion assessment and closure plan.
- Ongoing monitoring and adaptive management will also be critical to ensure the long-term sustainability of the final TSF landform.

Embankment erosion was assessed using flood study results undertaken by ATCW. This assessment was focused on the embankment surface, which will comprise coarse rockfill that is resistant to erosion. The flood study results were considered conservative with respect to flow velocities on the embankment and resulted in a recommended rockfill surface with a D50 ranging from 150-300 mm.

8.2 Recommendations

Some recommended forward works are listed below:

- Cover System
  - Confirmation of selection of appropriate cover system based on material availability and expected performance.
  - Further material sampling and lab testing of cover materials.
  - A more extensive investigation to identify additional material (both in quantity or type, e.g. clays).
  - Cover system trials (laboratory, column or field scale) to refine percolation and capillary rise estimates for the SAR, CAP and GCL cover systems. Understanding the salt concentration and depth of accumulation will be critical in ensuring plant growth is not detrimentally affected. Determine location of potential field trials.
  - Calibration of the model using field trial data, to improve model predictions over the longer term. This may then result in further optimisation of the cover profile for final rehabilitation.
- Construction
  - Construction methodology, including any proposed staging of the cover system.
  - Quality assurance / quality control (QA/QC) for the construction of the cover system, including implementation of corrective actions where deviations from the design are identified.
- Performance Monitoring
  - Performance Monitoring as per the rehabilitation milestones and milestone criteria relevant to the closure design for Rehabilitation Area 6 (RA6) (i.e. the TSF), presented in **TABLE 3**.
  - Operations and Progressive Rehabilitation Investigations/assessments on progressive rehabilitation of the TSF before closure, including potential trial plot/s.
  - Trials looking at vegetation establishment can reduce the cost of the larger scale rehabilitation.
- Landform

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- Alternate steeper final tailings surface which will include analysis of erosion, surface water flow and stability of rehabilitated embankment.
- Selection of location of the outlet channel, either Option A or Option B.
- Sizing and location of downstream sediment pond for active closure phase.

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Appendix F: TSF and Process Area Hydraulic Impact Assessment

REPORT

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Dugald River Mine – Progressive Closure and Closure Planning – TSF and Process Area Hydraulic Impact Assessment

108003-49
MAY 2021

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Document Control

Project Name:	Dugald River Mine – Progressive Closure and Closure Planning
Document Title:	TSF and Process Area Hydraulic Impact Assessment
File Location:	M:\Synergy\Projects\108\108003 Dugald River Mine\49 Progressive Rehabilitation & Closure Plan\Documents\R01\Text\108003-49R01-rev1.docx
Project Number:	108003-49
Revision Status:	1

Revision History

Revision	Issue	Prepared by	Reviewed by
A	Draft Issue	James Parker & Matthew Plucknett	Naomi Tyack
0	Final Issue	James Parker & Matthew Plucknett	Naomi Tyack
1	Final Issue – Updated	James Parker & Matthew Plucknett	Naomi Tyack

Issue Register

Distribution List	Date
MMG Australia Pty Ltd	18 May 2021 – Revision A
MMG Australia Pty Ltd	28 May 2021 – Revision 0
MMG Australia Pty Ltd	31 May 2021 – Revision 1

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FIGURE 001 – TSF PROBABLE MAXIMUM FLOOD– MAXIMUM FLOOD DEPTHS

FIGURE 002 – TSF PROBABLE MAXIMUM FLOOD – MAXIMUM FLOOD VELOCITY

FIGURE 003 – TSF 0.1 % AEP – MAXIMUM FLOOD DEPTHS

FIGURE 004 – TSF 0.1 % AEP – MAXIMUM FLOOD VELOCITY

FIGURE 005 – TSF 1 % AEP – MAXIMUM FLOOD DEPTHS

FIGURE 006 – TSF 1 % AEP – MAXIMUM FLOOD VELOCITY

FIGURE 007 – PROCESS AREA PROBABLE MAXIMUM FLOOD– MAXIMUM FLOOD DEPTHS

FIGURE 008 – PROCESS AREA PROBABLE MAXIMUM FLOOD – MAXIMUM FLOOD VELOCITY

FIGURE 009 – PROCESS AREA 0.1 % AEP – MAXIMUM FLOOD DEPTHS

FIGURE 010 – PROCESS AREA 0.1 % AEP – MAXIMUM FLOOD VELOCITY

FIGURE 011 – PROCESS AREA 1 % AEP – MAXIMUM FLOOD DEPTHS

FIGURE 012 – PROCESS AREA 1 % AEP – MAXIMUM FLOOD VELOCITY

APPENDICES

APPENDIX A: PMP CALCULATIONS

APPENDIX B: MMG CLOSURE CONCEPT (2016)

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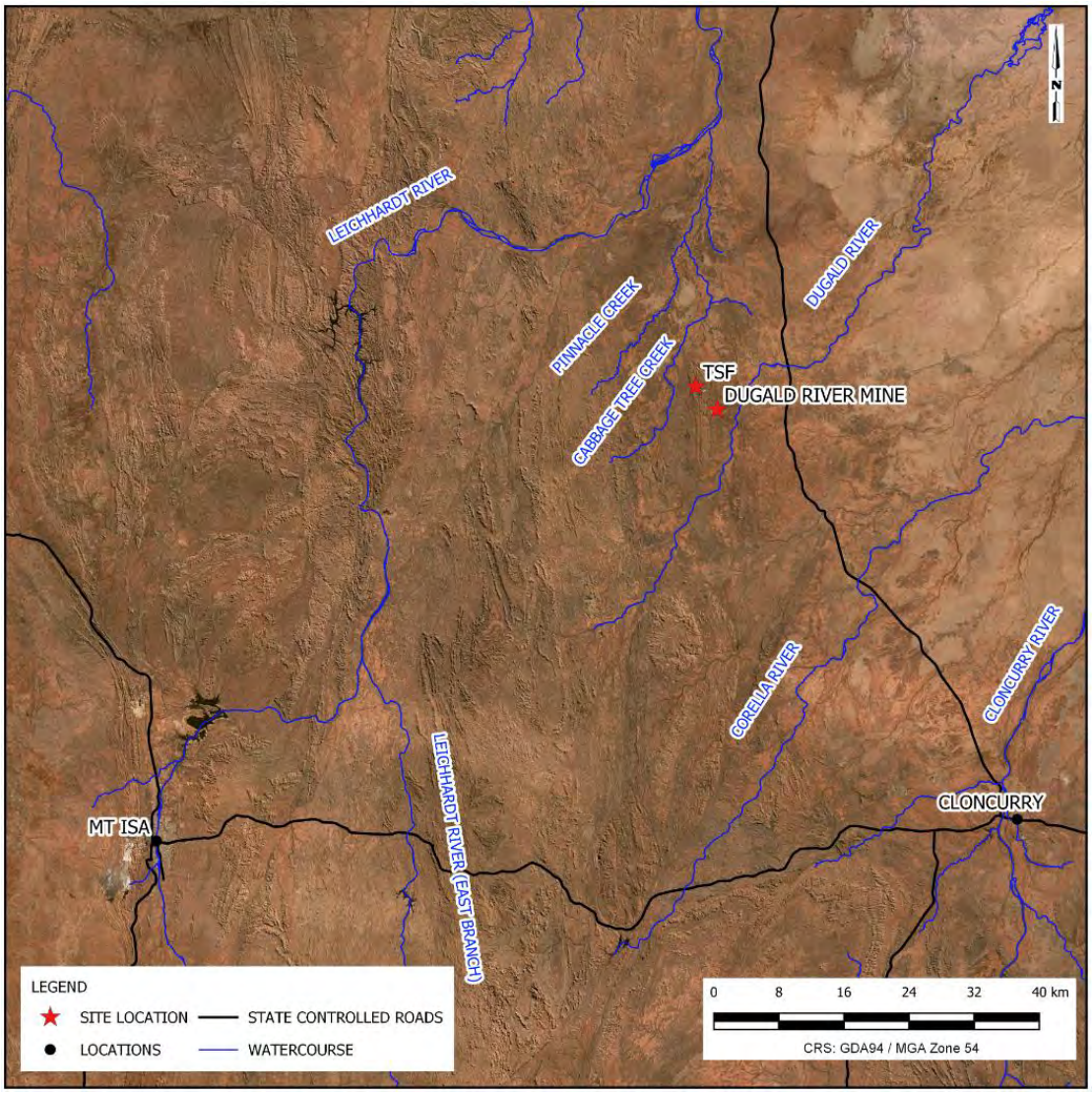
1 INTRODUCTION

1.1 Background and Purpose

MMG Australia Pty Ltd (MMG) owns and operates the Dugald River Mine (DRM) in northwest Queensland. The DRM is located approximately 60 km northwest of Cloncurry and is accessed from the Burke Development Road. DRM and its TSF locations are shown on **DIAGRAM 1**.

DIAGRAM 1: SITE LOCATION



The purpose of this study is to provide flood modelling in support of the DRM Progressive Closure and Rehabilitation Plan (PCRP). The PRCP requires flood risk assessments for two aspects of closure: to identify whether any mine voids will be in a floodplain post-closure; and to assess the flood risk to remaining infrastructure (in this case the closed and capped TSF). The floodplain is defined under the PRCP as being areas within the 0.1% AEP flood level.

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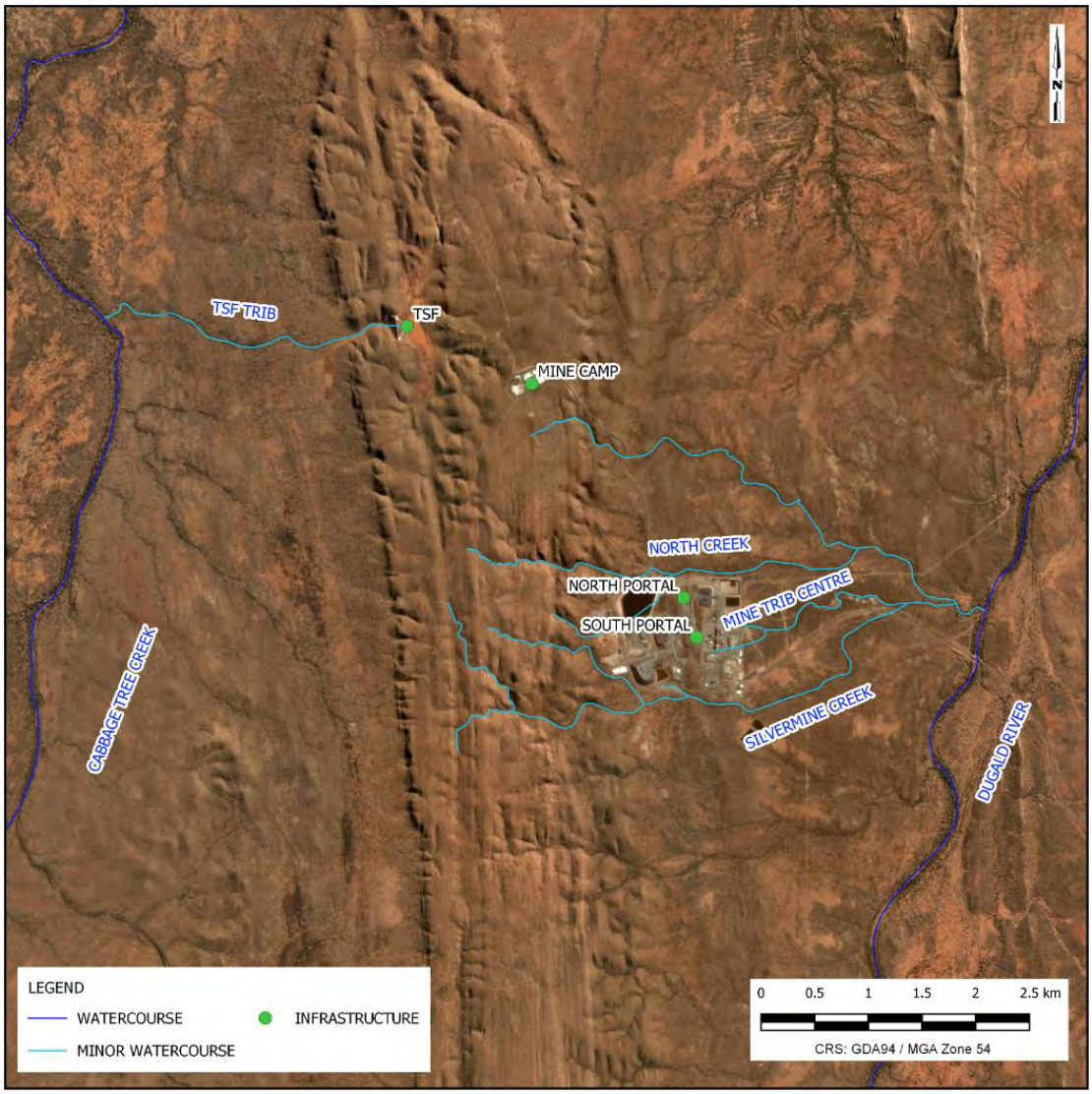
1.2 Site Watercourses/Drainage Setting

The DRM is located approximately 3 km west of the Dugald River. The TSF is located in the adjacent catchment, approximately 3 km east of Cabbage Tree Creek, as shown on **DIAGRAM 2**. The Dugald River is located within the Flinders River Basin, whereas Cabbage Tree Creek is located in the Leichardt River Basin. Both the Flinders River and Leichardt River discharge into the Gulf of Carpentaria.

Within the DRM area there are several small tributaries of the Dugald River, namely North Creek and Silvermine Creek. For the purpose of this study, the unnamed tributary to the centre of the DRM area has been named 'Mine Trib Centre'. The single tributary to Cabbage Tree Creek has been named 'TSF Trib'. The locations of these tributaries are depicted on **DIAGRAM 2**, along with key existing mine infrastructure.

DIAGRAM 2: SITE TRIBUTARIES AND INFRASTRUCTURE



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1.3 Project Scope and Methodology

The scope of works for the PRCP and updated flood study consist of:

- Hydrologic assessment of the site and upstream catchments.
- Hydraulic modelling of the site and upstream catchments.

As part of the PCRP, a flood profile for the TSF and DRM was required to be developed. In consultation with MMG, it was agreed to model the following events:

- Probable Maximum Flood (PMF) resulting from the Probable Maximum Precipitation (PMP);
- 1:1,000 AEP (0.1% AEP); and,
- 1:100 AEP (1% AEP) storm events.

Australian Rainfall and Runoff (ARR) (2019) **[1]** has been utilised to develop the rainfall estimates for input into a TUFLOW hydraulic model. Due to the size of the upstream catchments, the Regional Flood Frequency Estimation (RFFE) tool **[2]** was proposed to be used to estimate the peak discharges in the Dugald River and Cabbage Tree Creek that would be applied in the hydraulic model. Further details regarding the methodology and application of the RFFE is provided in **Section 3.0**.

1.4 Structure of Report

The structure of the report, to address the above scope of works, is as follows.

Section 2.0 Details the inputs and outcomes of the rainfall estimation process for the 1% AEP and PMP design events. The inputs from the Regional Flood Frequency Estimate (RFFE) for the Dugald River and Cabbage Tree Creek upstream catchment are presented.

Section 3.0 Details the development and outcomes of the TUFLOW hydraulic model utilised for determining the response of site areas to the hydrographs determined in **Section 2.0.**

Section 4.0 This section discusses the results of the base case and the design case scenarios, plus the sensitivity analyses outcomes.

Section 5.0 Discusses the hydraulic assessment with respect to the PRCP.

Section 6.0 Outlines the conclusions and recommendations from the hydraulic assessment.

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2 HYDROLOGY ASSESSMENTS

2.1 Overview

Upstream of the TSF and DRM areas the catchments are relatively small at 335 ha and 750 ha, respectively. The catchments have short times of concentration when compared the full regional catchments within which they are located. As such, the regional and local extreme storm events have very different characteristics and the impact of regional flooding from Cabbage Tree Creek and the Dugald River will be experienced hours after any rainfall at the TSF and DRM sites has passed. As a result of this, coincident flood event scenarios for the local mine site and TSF and the regional catchments have been applied, as detailed in **TABLE 1**.

TABLE 1: COINCIDENT FLOODING SCENARIOS

Site Rainfall Event	Dugald River/Cabbage Tree Creek Rainfall Event
PMP	1.0 % AEP
0.1 % AEP	1.0 % AEP
1 % AEP	5% AEP

The input hydrology for the PMP, 1:1,000, 1:100 and 1:20 AEP events was developed in accordance with ARR (2019) **[1]**, in line with the PRCP Guideline requirements**.** Development of the hydrology estimates for the TSF and DRM sites is detailed in **Sections 2.2** and **2.3,** below. The hydrology estimation methodology for the Dugald River and Cabbage Tree Creek is detailed in **Section 2.4**.

2.2 Probable Maximum Precipitation

The DRM site is located in the Generalised Tropical Storm coastal zone and therefore the Generalised Short Duration Method (GSDM) **[3]** was adopted for event durations between 0.25 hours and 6 hours.

The GSDM method requires catchment factors to be applied to the initial rainfall depth to estimate the PMP for the site. The GSDM factors are summarised in **TABLE 2**. A summary of the PMP calculations have been in included in **Appendix A**.

TABLE 2: GSDM FACTORS FOR PMP ESTIMATE

Parameter	Value
Duration Limit	0.25 - 6 hours
Proportion Smooth	0.0
Proportion Rough*	1.0
Mean elevation at site (m AHD)	210
Moisture Adjustment Factor (MAF)	0.9606

*Rough terrain is classified as that in which elevation changes of 50 m or more within horizontal distances of 400 m are common **[3]**.

These values were applied to generate the PMP envelope for 0.25 hours to 6 hours durations shown on **DIAGRAM 3** and summarised in **TABLE 3**.

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DIAGRAM 3: PMP RAINFALL DEPTH ESTIMATE

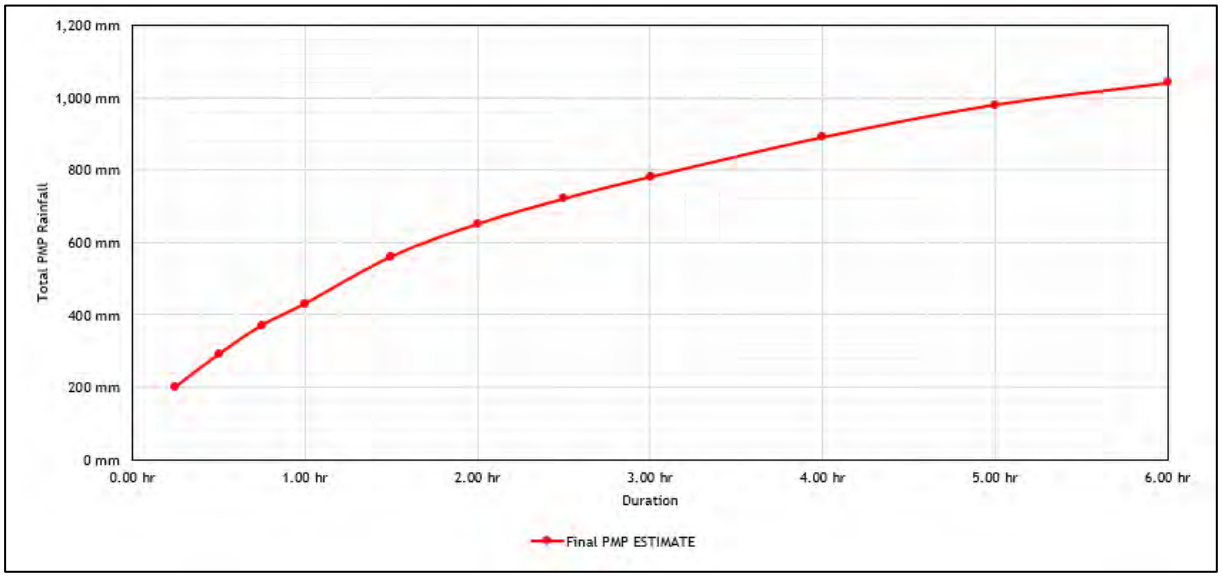

TABLE 3: PMP RAINFALL DEPTH ESTIMATE

Duration (hr)	Rainfall Depth (mm)
0.25	200
0.5	290
0.75	370
1.0	430
1.5	560
2.0	650
2.5	720
3.0	780
4.0	890
5.0	980
6.0	1,040

The GSDM temporal pattern was applied to the rainfall depths in PMP rainfall estimates from **TABLE 3** to obtain a rainfall hyetograph. The hyetographs were applied as direct rainfall to the hydraulic model.

2.3 Rare Precipitation Estimation

Rainfall estimates for the centroids of the Dugald River and Cabbage Tree Creek upstream catchments were obtained from the Bureau of Meteorology's 'Design Rainfall Data System' **[4]**. Rainfall depths for the 1% and 0.1% AEP events are summarised in **TABLE 4**.

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TABLE 4: RARE RAINFALL DEPTH ESTIMATES

Duration	Rainfall Depth (mm)	
	1% AEP	0.1% AEP
1 min	6.41	9.55
2 min	10.7	15.7
3 min	15.2	22.4
4 min	19.5	28.9
5 min	23.5	34.9
10 min	39.8	59.4
15 min	51.5	76.9
20 min	60.5	90.2
25 min	67.7	101
30 min	73.7	110
45 min	87.2	129
1 hour	96.9	144
1.5 hour	111	165
2 hour	122	181
3 hour	138	206
4.5 hour	157	236
6 hour	173	260
9 hour	200	301
12 hour	222	334
18 hour	260	390
24 hour	291	434
30 hour	318	464
36 hour	340	492
48 hour	378	542
72 hour	430	616
96 hour	463	664
120 hour	483	695
144 hour	494	713
168 hour	499	722

Rare events are defined as having an AEP equal to or greater than the 5% AEP event. Each event duration has an ensemble of ten different design temporal patterns (TP), as detailed in the Australian Rainfall and Runoff (ARR) Datahub **[1]**. The variations in the temporal patterns account for rainfall patterns not being uniform or the same for their duration, with periods of more intense and less intense rainfall occurring within a rainfall event. The ensemble temporal patterns have been designed to permit assessment of different rainfall patterns within a catchment. Rainfall estimates from **TABLE 4** were applied directly to the hydraulic model as rain on grid. This is discussed further in **Section 3.2**.

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2.4 Regional Flood Frequency Estimate

To represent the risk of co-incident flooding from Cabbage Tree Creek and the Dugald River, flood discharge estimates were included in the model as upstream inflow boundary conditions in the TUFLOW hydraulic model. It was decided to adopt the flood discharge estimates of these catchments generated by the Regional Flood Frequency Estimator (RFFE) **[2]**. The RFFE utilises the data from 853 gauged catchments across Australia and utilises Log Pearson Type 3 distributions to estimate flows based on records in similar catchments.

The decision to use the RFFE data was made because first, it was considered that there would be very little impact from the rivers on the TSF or the DRM sites. This was tested by undertaking sensitivity tests on the discharge in the rivers. Secondly, the duration of the regional flood events in the Dugald River and Cabbage Tree Creek would be much longer than that in the tributaries from the TSF and the DRM so a steady state condition could be applied to the major creeks under the coincident flood event conditions as a conservative, but reasonable approach.

The resultant flow estimates for the Dugald River and Cabbage Tree Creek are summarised in **TABLE 5**.

TABLE 5: RFFE MEAN DISCHARGE SUMMARY

AEP (%)	Dugald River (m^3/s)	Cabbage Tree Creek (m^3/s)
50	394	203
20	809	410
10	1,150	583
5	1,570	790
2	2,130	1,070
1	2,680	1,340

The catchment areas, outlet locations and centroid locations for the Dugald River and Cabbage Tree Creek were derived from Shuttle Radar Topographic Mission (SRTM) data **[5]**. This information is shown on **DIAGRAM 4**.

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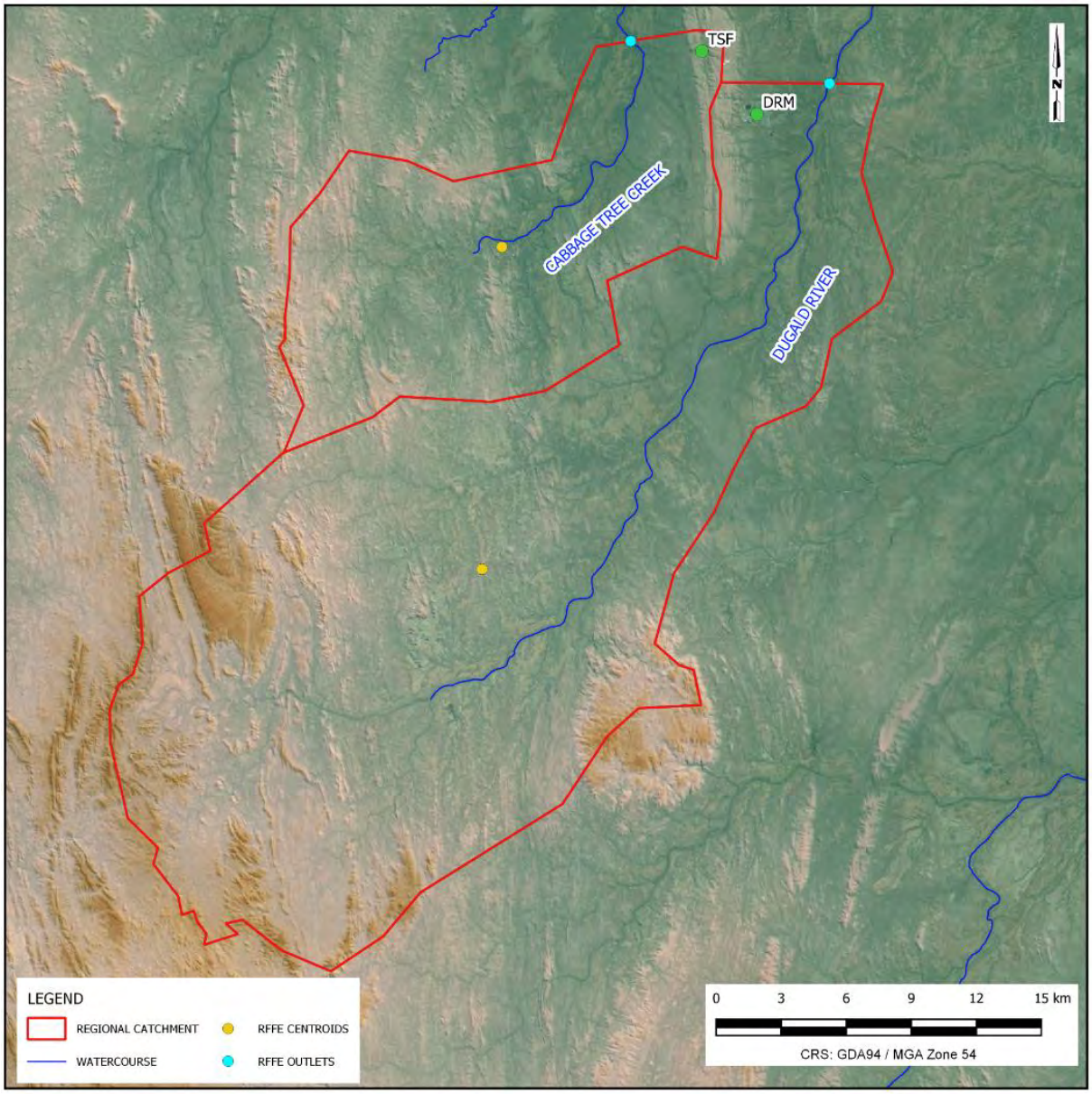
DIAGRAM 4: RFFE CATCHMENTS



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3 HYDRAULIC ASSESSMENT

3.1 Model Overview

Hydraulic analysis of the study area has been undertaken using the two dimensional (2D) finite difference program TUFLOW, which is an industry accepted software package highly suited to the investigation of flood behaviour in complex flow scenarios. The model can simulate unsteady hydrodynamic flow in two dimensions on a rectilinear grid, as well as a one-dimensional unsteady hydrodynamic flow through waterway structures such as culverts. The model is based on a robust finite difference solution scheme that is able to compute both sub-critical and supercritical flow regimes. The selected hydraulic solver for the 2D model was the HPC scheme.

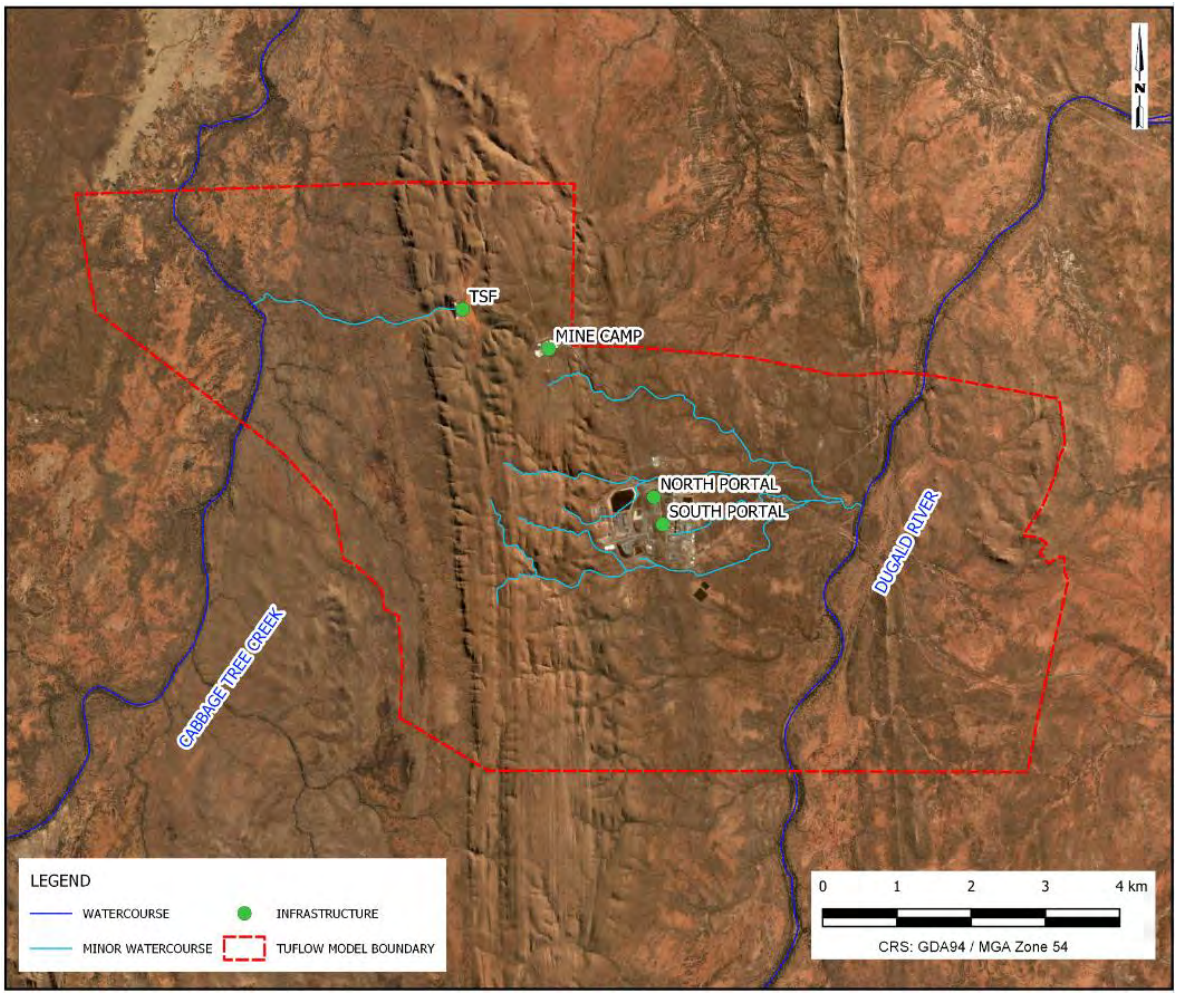
3.2 Model Domain, Grid Size and Time Step

3.2.1 Domain

The 2D TUFLOW model was set up to quantify the impacts of the PMP, 0.1% AEP and 1% AEP design storm events. The model domain is depicted on **DIAGRAM 5** and includes the following structures and areas:

- TSF (Post closure surface and spillway)
- North Portal
- South Portal

DIAGRAM 5: TUFLOW MODEL DOMAIN



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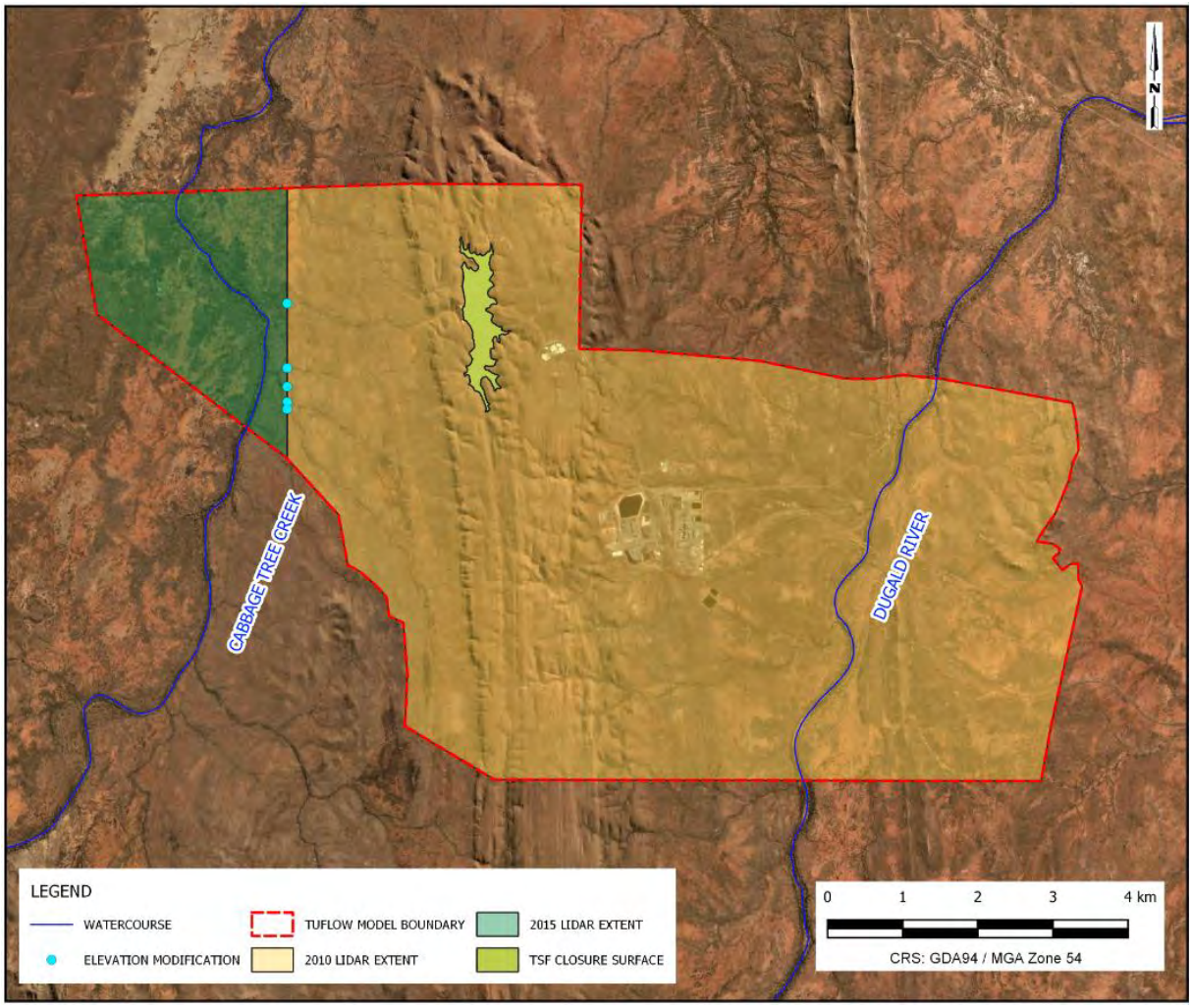
3.2.2 Topography

The TUFLOW model development was based on a 5m x 5m gridded elevation raster model, resampled from site LIDAR survey provided by MMG, to form a base topography. The LIDAR survey files provided by MMG including the following:

- Site Lidar – 2010 **[6]**
- Site Lidar – 2015 **[7]**

It is understood that MMG intend to rehabilitate the main mine site and camp to the pre-mining topography as much as is practically possible. As such, the MMG provided 2010 Site LIDAR was used as the base topographic input, supplemented on the western extent by the 2015 Site LIDAR (refer **DIAGRAM 6**). The TSF is to remain, with a capping layer added, so a TSF closure surface and spillway were incorporated within the topography, with details provided in **Sections 3.2.3** and **3.2.4**, respectively. The survey elevations were modified by smoothing in the TUFLOW model at the intersection of the surveys to ensure free flowing drainage through the drainage features where there were differences in level between the two data sets. These points are shown by the blue dots on **DIAGRAM 6**.

DIAGRAM 6: TOPOGRAPHICAL INPUTS



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3.2.3 TSF Closure Surface

In 2016, ATC Williams undertook the design of the TSF **[8]**. This design included a concept closure plan and surface of the TSF **[9]**. The cover system is proposed to be self-shedding, with a nominal gradient of 1.5%. The embankment will be modified with a 1:5 (V:H) grade at the crest of the embankment, transiting to 1:8 (V:H) at the base, where it then joins natural surface. The closure plan is included in **Appendix B**. This proposed closure surface has been incorporated within the hydraulic model.

Further work on the design of the closure cover system was undertaken by SGM Environmental in 2019, consisting of column trials and a semi-calibrated model, which indicated that the TSF cover will likely require a 1.0 m thick infiltration storage layer (ISL) to reduce the potential for seepage into the tailings **[10].** Run-of-mine NAF waste rock blends will be used in the TSF final cover to protect against surface erosion of the ISL. The final cover will be reshaped for effective drainage to the nominal 1.5% gradient. Although the cover system will store some rainfall runoff, the hydraulic assessment has assumed a self-shedding cover (refer **Section 3.4**).

3.2.4 TSF Closure Spillway

During the design of the TSF, it was envisaged that two (2) closure spillways would be constructed to convey flows up to and including the Probable Maximum Flood. Based on preliminary modelling results, it is proposed to construct a single spillway with the details provided in **TABLE 6**.

TABLE 6: TSF CLOSURE SPILLWAY DETAILS

Parameter	Value
Upstream Invert Level	235.0 m AHD
Downstream Invert Level	228.3 m AHD
Base Width	30.0 m
Side Slopes	1: 2 (V:H)
Length	330 m
Longitudinal Grade	2.0 %

3.2.5 Grid Size and Time Step

A 5 m x 5 m grid was applied to the digital terrain model. Direct rainfall was applied to the grid with an initial timestep of 2.5 seconds. To ensure the maximum impacts of the proposed development were captured in the model, a lag time of approximately 3 hours was applied to the direct rainfall to allow for the RFFE flows in the Dugald River and Cabbage Tree Creek to reach the TSF and DRM areas before rainfall was applied to the study areas. The adopted simulation times are summarised in

TABLE 7.

TABLE 7: HYDRAULIC MODEL SIMULATION TIME

Event Duration	Simulation Time (hr)
20 min	4.0
25 min	4.0
45 min	4.0
1 hour	4.5
1.5 hour	5.0
2 hour	5.5
3 hour	6.5

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Event Duration	Simulation Time (hr)
4.5 hour	8.0
6 hour	8.5
9 hour	13.0
12 hour	16.0

3.3 Boundary Conditions

As detailed in **Section 2.4**, RFFE flows for the Dugald River and Cabbage Tree Creek were applied to the upstream inflow boundaries in the model domain. The location of upstream inflows are depicted by pink lines on **DIAGRAM 7** and are detailed in **TABLE 8**.

DIAGRAM 7: BOUNDARY LOCATIONS

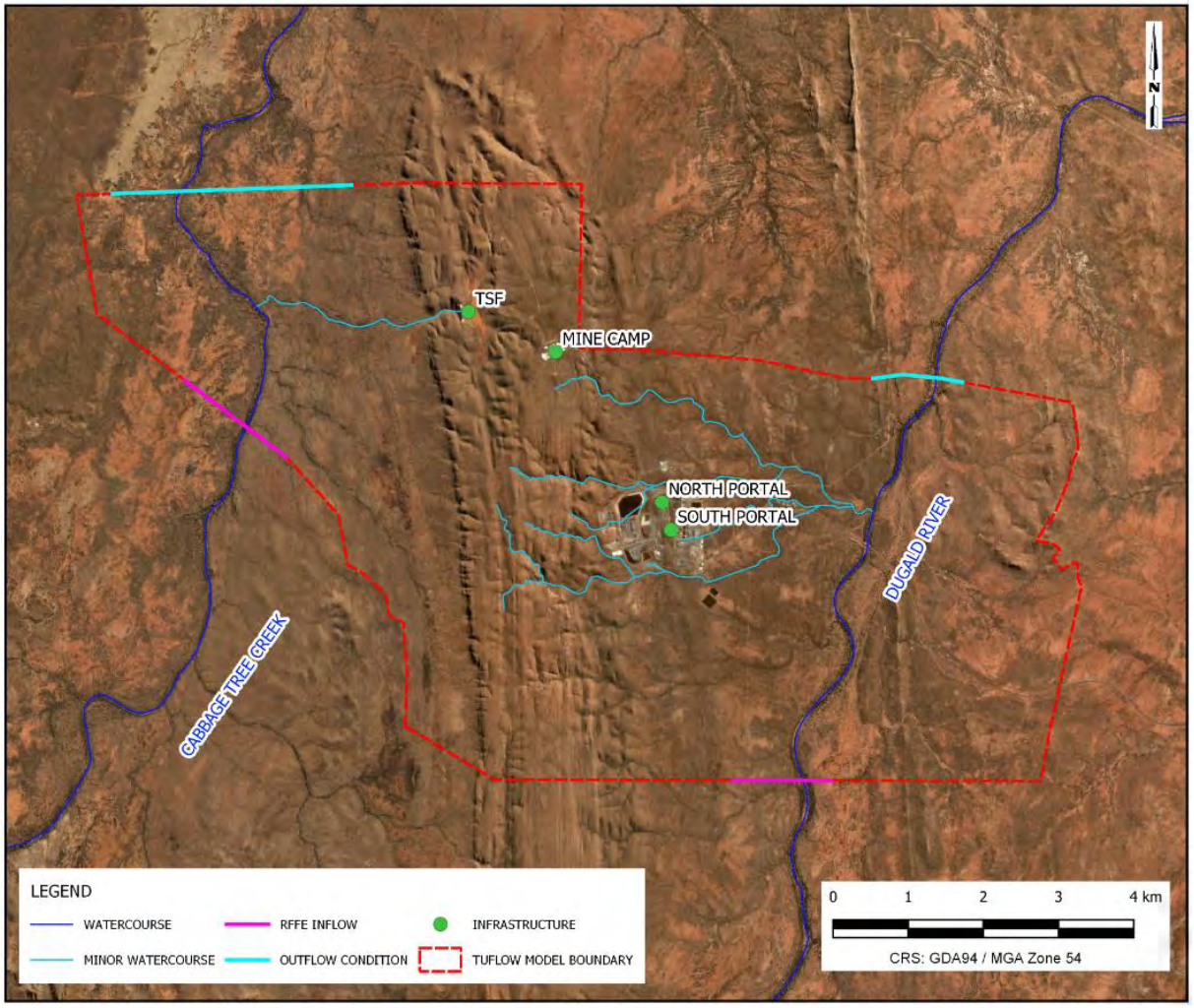

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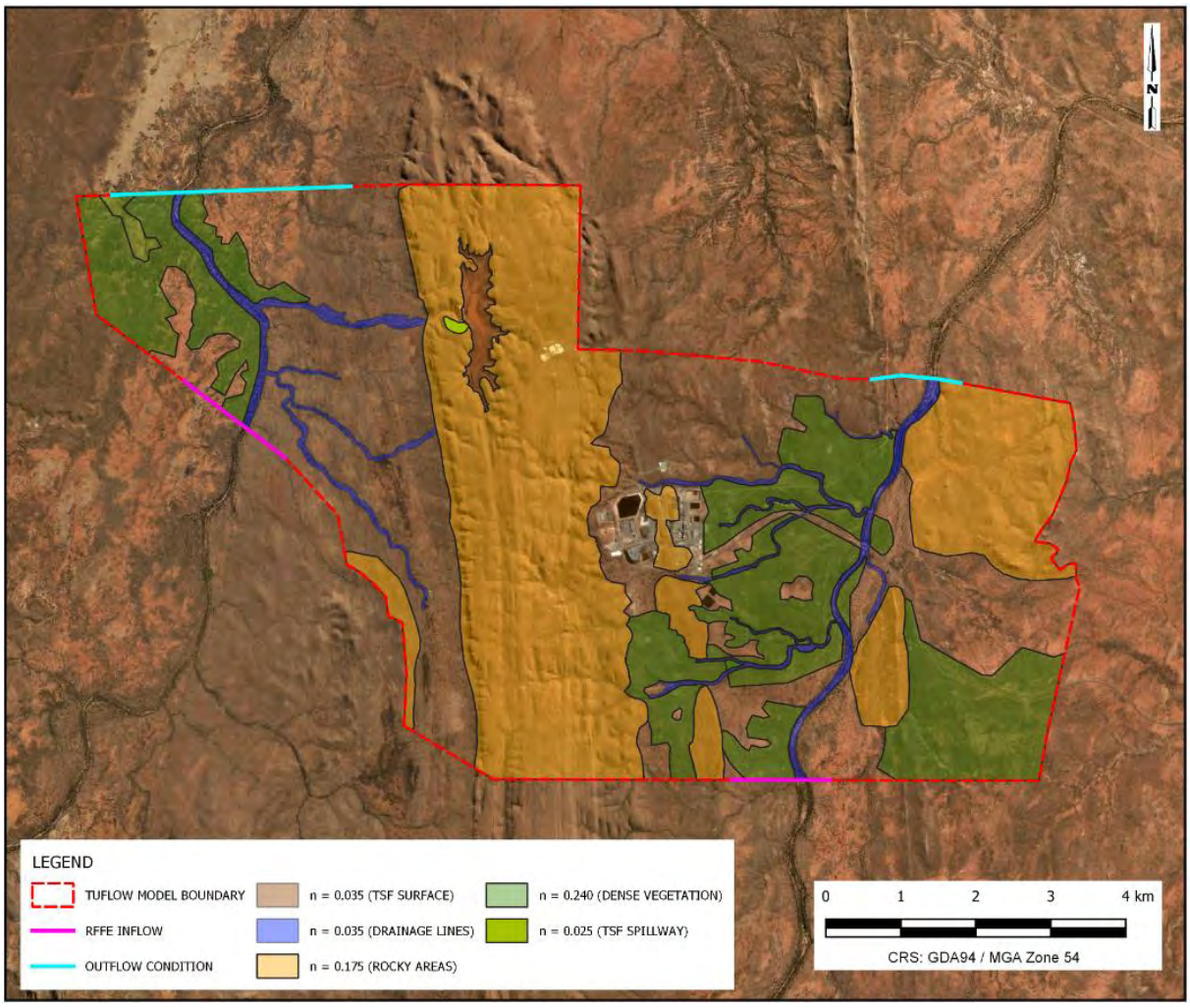
TABLE 8: BOUNDARY CONDITIONS

Site Rainfall Event	RFFE Event	Dugald River (m^3/s)	Cabbage Tree Creek (m^3/s)
PMP	1 % AEP Mean Flow	2,680	1,340
0.1 % AEP	1 % AEP Mean Flow	2,680	1,340
0.1 % AEP Sensitivity	1% AEP 95th Percentile Flow	11,500	5,540
1 % AEP	5% AEP Mean Flow	1,570	790

3.4 Surface Roughness

The Manning's 'n' surface roughness coefficient is used to describe the surface conditions within the model domain. Manning's roughness coefficients were assigned to the model domain, as depicted on **DIAGRAM 8**. Selection of the coefficient was made considering the apparent roughness of surfaces based upon inspection of available aerial imagery. The default surface roughness of 0.13 was adopted to represent the areas of bare earth and sparse vegetation.

DIAGRAM 8: MANNINGS ROUGHNESS



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Reference values from Innovyze (2019) **[11]** were adopted for the following surfaces. Innovyze are the developers of a range of hydraulic and hydrology software with a comprehensive online resource library.

- Natural flow and deep flow within the drainage features – adopted a roughness of 0.035 representing steams on a plain; clean, winding, some pools and shoals, and major streams; tranquil flow with dunes.
- TSF surface – adopted a roughness of 0.035 representing a finished surface that sheds water,
- TSF spillway channel – adopted a roughness of 0.025 representing a straight unlined channel,
- Dense vegetation – adopted a roughness of 0.240 representing dense vegetation,
- Rocky elevated surfaces – adopted a roughness of 0.175.

3.5 Sensitivity Analysis

As discussed in previous sections of the report, there are aspects of the hydraulic modelling that have been assumed or estimated. Sensitivity analyses were undertaken to accommodate for uncertainties adopted in the approach. The following considerations were adopted as part of the sensitivity analyses:

- 1.0% AEP 95th percentile RFFE inflows – takes into account the uncertainty in the hydrological inputs from the RFFE (refer **TABLE 8**).
- A 20% increase in rainfall depths – takes into account the uncertainty with more extreme rainfall events due to climate change.
- Assigning a 20% increase in Manning's roughness coefficients. Higher roughness coefficients reduce the flow velocity and consequently increase the modelled flow depths.

Initially, a 10 m x 10 m grid size was selected, but it did not provide sufficient model refinement in the TSF spillway. A 5 m x 5 m grid size gave better model resolution and so was adopted for all scenarios. The 2015 site LIDAR topography **[6]**, used on the western extent of the model, was provided with a cell size of 5 m, so the accuracy of the modelled surface matched that of the data provided.

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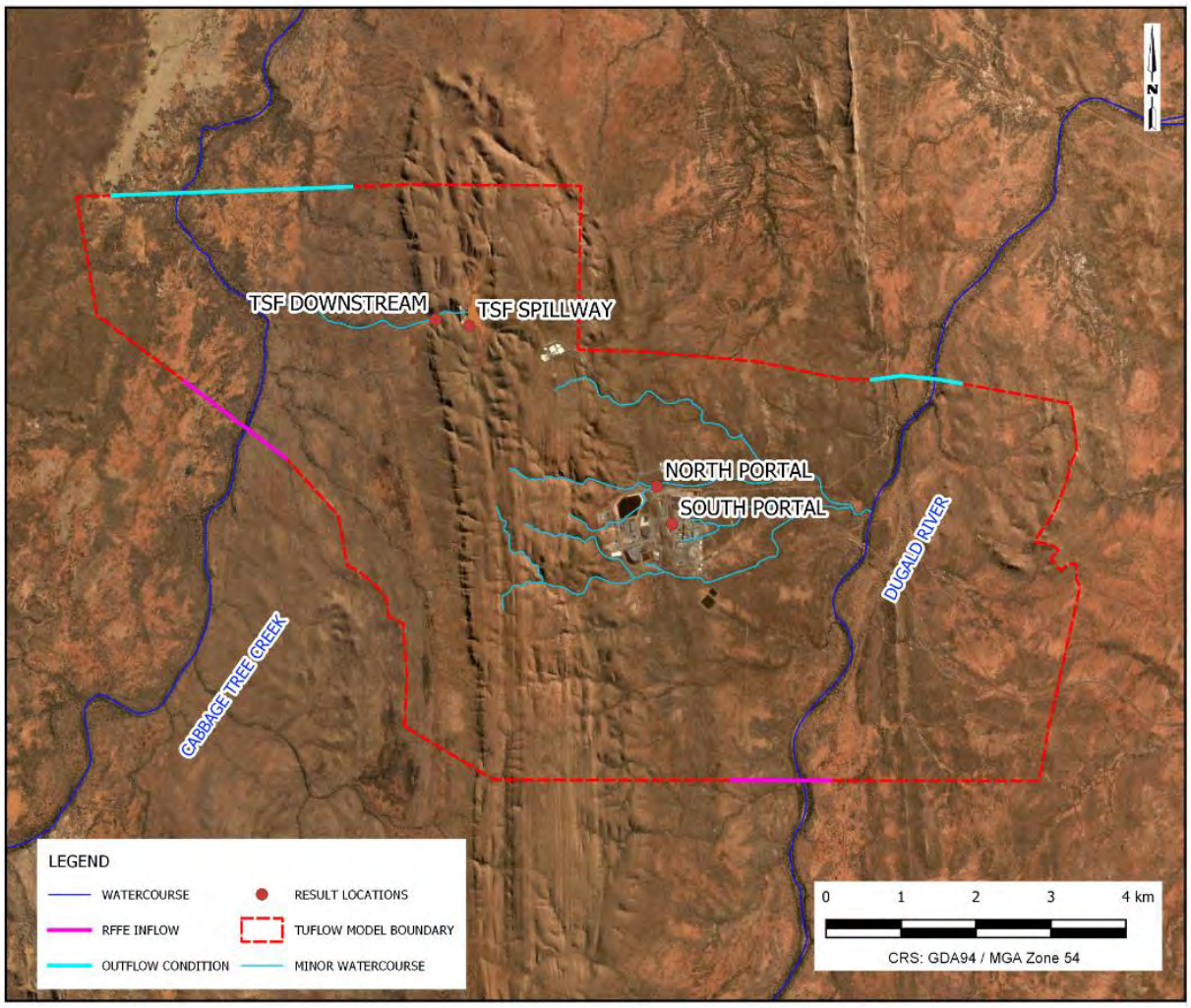
4 RESULTS AND IMPACTS

4.1 General

The results of the TUFLOW model showing maximum water depths and velocities are presented in **Figure 001** to **Figure 012**.

A summary of impacts on the TSF, North Portal, South Portal, and the tributaries downstream of the sites are summarised below. The key locations at which results are derived are outlined on **DIAGRAM 9**.

DIAGRAM 9: PEAK FLOOD LEVEL LOCATIONS



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4.2 TSF

The maximum recorded flow immediately downstream of the TSF, as well as the storm duration and temporal pattern producing the peak flow are summarised in **TABLE 9**. The impacts on the TSF Spillway are summarised in **TABLE 10**. It is noted that upon closure, with only a single spillway, the embankment crest should be raised to a level of 238.5 m AHD.

TABLE 9: TSF PEAK FLOWS

	PMP	0.1% AEP	1% AEP
Peak Flow m³/s	282.9	74.6	44.6
Critical Storm Duration and Temporal Pattern	90 min	540 min TP10	540 min TP10

TABLE 10: TSF SPILLWAY IMPACTS

	PMP	0.1% AEP	1% AEP
TSF Embankment Levels (m AHD)	238.0	238.0	238.0
Upstream Spillway Elevation (m AHD)	235.0	235.0	235.0
Upstream Maximum Surface Elevation (m AHD)	237.59	236.00	235.67
Upstream Maximum Flow Depth (m)	2.59	1.0	0.67
Upstream Spillway Flow Velocity (m/s)	4.2	2.9	2.5
Downstream Spillway Elevation (m AHD)	228.3	228.3	228.3
Downstream Maximum Surface Elevation (m AHD)	230.0	229.12	228.92
Downstream Maximum Flow Depth (m)	1.70	0.82	0.62
Downstream Spillway Flow Velocity (m/s)	6.2	4.1	3.5
Peak Spillway Flow (m³/s)	274.1	72.4	43.7

Modelled results for the TSF indicate that for the PMP event a backwater effect was present at the downstream toe of the TSF closure embankment. The flow down the spillway is confined by the downstream channel and some of the spillway discharge is forced upstream to the TSF closure embankment. The modelled maximum depth at the toe of the TSF closure embankment was some 3.7 m. This backwater effect could be limited by re-alignment of the spillway channel during the detailed design process, to allow for greater alignment with the downstream flow path. Furthermore, maximum velocities recorded for the PMP event were some 6.2 m/s within the spillway channel. These modelled velocities have a high potential for erosion, and as such erosional velocity dampeners or a similar method of limiting velocity through the spillway channel would potentially need to be implemented. These issues will require further examination during detailed design of the closure spillway.

4.3 Portals and Tributaries

The maximum recorded water surface elevations immediately adjacent to the North Portal (recorded in North Creek) are summarised in **TABLE 11**. Maximum recorded water surface elevations immediately adjacent to the South Portal (recorded in Mine Trib Centre) are summarised in **TABLE 12**. The locations where water surface elevations are recorded are depicted on **DIAGRAM 9.**

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TABLE 11: NORTH PORTAL IMPACTS

	PMP	0.1% AEP	1% AEP
Portal Crest Level at top of ramp (m AHD)	207.5	207.5	207.5
Maximum Water Surface Elevation (m AHD)	204.00	201.77	201.45
Depth of water impacting portal (m)	-	-	-
Freeboard to portal crest level (m)	3.50	5.73	6.05

As can be seen in **TABLE 11**, the North Portal is not subject to inundation in any events up to and including the PMF, and as such is not considered to be in the floodplain.

TABLE 12: SOUTH PORTAL IMPACTS

	PMP	0.1% AEP	1% AEP
Portal Crest Level at top of ramp (m AHD)	206.0	206.0	206.0
Maximum Water Surface Elevation (m AHD)	205.50	204.84	204.74
Depth of water impacting portal (m)	-	-	-
Freeboard to portal crest level (m)	0.50	1.16	1.26

TABLE 12 shows the South Portal is not subject to inundation in any events up to and including the PMF, and as such is not considered to be in the floodplain.

The modelled results indicate that the mine portals are clear of local flooding and are outside the floodplain. Notwithstanding, there are small drainage lines in the area which are depicted on **DIAGRAM 10**. These drainage lines are artefacts of the original topography prior to any mine disturbance and not a definitive representation of the final landform. Local topography and drainage will be modified during closure, to ensure that local runoff is directed away from the portals and will aim to reconnect drainage lines with downstream watercourses.

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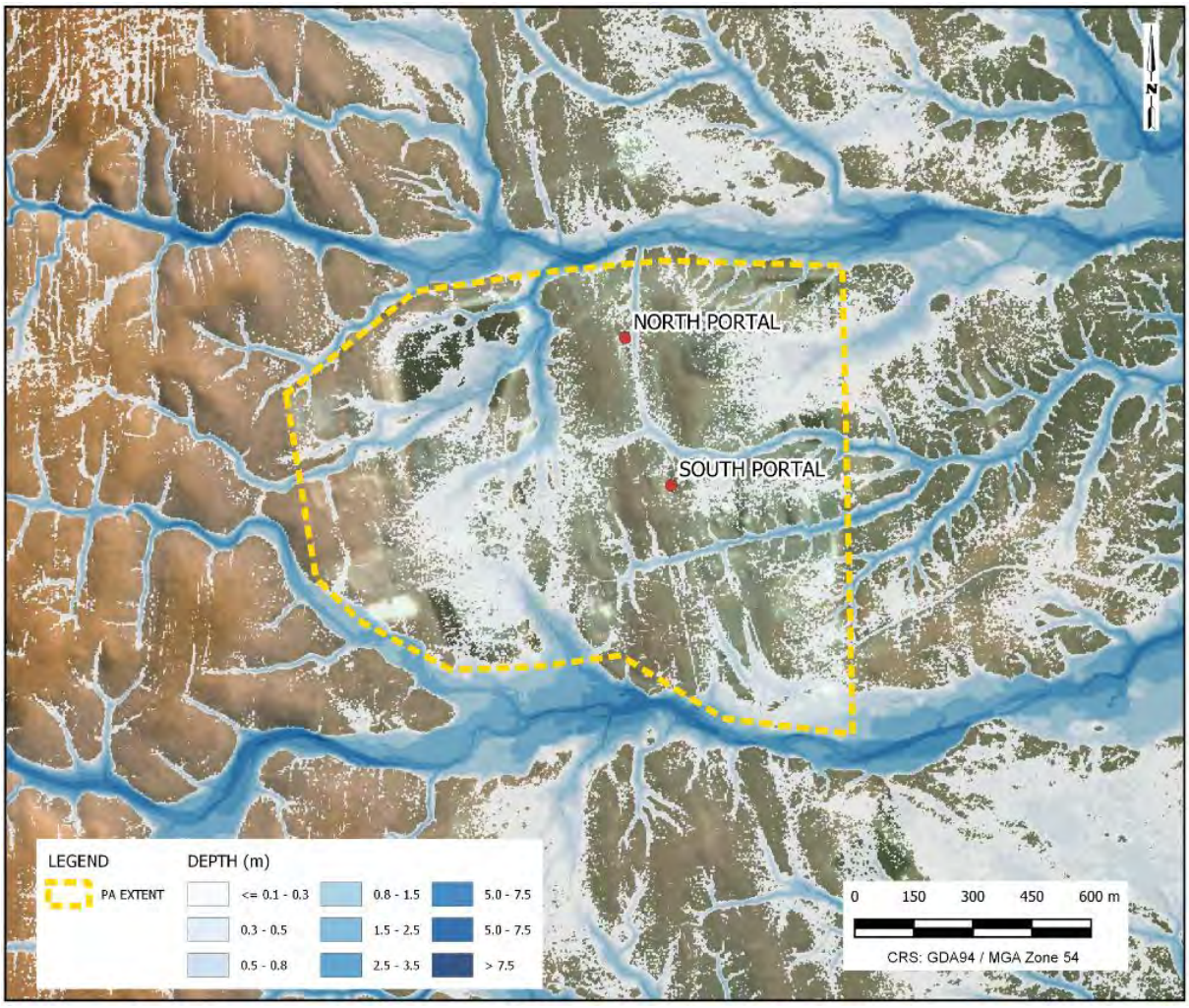
DIAGRAM 10: PROCESS AREA - PMP FLOOD DEPTH



The maximum recorded water surface elevation and maximum velocities in North Creek, Mine Trib Centre and Silvermine Creek downstream of the Process Area are summarised in **TABLE 13** and **TABLE 14**. The locations where results are recorded in **TABLE 13** and **TABLE 14** are depicted on **DIAGRAM 11**.

TABLE 13: PROCESS AREA TRIBUTARY PEAK WATER SURFACE ELEVATIONS

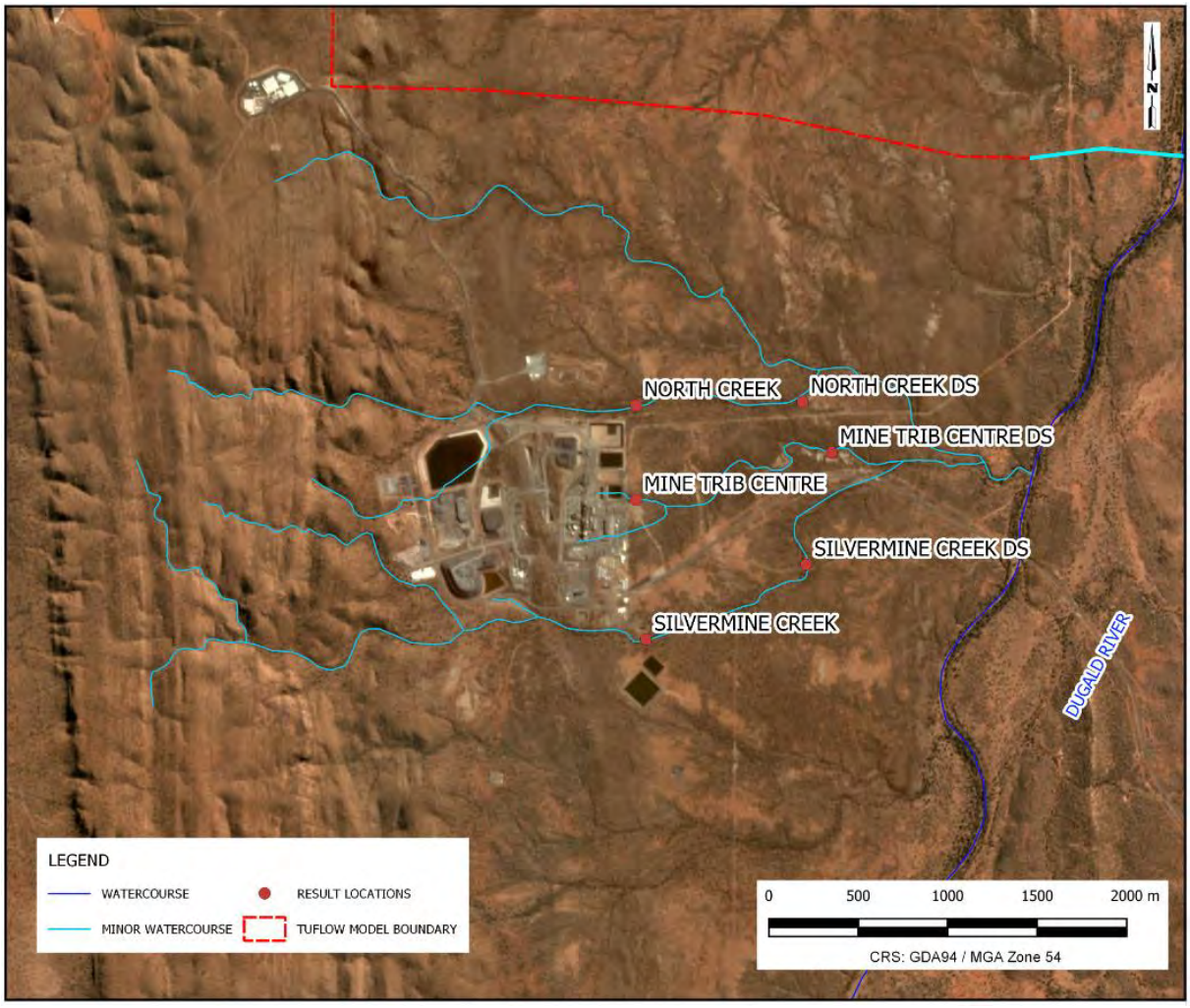
Location	Peak Water Surface Elevation (m AHD)		
	PMP	0.1% AEP	1% AEP
North Creek	197.48	195.43	195.19
North Creek DS	191.65	191.63	191.62
Mine Trib Centre	198.33	197.14	196.86
Mine Trib Centre DS	189.95	188.28	188.00
Silvermine Creek	200.97	198.91	198.57
Silvermine Creek DS	193.29	191.05	190.74

TAILINGS.WATER.WASTE.

TABLE 14: PROCESS AREA TRIBUTARY MAXIMUM VELOCITIES

Location	Maximum Velocity (m/sec)		
	PMP	0.1% AEP	1% AEP
North Creek	3.15	2.74	2.46
North Creek DS	3.14	2.46	2.27
Mine Trib Centre	0.79	0.50	0.43
Mine Trib Centre DS	0.41	0.37	0.31
Silvermine Creek	2.51	1.90	1.83
Silvermine Creek DS	2.07	1.97	1.95

DIAGRAM 11: PROCESS AREA FLOOD LEVEL LOCATIONS



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4.4 Sensitivity Outcomes

The sensitivity analysis was conducted for the conditions listed in **Section 3.5**. The results for the 1.0% AEP 95th percentiles RFFE inflows indicated no impacts on the TSF closure embankment and spillway from flows in Cabbage Tree Creek, and no impacts on the plant process area from flows in the Dugald River. Under the modelled scenario a backwater effect from the increased sensitivity inflow does not impact the model.

Relative to the base model, a 20% increase in Manning's roughness coefficient does not have a significant impact on the maximum water surface elevations at the North Portal and has a slight negative impact at the South Portal. A 20% increase in the applied rainfall depth results in an increase in flows depths up to 0.36 m adjacent to the North Portal and 0.15 m at the South Portal. A comparison of base model and sensitivity test results is shown in **TABLE 15**.

TABLE 15: PORTAL SENSITIVTY IMPACTS

Location	Model Type	Maximum Water Surface Elevation (m AHD)		
		PMP	0.1% AEP	1% AEP
North Portal	Base Model	204.00	201.77	201.45
	+ 20% Manning's Sensitivity	204.04	201.79	201.46
	+ 20% Rainfall Depth	204.36	201.98	201.60
	Maximum Modelled Difference	+ 0.36 m	+ 0.21 m	+ 0.15 m
South Portal	Base Model	205.50	204.84	204.74
	+ 20% Manning's Sensitivity	205.35	204.77	204.75
	+ 20% Rainfall Depth	205.65	204.90	204.79
	Maximum Modelled Difference	+ 0.15 m	+ 0.06 m	+ 0.05 m

Relative to the base model, an increase of 20% in Manning's roughness coefficient has no significant impact on the water surface elevation of the model in all events up to the PMF. An increase of 20% rainfall depth results in an increase in water surface elevation of up to 0.27 m in the TSF spillway. Increasing the surface roughness decreases the peak flow rate because surface flows are retarded upstream of the spillway, as reflected in **TABLE 17**. Conversely, increasing rainfall depths by 20% had the result of increasing peak flow rate by between 18% and 27% for the PMP and 1% AEP events, respectively. Comparisons of base model results and sensitivity test results are shown in **TABLE 16** and **TABLE 17**.

TABLE 16: TSF SPILLWAY IMPACTS – MAXIMUM DEPTH

Location	Model Type	Maximum Water Surface Elevation (m AHD)		
		PMP	0.1% AEP	1% AEP
TSF Spillway - Upstream	Base Model	237.59	236.00	235.67
	+ 20% Manning's Sensitivity	237.51	235.94	235.68
	+ 20% Rainfall Depth	237.85	236.14	235.78
	Maximum Modelled Difference	+ 0.26 m	+ 0.14 m	+ 0.11 m
TSF Spillway - Downstream	Base Model	230.00	229.12	228.92
	+ 20% Manning's Sensitivity	229.98	229.09	228.67
	+ 20% Rainfall Depth	230.27	229.26	229.04
	Maximum Modelled Difference	+ 0.27 m	+ 0.14 m	+ 0.12 m

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TABLE 17: TSF SPILLWAY IMPACTS – MAXIMUM FLOW RATE

Location	Model Type	Peak Flow Rate (m^3/sec)		
		PMP	0.1% AEP	1% AEP
TSF Spillway	Base Model	282.9	74.6	44.6
	+ 20% Manning's Sensitivity	246.0	71.1	43.7
	+ 20% Rainfall Depth	333.5	89.3	56.5
	Maximum Modelled Difference	+ 50.6	+ 14.7	+ 11.9

The sensitivity tests indicate that the model is not very sensitive to increases in the surface roughness, but has some sensitivity to increases in rainfall depths at both the main mine site and the TSF area.

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5 PCRP INPUTS

The PRCP requires flood risk assessments for two aspects of closure; to identify whether any mine voids will remain in the floodplain post-closure, and to assess the flood risk to any remaining infrastructure.

5.1 Mine Portals

Post closure, if there was a mine void located in a floodplain the void would need to be rehabilitated to a stable condition. A mine portal could potentially be considered as a void, and the floodplain is defined as land which is at or below the peak water level for the 0.1% AEP design storm event.

The modelling outputs presented in **Section 4** show that the mine portals are not located below the 0.1% AEP flood level and are therefore not located within the floodplain. Further, both portals are at very low risk from flooding. The North Portal and the South Portal are not subject to inundation in any events up to and including the PMF.

Flood mapping shows that the portals are clear of local flooding and are outside of the floodplain, but there are small drainage lines in the area. These drainage lines are artefacts of the original topography prior to any mine disturbance and not a definitive representation of the final landform (refer **DIAGRAM 10**). Local topography and drainage will be modified during closure, to ensure that local runoff is directed away from the portals and will aim to reconnect drainage lines with downstream watercourses.

It should also be noted that the mine portals will be capped at closure, to prevent water entering the mine workings.

5.2 TSF

Post closure, the TSF will be the only remaining piece of infrastructure, although this will be closed and capped. Preliminary design has adopted a self-shedding cover system, with a nominal gradient of 1.5%, and a modified embankment. A spillway channel will be added, to achieve the following:

- Prevent water from ponding against the upstream face of the embankment;
- Prevent flow over the top of the embankment;
- Divert flows away from the toe of the embankment; and
- Reconnect catchment flows with the downstream watercourse.

The flood modelling presented in **Section 4** has demonstrated that the proposed spillway design (**TABLE 6**) is suitable to safely convey design events up to and including the PMF. Flooding from the downstream tributary and Cabbage Tree Creek does not affect the TSF embankment. Notwithstanding, modelled results indicated that a backwater effect was exhibited on the downstream toe of the TSF embankment, as a result of the spillway outflows. Re-alignment of the spillway channel, to properly convey catchment flows to the downstream tributary, will be required during detailed design of the spillway.

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6 SUMMARY AND CONCLUSION

Hydraulic analysis of the site was undertaken using the two dimensional (2D) finite difference program TUFLOW, with ARR **[1]** utilised to develop the rainfall estimates for input into the hydraulic model. It is understood that MMG intends to rehabilitate the site to the pre-mining topography, as much as is practically possible. As such, the pre-mining surface and the preliminary TSF closure plan, developed by ATCW in 2016, were incorporated in the hydraulic model.

The PRCP requires flood risk assessments for two aspects of closure: to identify whether any mine voids will remain in the floodplain post-closure; and to assess the flood risk to remaining infrastructure. The modelling outputs presented in **Section 4.3** show that the mine portals are not located below the 0.1% AEP flood level and are therefore not within the floodplain. Additionally, the modelling results indicated that both portals are at a low risk of flooding. The North Portal and the South Portal are not subject to inundation in any events up to and including the PMF.

The remaining infrastructure proposed to be left at the site is the rehabilitated and capped TSF. Modelled results indicate that flooding from the downstream tributary and Cabbage Tree Creek does not affect the TSF embankment. Notwithstanding, a backwater effect was exhibited on the downstream toe of the TSF embankment, due to the spillway outflows. Re-alignment of the spillway channel, to properly convey catchment flows to the downstream tributary, will be required during detailed design of the spillway. Modelling results indicated that, with only a single spillway, the TSF embankment crest should be raised to a level of 238.5 m AHD. Additionally, the maximum velocities recorded for the PMP event were some 6.2 m/s within the spillway channel. These modelled velocities have a high potential for erosion, and as such erosional velocity dampeners, re-grading of the spillway channel or a similar method of limiting velocity would potentially need to be implemented.

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[9] ATCW (2016b), 'MMG Dugald River – Tailings Storage Facility - Design Report Closure Concept – Figure 15.1' (Ref: 108003.20.Figure 15.1 – dated 22 February 2016).

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[11] Innovyze (2019), 'Manning's n Roughness Coefficients – Open Channel', October 2019.

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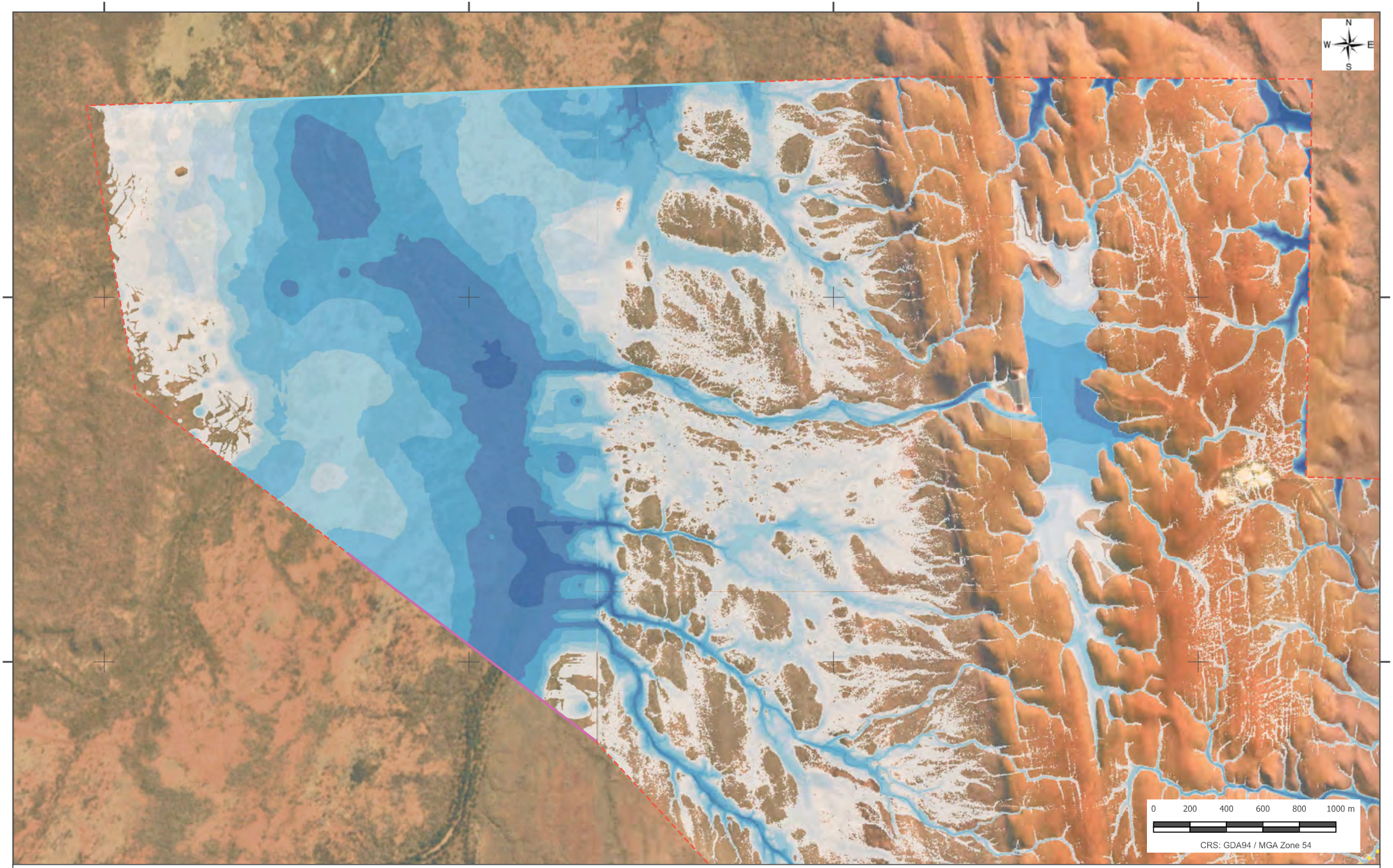
FIGURES



LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

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DUGALD RIVER MINE
TSF PMP - MAXIMUM FLOOD DEPTH

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FIGURE 001

108003-49

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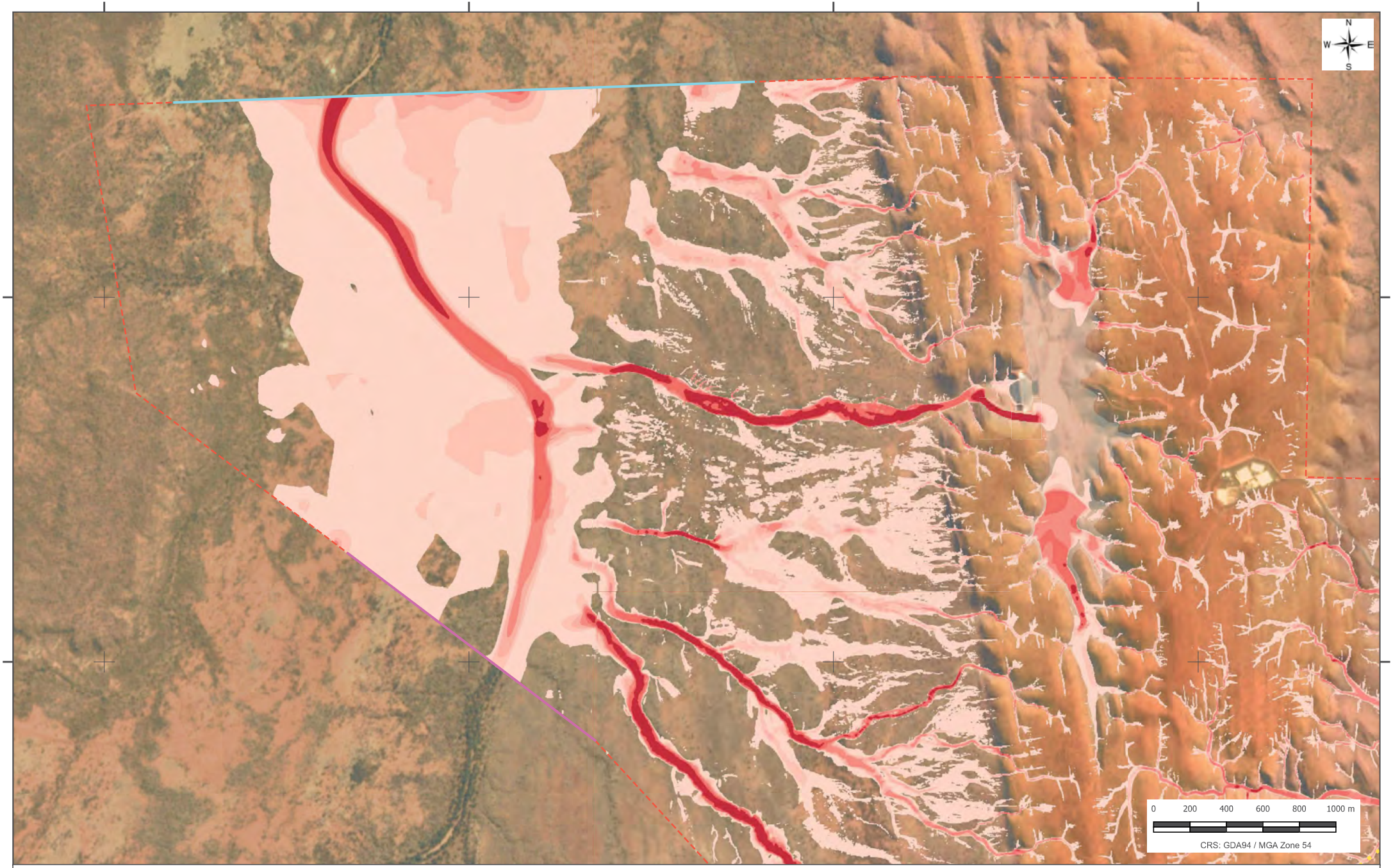

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6	0.8 - 1.0	> 2.5
0.6 - 0.8	1.0 - 1.5	
0.6 - 0.8	1.5 - 2.5	

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DUGALD RIVER MINE
TSF PMP - MAXIMUM FLOOD VELOCITY

ATC WILLIAMS

FIGURE 002

108003-49

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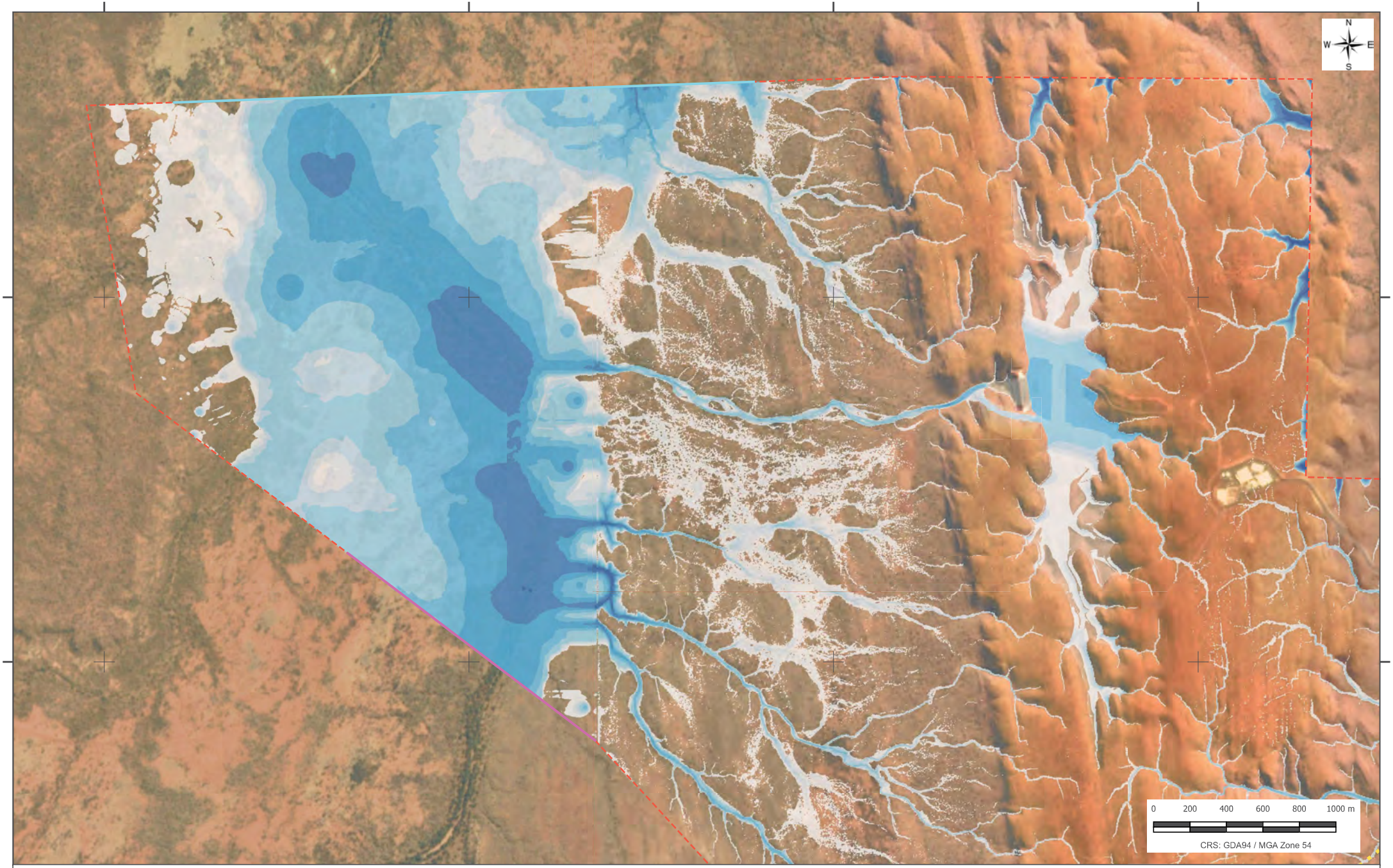

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

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DUGALD RIVER MINE
TSF 0.1% AEP - MAXIMUM FLOOD DEPTH

ATC WILLIAMS

FIGURE 003

108003-49

DATE: 2021-05-18

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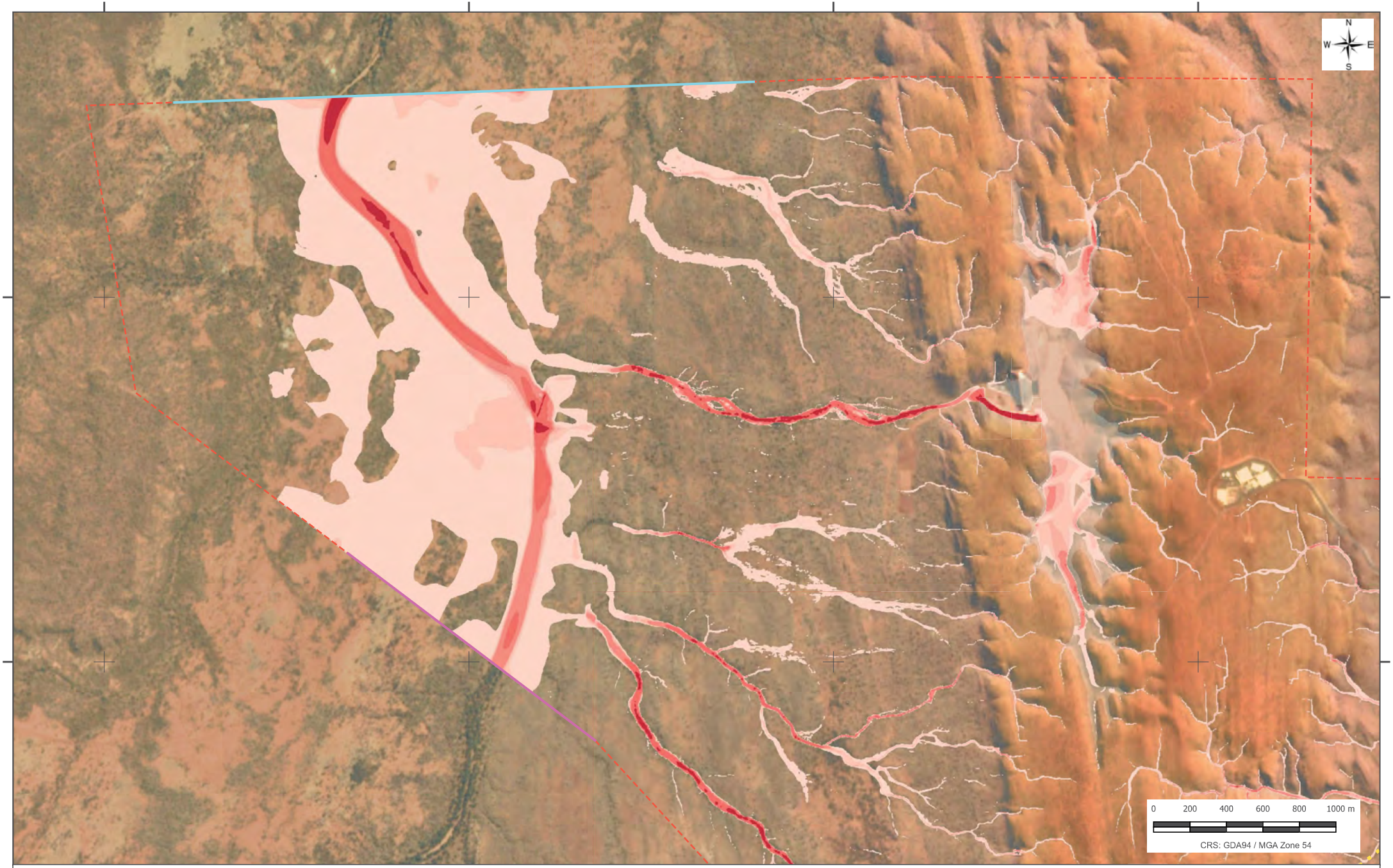

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170 | 205 | 240 | 275 | 310

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 | 0.6 - 0.8 | 0.6 - 0.8 | 0.8 - 1.0 | 1.0 - 1.5 | 1.5 - 2.5 | > 2.5

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DUGALD RIVER MINE
TSF 0.1% AEP - MAXIMUM FLOOD VELOCITY

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FIGURE 004

108003-49

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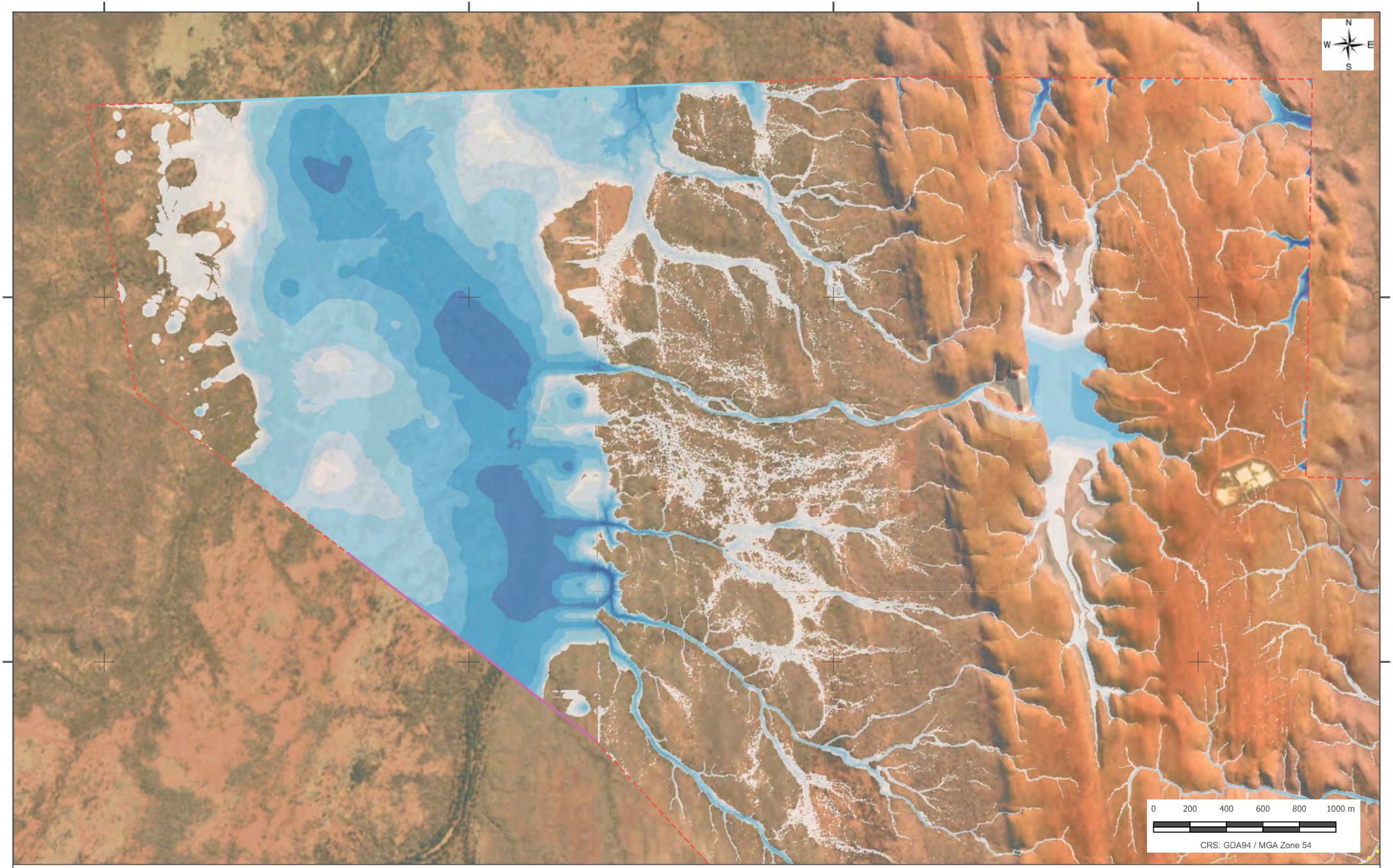

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

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DUGALD RIVER MINE
TSF 1.0% AEP - MAXIMUM FLOOD DEPTH

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FIGURE 005

108003-49

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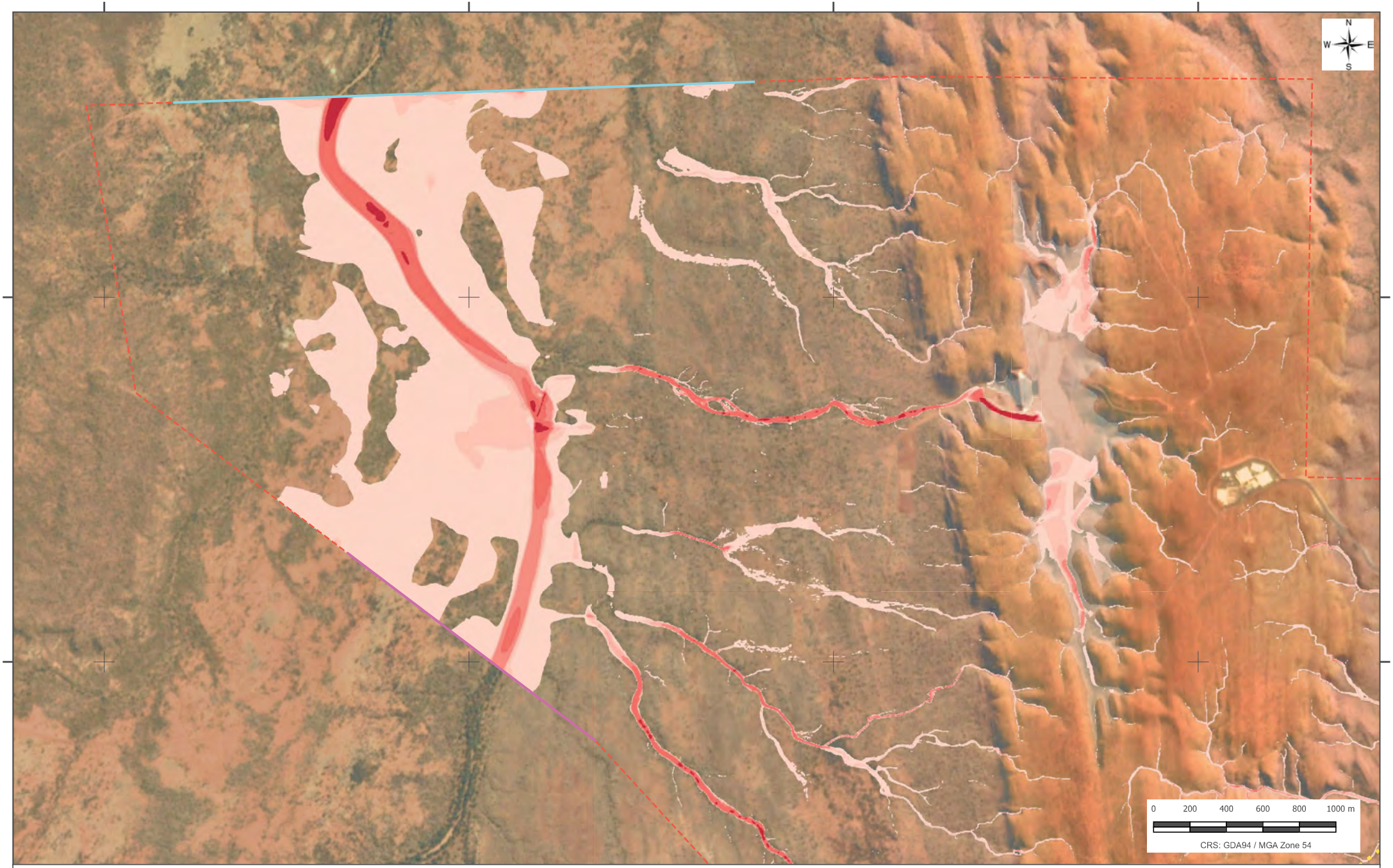

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6	0.8 - 1.0	> 2.5
0.6 - 0.8	1.0 - 1.5	
0.6 - 0.8	1.5 - 2.5	

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DUGALD RIVER MINE
TSF 1.0% AEP - MAXIMUM FLOOD VELOCITY

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FIGURE 006

108003-49

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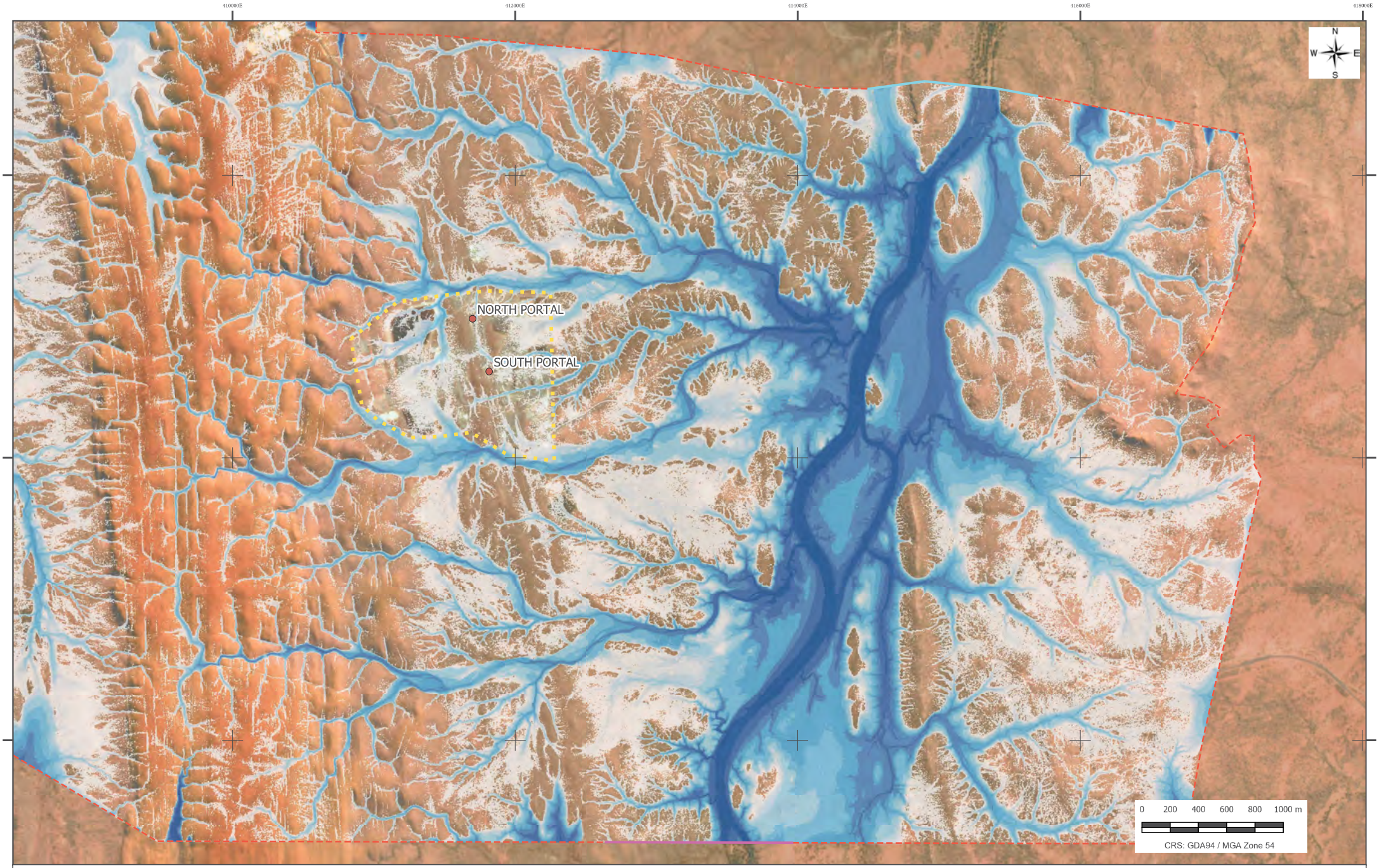

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170	275	
205	310	
240		

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

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DUGALD RIVER MINE
PROCESS AREA PMP - MAXIMUM FLOOD DEPTH

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FIGURE 007

108003-49

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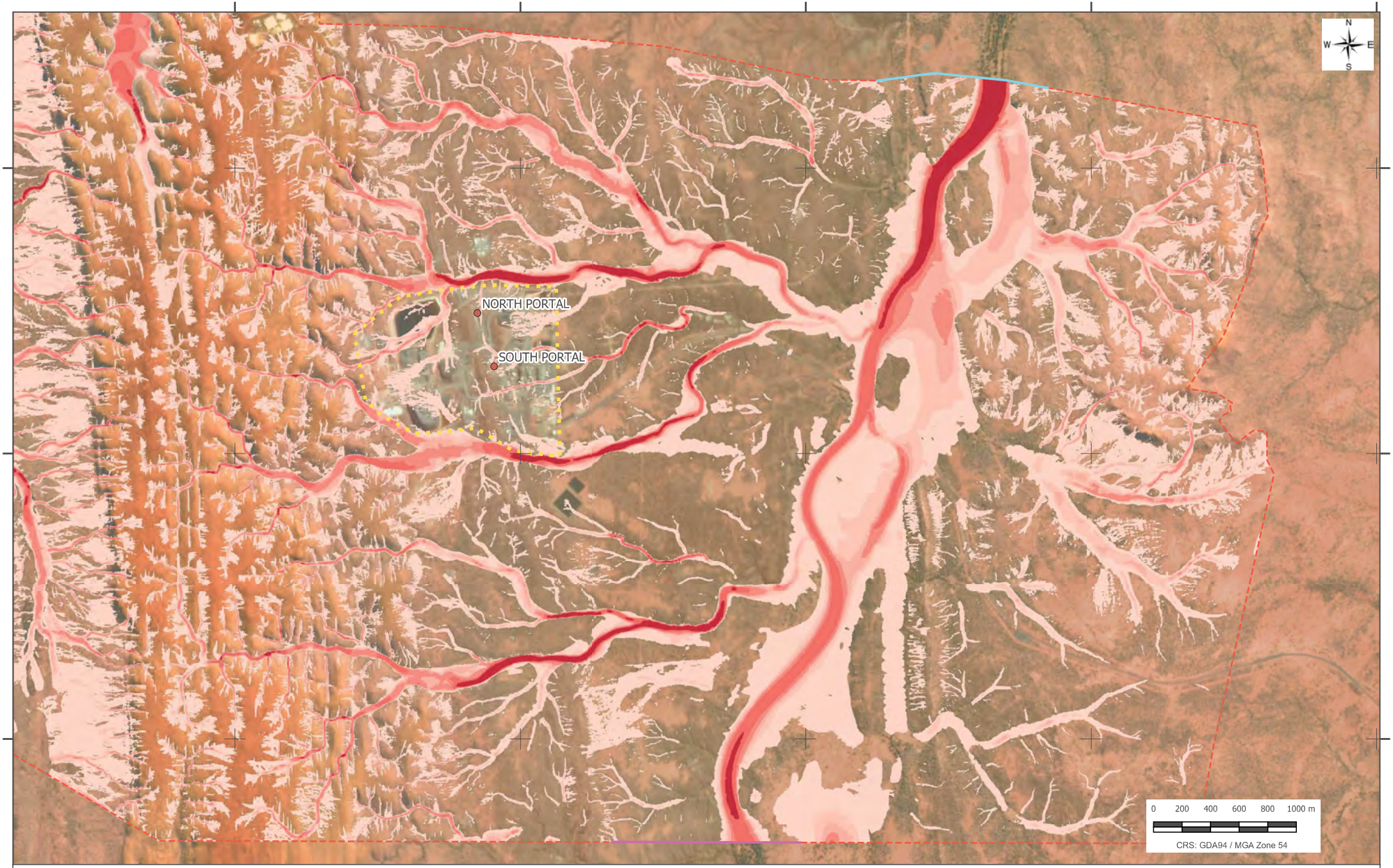

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 | 205 | 240 | 275 | 310

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 | 0.6 - 0.8 | 0.6 - 0.8 | 0.8 - 1.0 | 1.0 - 1.5 | 1.5 - 2.5 | > 2.5

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DUGALD RIVER MINE
PROCESS AREA PMP - MAXIMUM FLOOD VELOCITY

ATC WILLIAMS

FIGURE 008

108003-49

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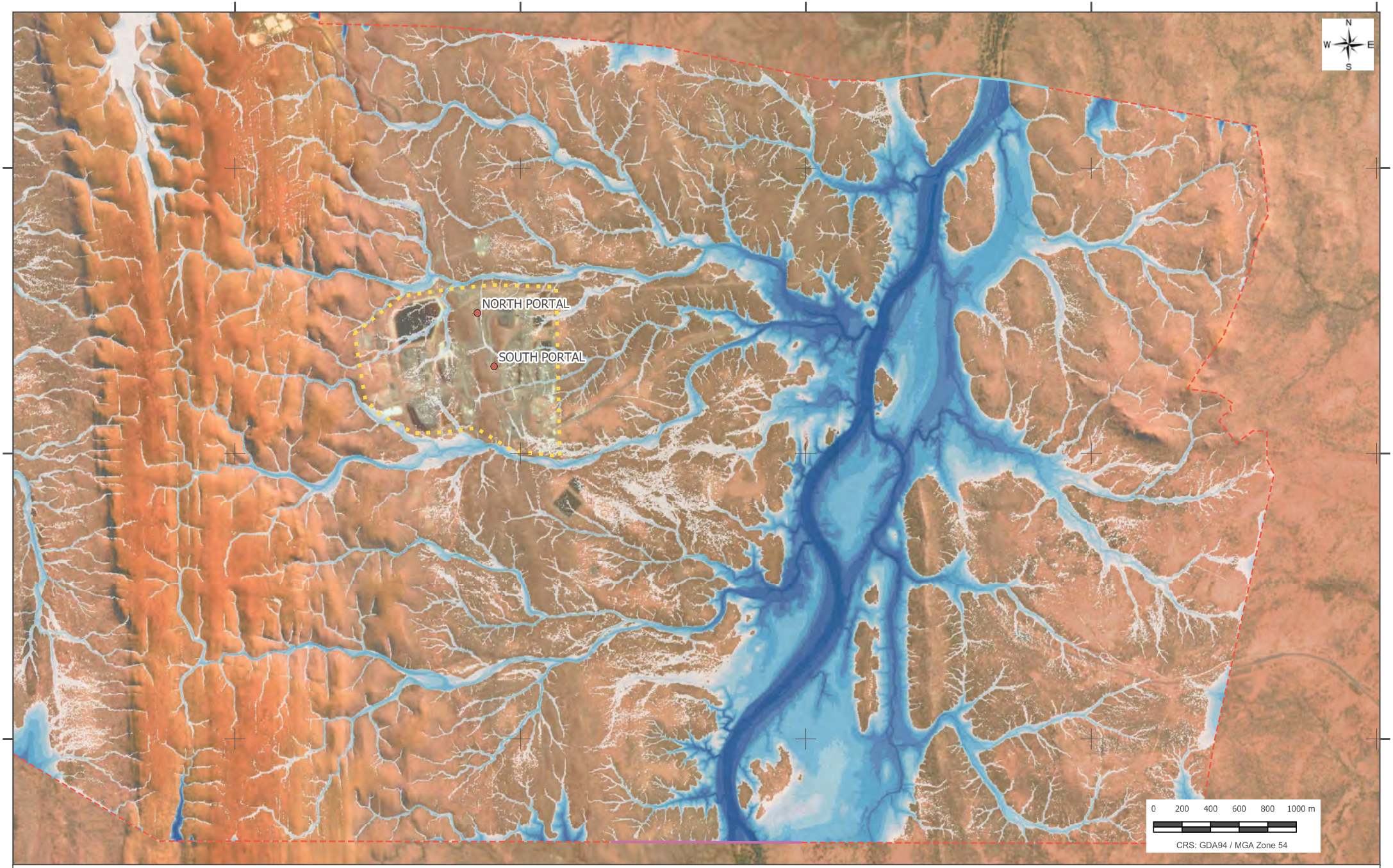

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 | 205 | 240 | 275 | 310

MAXIMUM DEPTH (m)

0.3 - 0.5 | 0.5 - 0.8 | 0.8 - 1.5 | 1.5 - 2.5 | 2.5 - 3.5 | 5.0 - 7.5 | 5.0 - 7.5 | > 7.5

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DUGALD RIVER MINE
PROCESS AREA 0.1% AEP - MAXIMUM FLOOD DEPTH

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FIGURE 009

108003-49

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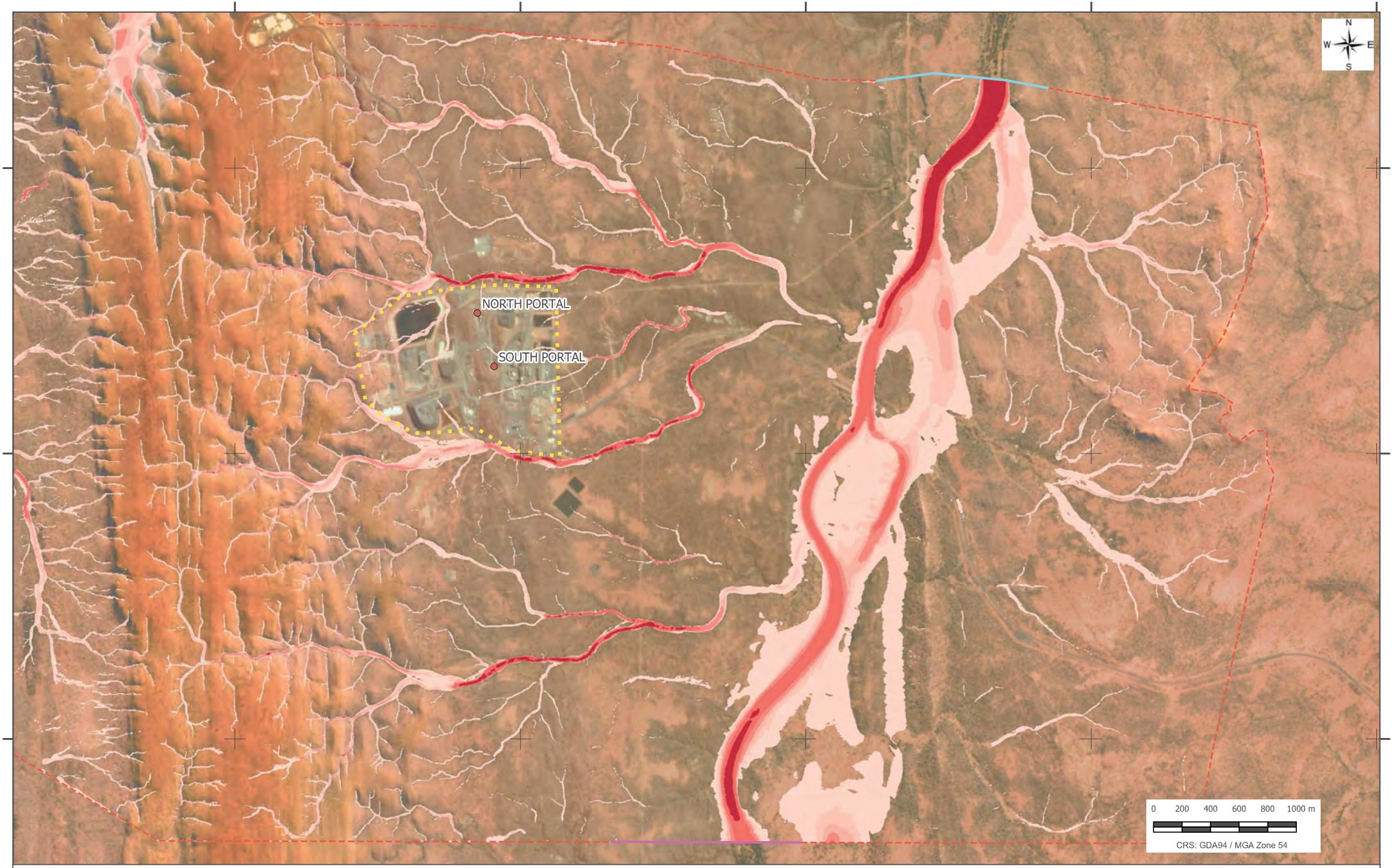

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 | 205 | 240 | 275 | 310

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 | 0.6 - 0.8 | 0.6 - 0.8 | 0.8 - 1.0 | 1.0 - 1.5 | 1.5 - 2.5 | > 2.5

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DUGALD RIVER MINE
PROCESS AREA 0.1% AEP - MAXIMUM FLOOD VELOCITY

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FIGURE 010

108003-49

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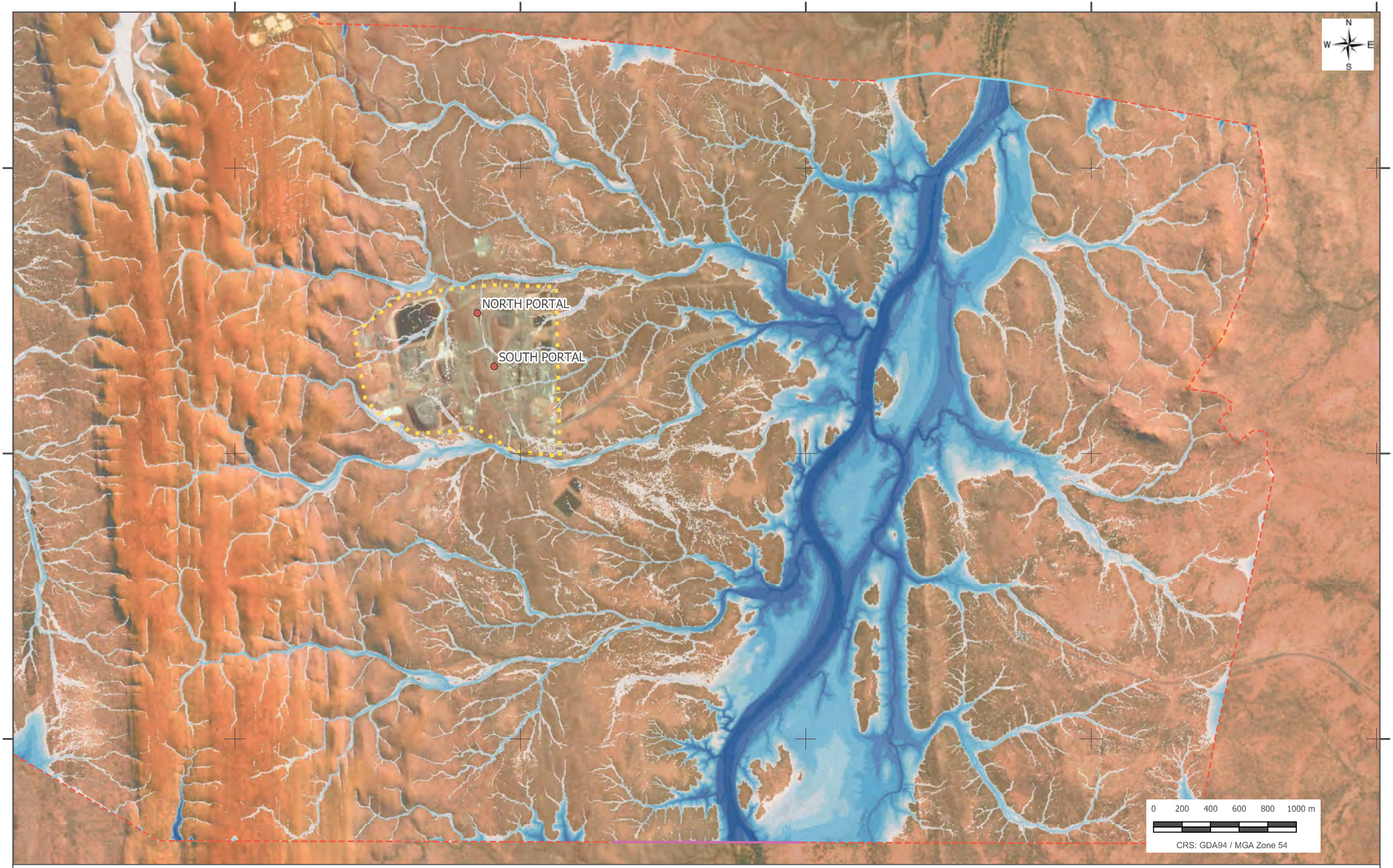

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 275
205 310
240

MAXIMUM DEPTH (m)

0.3 - 0.5 1.5 - 2.5 5.0 - 7.5
0.5 - 0.8 2.5 - 3.5 > 7.5
0.8 - 1.5 5.0 - 7.5

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DUGALD RIVER MINE
PROCESS AREA 1.0% AEP - MAXIMUM FLOOD DEPTH

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FIGURE 011

108003-49

DATE: 2021-05-18

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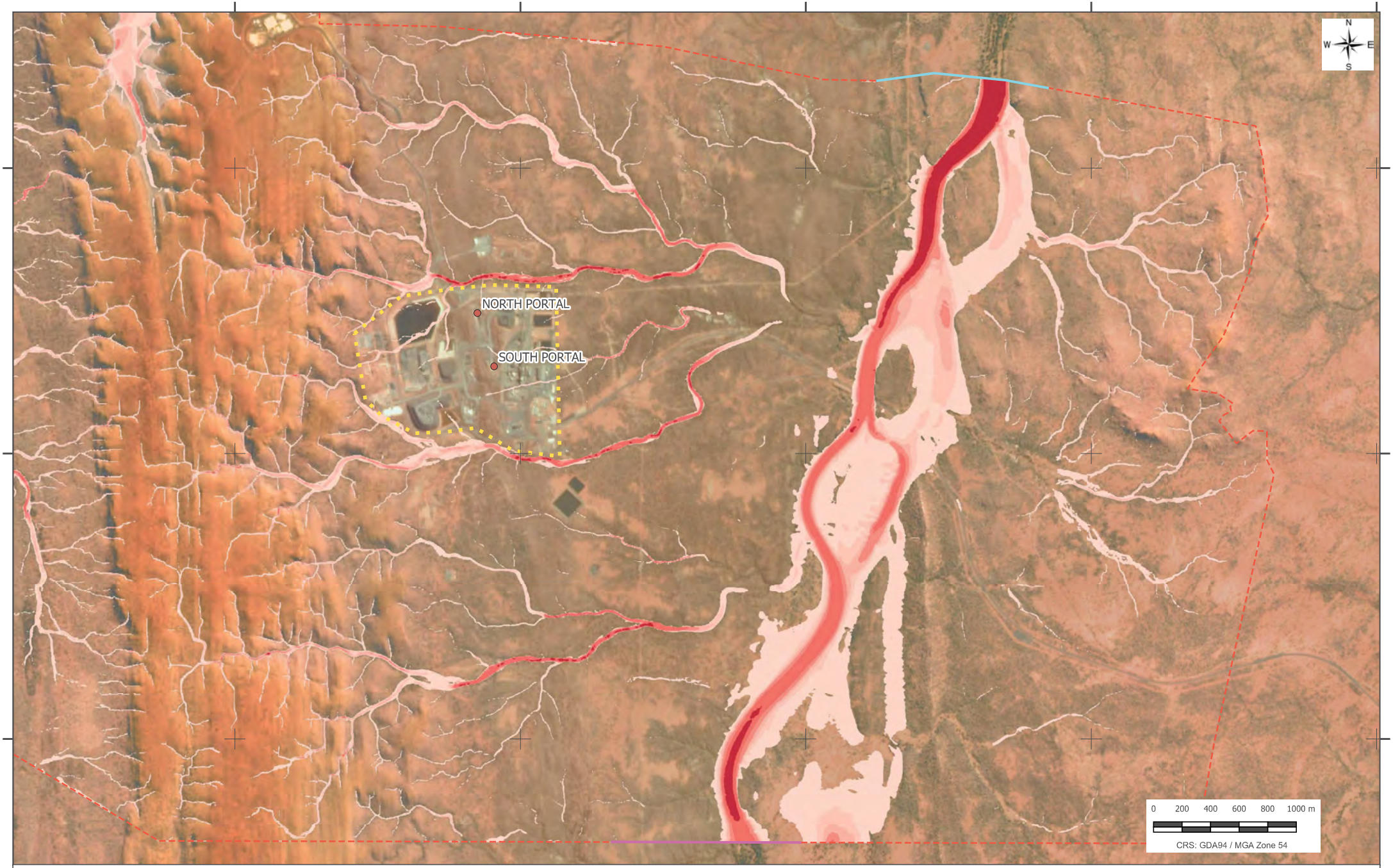

LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 275
205 310
240

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 0.8 - 1.0 > 2.5
0.6 - 0.8 1.0 - 1.5
0.6 - 0.8 1.5 - 2.5

MMG AUSTRALIA PTY LTD

DUGALD RIVER MINE
PROCESS AREA 1.0% AEP - MAXIMUM FLOOD VELOCITY

ATC WILLIAMS

FIGURE 012

108003-49

DATE: 2021-05-18

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APPENDICES

APPENDIX A PMP CALCULATIONS

TAILINGS.WATER.WASTE.

Generalised Short-Duration Method (GSDM)

LOCATION INFORMATION

Catchment Name	Dugald River Mine and TSF		*Reference: Generalised Short Duration Method (BOM, 2003)*	
Catchment Area	16.6 km²			
State	Qld			
Latitude	Longitude	Duration Limit	Prop Smooth	Prop Rough
-20.224	140148.000	6 Hrs	0%	100%

ELEVATION ADJUSTMENT FACTOR (EAF)

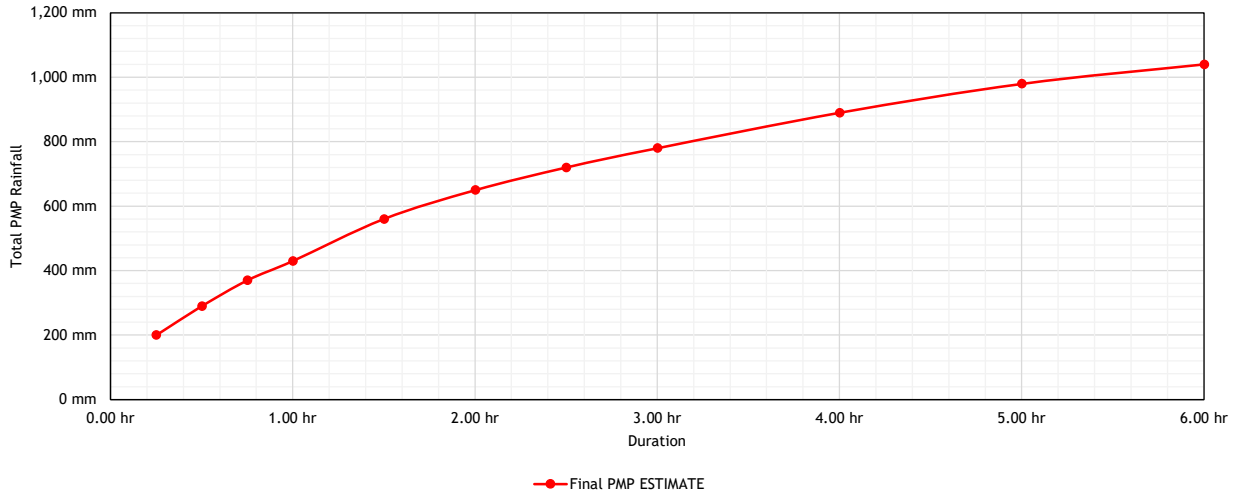
Mean Elevation at Site Location:	236 m	**EAF**	1

MOISTURE ADJUSTMENT FACTOR (MAF)

	MAF	0.960649

PMP VALUES (mm)

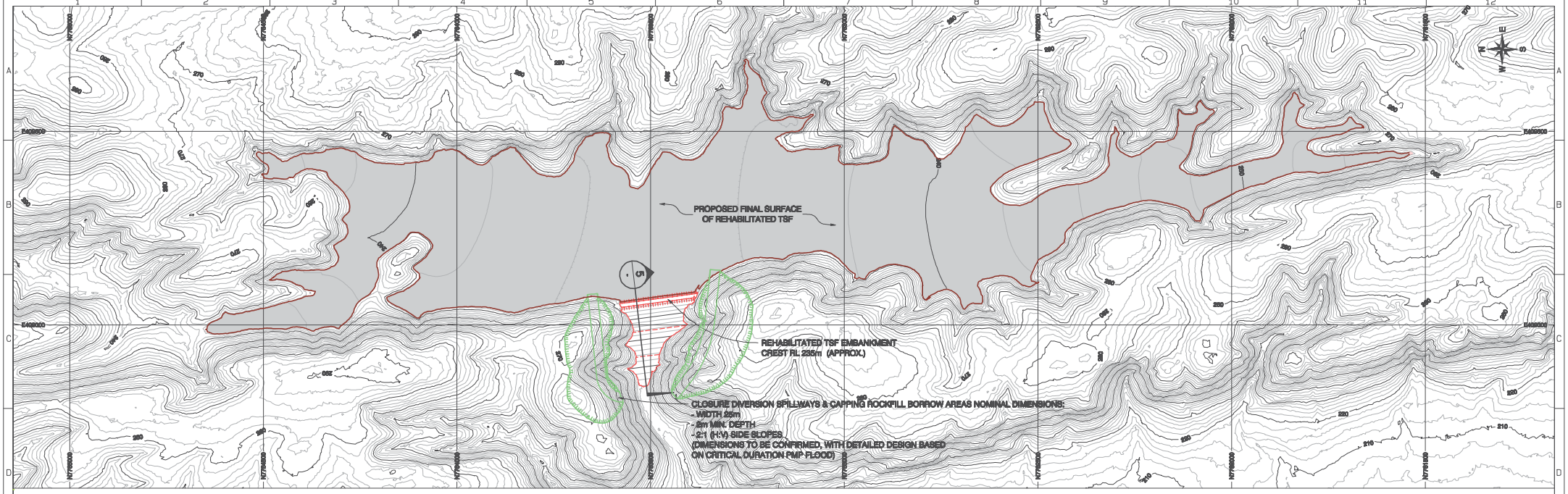
Duration (hours)	Initial Depth - Smooth (DS)	Initial Depth - Rough (DR)	PMP Estimate = (Ds x S + DR x R) x MAF x EAF	Rounded PMP Estimate (nearest 10 mm)
0.25 hr	203.1 mm	203.1 mm	195.1 mm	200 mm
0.50 hr	298.9 mm	298.9 mm	287.2 mm	290 mm
0.75 hr	381.2 mm	381.2 mm	366.2 mm	370 mm
1.00 hr	447.6 mm	447.6 mm	429.9 mm	430 mm
1.50 hr	511.2 mm	573.3 mm	550.7 mm	560 mm
2.00 hr	573.4 mm	670.2 mm	643.9 mm	650 mm
2.50 hr	610.2 mm	740.6 mm	711.5 mm	720 mm
3.00 hr	640.3 mm	807.7 mm	775.9 mm	780 mm
4.00 hr	708.8 mm	923.7 mm	887.4 mm	890 mm
5.00 hr	763.3 mm	1,014.6 mm	974.7 mm	980 mm
6.00 hr	808.6 mm	1,081.2 mm	1,038.6 mm	1040 mm



Dugald River Mine and TSF	**PMP ESTIMATES** **Short Duration** **GSDM**
ATC Williams www.atcwilliams.com.au perth@atcwilliams.com.au T +61 8 9213 1600	**Job No: 108003.49** **Date: 18/05/2021** **FIGURE 1**

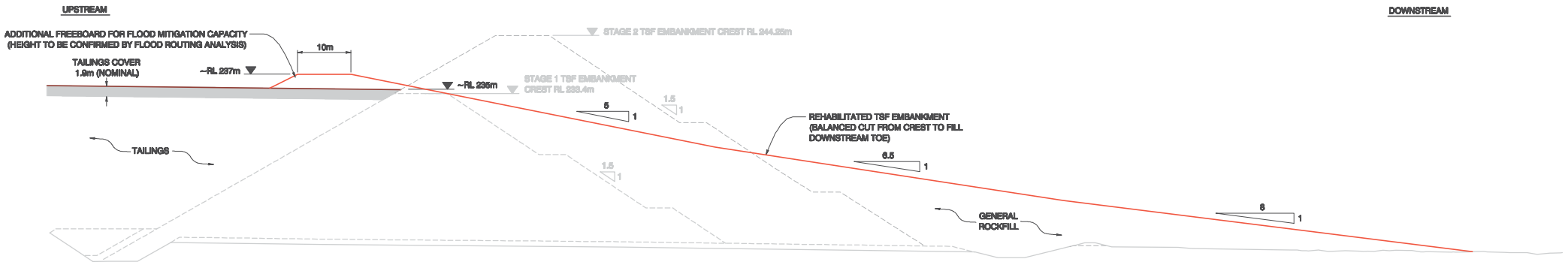
APPENDIX B DUGALD RIVER MINE TSF – CLOSURE CONCEPT

TAILINGS.WATER.WASTE.



FINAL CLOSURE PLAN

SCALE 1:10,000



SECTION 5

REHABILITATED TSF EMBANKMENT

SCALE 1:750

No.	DESCRIPTION	DATE	DRAWN	CHECKD	APPRD

SCALE AS SHOWN	
JOB No.	108003.20
DATE	22.02.16
DESIGN	CN
DRAWN	HR
CHECKED	
APPROVED	

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MMG DUGALD RIVER
TAILINGS STORAGE FACILITY

DESIGN REPORT
CLOSURE CONCEPT

FIGURE 15.1

CLIENT No.
CAD REF.
REV. 0 | SHT SIZE A3
SHEET 1 OF 1

J:\2008\108003 Dugald River\18 Revised TSF Design\Terramodel\Dugald River Design Report Figures.pro (Terramodel) Thu 25 Feb 2016 15:26:52

Appendix G: Surface Subsidence Risk

MEMORANDUM

To	Jonathon Crosbie, Martin Brownlee
Cc	Charles Smith, Adam Barton, Tim Akroyd
From	Madeline Merrett
Date	19/05/2020
Subject	**DRM SURFACE SUBSIDENCE RISK**

MEMORANDUM SURFACE SUBSIDENCE GEOTECHNICAL RISK REVIEW

BACKGROUND

As part of the DRM Progressive Closure and Rehabilitation Plan (PRCP), the surface and underground subsidence risk needs to be reviewed to ensure long term stability. As part of the Department of Environment and Science progressive rehab and closure guidelines a geotechnical study must be completed on surface subsidence risk and should include the following:

- Post closure stabilisation of underground workings (Geotechnical assessment of the stability of the underground openings, assessment of ground water conditions and ground water impacts on the design)
- Sealing off surface openings to underground workings (Geotechnical assessment of bulkhead materials, competency and stability of the ground containing the bulkhead, the need for additional ground support and reinforcement)
- Extent of post closure residual subsidence of underground workings (Geotechnical assessment of the stability of the underground openings and over burden, surface and ground water conditions and ground water impacts on subsidence)

INTRODUCTION

The Dugald Rive Mine crown pillar and mine extraction method has been designed to ensure long term stability and prevent surface and underground subsidence. The primary purpose of the crown pillar is to protect surface land users, the mine, and all those who work within the mine. It is vital that the surface pillar remains stable throughout the life of the mine and remain stable beyond this time. Dugald River mine has adopted a sub level open stope mine method with backfill to increase the long-term stability of the mine and ensure consolidation of voids. The crown pillar has been designed to prevent surface subsidence and underground stope design guidelines are in place to prevent cave like failure underground.

All geotechnical risk on site at Dugald River Mine are captured in the ground control risk bowtie and the Ground Control Management Plan (GCMP). Previous work has been completed by consultants on the stability and design of the crown pillar and the influence of ground water on the stability of the mine which all form a part of the GCMP.

WEATHERING

Weathering varies across the Dugald River deposit from gossan to a shallow weathering profile. The gossan marks the outcropping line of lode and extends along the crest of a low ridge for >2 km and at a width of up to 10 m. Weathering is a critical component of the rock mass characterisation and will have a significant impact on the overall crown pillar stability.

The DRM weathering and leaching depths are estimated in the following table:

Table 1: DRM Weathering Depths (AMC 2011)

	Hanging wall	Dugald Lode	Footwall
Base of complete Oxidation	12m	Variable	1m
Base of Leaching	31.5m	Variable	5m

Weathering to significantly greater depths is likely down sheared or faulted zones that intersect the surface particularly along the contact of the Dugald lode with the hangingwall and footwall slates.

The following assumptions have been made regarding the weathering profile for the crown pillar design (AMC 2011)

- Within the hangingwall, extremely to partially weathered rock can extend to depths of approximately 30m. Rock that is slightly weathered or weathered only on fractures, may extend to a depth in the order of 40m.
- Within the Dugald Lode and Footwall sequence, the weathering profile is shallow. In the absence of significant shears or fault zones, extremely to partially weathered rock may extend to depths of approximately 1m. Beyond 5m depth, weathering is only expected on fractures.

To ensure long term stability the crown pillar has been designed in fresh rock, below the level of significant weathering (Figure 1)

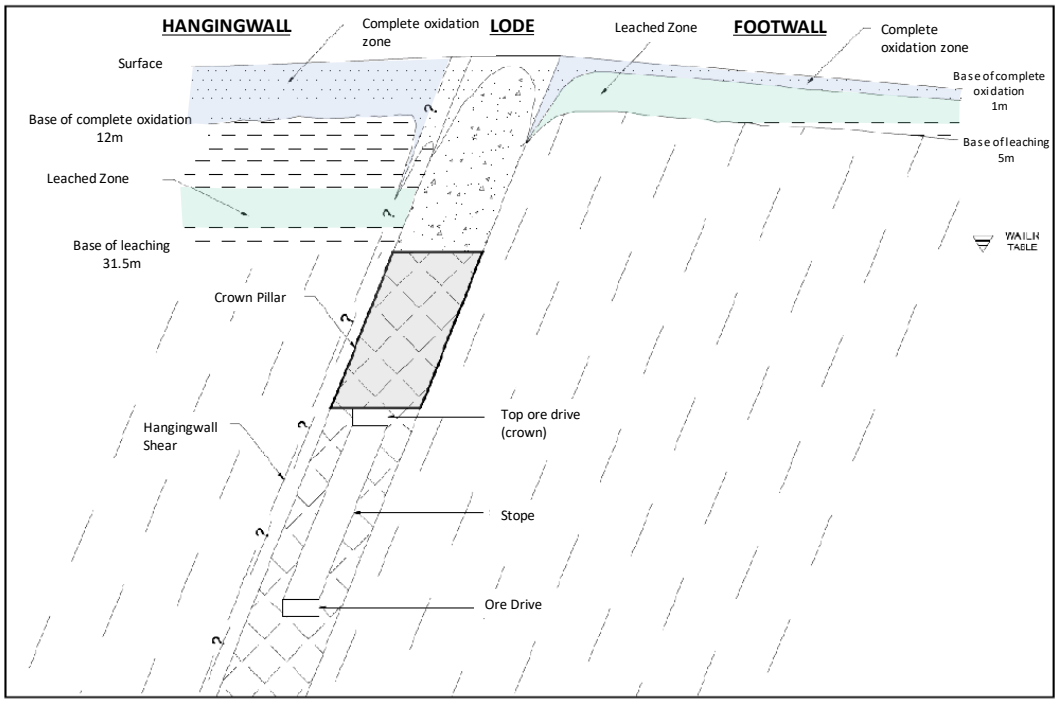

Figure 1 DRM Depth of Weathering

GROUND WATER

The Dugald River hydrogeological conditions have been summarised in the document MMG Dugald River Mine Groundwater Monitoring Program (Big Dog Hydrogeology, September 2014) and in the Environmental Impact Statement (Rob Lait & Associates, 2010).

The following observations were outlined:

- Ground water depths, in bores around the project, range from 10.1m to 230m depth, with a median depth of 31.5m.

- Flows range from 0.13L/s to 9.3L/s, with a median value of 0.98L/s, with groundwater flows in excess of 2L/s being the exception
- The geological units around the Dugald River Project are not highly productive and the majority of the ground water occurs at shallow depths
- Very minor supplies of groundwater occur in the Dugald River Slates, which form the immediate hanging wall and footwall of the Dugald Lode.
- The gradient of the potentiometric surface is 0.009, which is typical of low bulk permeability.
- Ground water flow occurs predominantly in zones of fracturing close to the base of weathering in metasediments.
- Overall, the mining observations to date indicate low to moderate permeability for fracture zones within the Dugald River slate, with limited ground water storage.

Groundwater samples have been taken underground from STH-175 Level, STH Stock Pile _1 and NTH Stock Pile 3. Generally, water flow into development at Dugald River Mine can be classified between wet and dripping.

Table 2 Ground Water Testing

Location	Electrical Conductivity (EC) µS/cm	TDS Mg/L ppm	pH	Temperature	Redox mV	Dissolved Oxygen % Sat
STH_175	1722	682	7.5	31.2	-108.7	10.4
STH_SP1	1545	612	6.06	30.5	-55.8	5.2
NTH_SP3	2055	814	7.34	30.2	-29.2	13.1

An assessment of the corrosivity of the ground water (MMG Internal File Note, December 2013) identified that the following:

- Groundwater intersected in development is associated with faults.
- Given the dissolved oxygen reading a corrosion rate of 0.12 (wet) to 0.20 mm/yr (dripping) can be expected.

CROWN PILLAR STABILITY (SURFACE SUBSIDENCE)

AMC Consultants completed a study in March 2011 to investigate the geotechnical conditions of the crown surface pillar for the Dugald River Project (Dugald River Crown Pillar Assessment – AMC 111005 March 2011). As part of this study AMC assessed the weathering profile, depth of the water table and crown pillar stability and size.

Standard empirical assessment techniques based on ground conditions and Lode Geometry was used to determine the appropriate crown pillar size and thickness along the length of the orebody. Rock mass Quality Q (after Barton et al, 1974) was used to assess the rock mass and the scaled crown span concept and Critical span limits developed by Carter (1992) was used to assess the stability of the crown pillar.

It is assumed that any crown pillar instability at Dugald River mine will be the result of a significant geological feature such as faults or shears. The Dugald River rock mass data indicates that the overall rock mass quality of the Dugald Lode is better than the host slate material.

To ensure long term stability the crown pillar has been designed in fresh rock, below the level of significant weathering. The top-level stopes beneath the crown must also be backfilled, as tight as practically possible, to minimise the change of hangingwall unravelling in the long term.

Only shallow depths of ground water is expected to be encountered and ground water is only expected to occur above the base of weathering. The mine crown regional pillar has been designed beneath the base of weathering zone and hence this shallow ground water will not impact the stability of the crown and henceforth affect surface subsidence.

The results of the assessment indicate that the crown pillar is likely to be stable at the design strike of 25m between dip pillars for the widths proposed in the current mine design and the dimensions. (Figure 2 and Table 3)

Table 3: DRM Crown Pillar Size (AMC 2011)

Mining Area	Maximum Design Width	Minimum Crown Pillar Thickness in Unweathered Rock	Thickness of Weathered Rock	Minimum Distance to Surface (Ultimate Surface Crown Pillar)
North	3.4m	5.5m	31.5m	37m
South	9.8m	19m	31.5m	50.5m

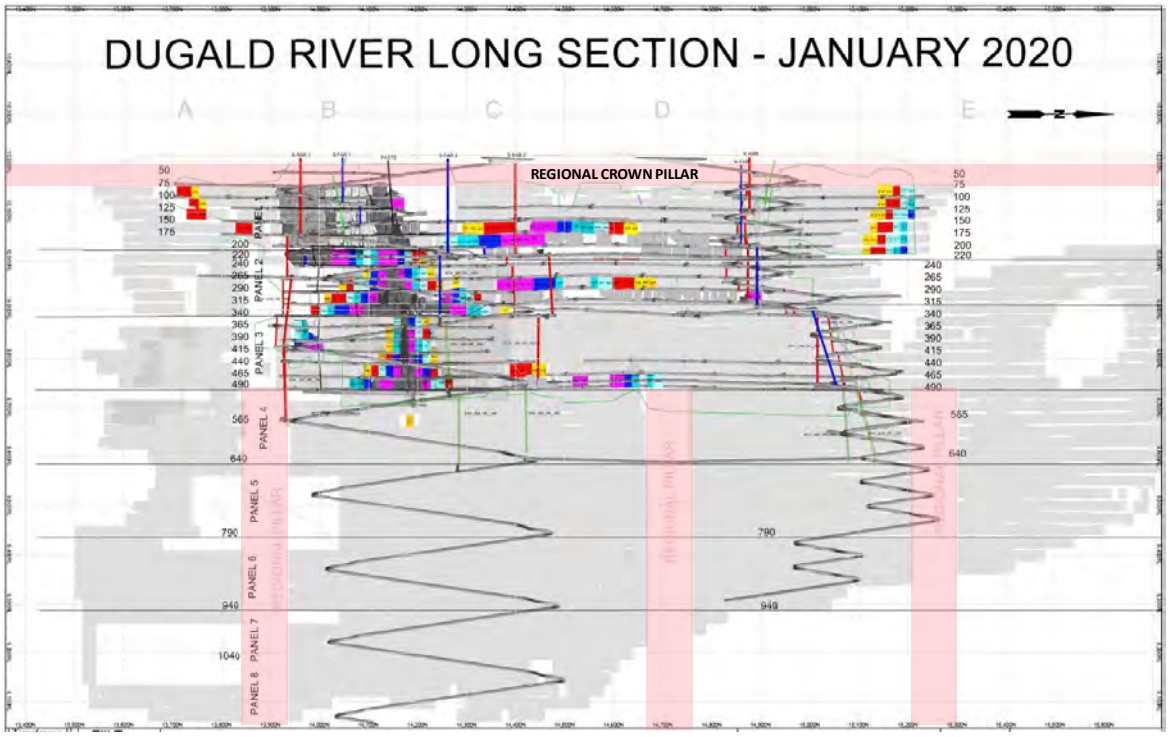

Figure 2 DRM Life of Mine Regional Pillar Locations

UNDERGROUND OPENING STABILITY (UNDERGROUND SUBSIDENCE)

Dugald River mine extraction method is a Sub Level Open Stope operation with both Cemented and rockfill backfill methods.

All design requirements and stability assessment for underground excavations are covered in the GCMP Section 11 – Geotechnical Mine Design. The empirical modified Mathews Stability Graph (Mathews et al. 1981) is used to determine stable dimensions for open stopes. Stope span limited are determined using the geotechnical classification values developed from core logging, underground mapping and structural data available. All stopes underground are backfilled to eliminate the potential for subsidence underground. Backfill design methods are presented in the DRM Backfill Design Work Quality Requirement 15811530. A void register is in place to manage backfill type and potential voids underground in order to manage consolidation of voids underground.

All underground stope excavations have a short life span and are completely backfilled. All stopes are assessed based on local ground conditions experienced and there is minimal influence of ground water on stope stability long term.

The Modified Stability Graph Method has been used to determine the stability of the top stope back and hangingwall spans (AMC 2011). If any failure initiates in the top stope hangingwall material, it has potential to destabilise the stope backs, effectively increase the crown span and failure may occur. In order to prevent crown pillar failure throughout stoping the top stope back, maximum stope spans have been determined to prevent failure before backfilling. The stopes below the crown pillar spans are to be kept at 14m for black slate hangingwall and 22m for Dugald Lode hangingwall. These stopes must be tight filled.

The main cause of instability in the crown pillar is likely to be via collapse and progressive unravelling of the hangingwall and weathered material. This is prevented in the short term by using appropriate stope spans and cable bolts and in the long term by tight filling of the stope voids to provide confinement.

There is potential for ground water to permeate along fractured zones due to faulting and zones of weak rock mass. It has been recommended that rib pillars be left at all locations where E-W off-setting structures are identified. The rock mass in these fault zones are expected to have poorer rock mass which will enable ingress of water and increased weathering. The probability of unravelling, block, or chimney failure mechanisms will be higher in these localised areas.

SEALING OFF SURFACE OPENINGS TO UNDERGROUND

There has been no design work completed on bulkhead design to seal off the underground mine for mine closure. At this stage due to the mine method and completely tight filling voids underground there is minimal risk of significant build-up of water in the underground workings and this assessment has not been deemed necessary.

CURRENT SURFACE SUBSIDENCE CONTROLS IN PLACE

The following recommendations are for the exclusion zones and regional Crown pillars as per the GCMP:

- No extraction to occur above 10150RL (75 level) for both the South and North Mine. The crown pillar located above this RL is considered a primary pillar and cannot be mined for the Life of Mine (LOM).
- For stopes near the crown pillar, unravelling to be prevented by appropriate stope spans and cable bolts. Long-term stopes are required to be tight-filled to the floor of the drill drive as a minimum.
- No permanent civil infrastructure should be constructed over the crown pillar zones, or within 90m on the hanging wall side of the crown pillar.
- Commence regular surface subsidence monitoring by Permanent Survey Marks or other means during mining of the top stopes beneath the crown pillar. Focus on the Potentially Acid Forming (PAF) runoff dams and surface fault expression. Monitoring should continue for at least 6 months after tight filling is completed
- No water storage or settling ponds are to be located on the crown pillar zone, where water may infiltrate the ground surface and into the rock mass, owing to surface subsidence.
- crown pillar has been designed in fresh rock, below the level of significant weathering.
- All excavated voids underground are backfilled and managed in a void register

Crown pillar failure or uncontrolled failure underground can impact surface infrastructure, stockpiles, roads and dams. As an additional control the critical mill infrastructure is located to the east of all workings and the surface dams located to the west. In the event of an uncontrolled failure underground no critical infrastructure is likely to be affected.
Figure 3 shows the location of the surface infrastructure with relation to the underground workings.

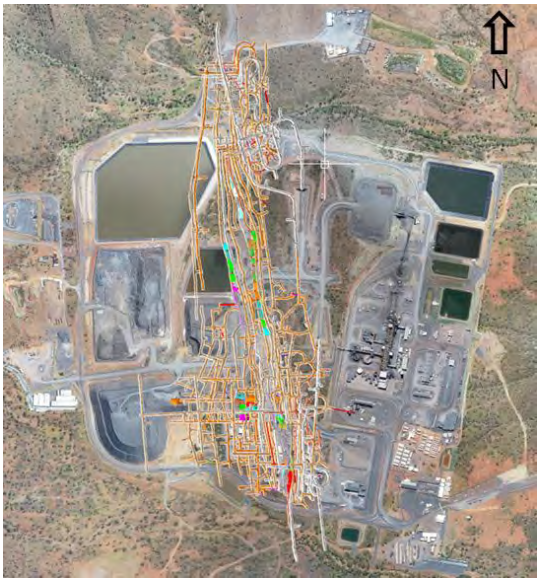

Figure 3 Plan view showing the surface of Dugald River mine with the as-built development and design stopes from Panel 1 and Panel 2

NOTE: Panel 1 stopes closest to the surface are located to the east. The red coloured stopes are the crown stopes for panel 2 located 215m below surface.

CONCLUSION

From the geotechnical stability assessments completed based on weathering and ground water profiles and controls in place at Dugald river, post-mine closure underground stability and surface subsidence risk is low. Dugald river mine has a shallow weathering profile and shallow ground water therefore there is minimal influence of ground water on the underground stability and crown pillar stability.

All stopes extracted underground have limited stope strikes and are cable bolted to increase the short-term stability and are all backfilled with either waste rock or cemented backfill to ensure long term stability and confinement of voids to prevent long term subsidence.

SUPPORTING REFERENCES

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DRM Backfill Design Work Quality Requirement 15811530

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Appendix H: Assessment of the Geochemical Characteristics and ARD Potential of Waste Rock for the Dugald River Zinc, Lead & Silver Deposit

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Minerals and Metals Group

Document No. 6412/934

Dugald River Project Qld

Assessment of the Geochemical Characteristics and ARD Potential of Waste Rock for the Dugald River Zinc, Lead & Silver Deposit

September 2010

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4: Elemental composition of Dugald River waste rock

5: Geochemical abundance indices for Dugald River waste rock

6: Water extractable elements in Dugald River waste rock

7: Acid extractable elements in Dugald River waste rock

8: Peroxide extractable elements in Dugald River waste rock

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1: Dugald River Project - Waste rock sampling program

2: Statistical summary of sulphur data for Dugald River waste rock

3: Statistical summary of ANC data for Dugald River waste rock

4: Statistical summary of NAPP data for Dugald River waste rock

5: Acid-base account plot for Dugald River waste rock

6: ARD classification plot for Dugald River waste rock

7: Acid buffer characteristics curve of Dugald River waste rock

(a) calc-silicate (#80448)

(b) mafic feldspar porphyry (#80424)

(c) lode waste (#80478)

(d) foot wall slate (#80430)

(e) foot wall limestone (#80436)

8: Sulphur speciation results for Dugald River waste rock

9: Kinetic NAG test profiles for Dugald River waste rock

(a) lode waste (#80454)

(b) lode waste (#80429)

(c) foot wall slate (#80443)

(d) hanging wall slate (#80483)

(e) foot wall slate (#80438)

10: Box plot showing the ratios of elemental concentrations in Dugald River waste rock relative to median soil composition

Figures (*continued*)

11: Statistical summary of extract assay data for water (w), acid (ac) and peroxide (ox) extractions tests on Dugald River waste rock

12: Plot of leachate pH for AARC column leach tests on Dugald River waste rock

13: Plot of sulphate concentrations in leachates from AARC column leach tests on Dugald River waste rock

14: Plot of calcium concentrations in leachates from AARC column leach tests on Dugald River waste rock

15: Statistical summary of AARC column leach assay data for samples comprising NAF Dugald River waste rock

16: Plot of Fe, Zn, Mn and Al concentrations in leachate from Column 3 containing a PAF waste mixture

Appendices (*after text*)

A: Acid forming characteristics of drill core samples from previous geochemical studies of Dugald River waste rock

B: Multi-element data and geochemical abundance indices for drill core samples from previous geochemical studies of Dugald River waste rock

- B-1 Multi-element data
- B-2 Geochemical abundance indices

C: Results of column leach tests involving Dugald River waste rock

- C-1 Acid forming characteristics of column leach samples
- C-2 Leachate composition for HW slate (Column 1)
- C-3 Leachate composition for FW limestone (Column 2)
- C-4 Leachate composition for PAF rock mixture (Column 3)
- C-5 Leachate composition for FW slate (Column 4)
- C-6 Leachate composition for HW calc-silicate (Column 5)
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- C-8 Leachate composition for HW mica schist (Column 7)

1.0 Introduction

This report presents the results and findings of a geochemical assessment of drill core samples representing waste rock that will be produced at the Dugald River project located near Cloncurry in the north west region of Queensland. The study was commissioned by Minerals and Metals Group (MMG) as part of environmental studies being undertaken for the project.

The project will involve conventional underground mining of a stratabound, massive zinc/lead deposit hosted within a black slate environment and copper mineralisation in the adjacent hanging wall. The Dugald River deposit is estimated to contain 53 million tons of zinc/lead ore and 3.4 Mt of copper ore which will be mined over a 23 year mine life. Ore will be processed on site using conventional flotation technology, producing zinc, lead and copper concentrates for shipment and tailings that will be discharged to a tailings storage facility located to the west of the Knapdale Ranges. There will also be approximately 7 Mt of waste rock produced, mainly during the development of the decline.

Seven waste lithologies will be intercepted during mining of the Dugald River deposit. They are calc-silicate, white mica schist, mafic feldspar porphyry, hanging wall slate, mineralized lode waste, footwall slate, and footwall limestone. Calc-silicate, white mica schist and mafic feldspar porphyry will only be intercepted if mining of the copper ore is undertaken. The results of geochemical testing carried out by AARC (2008) indicated that most waste should be non-acid forming (NAF) but that some potentially acid forming (PAF) rock may be encountered, primarily as lode waste but also within the hanging wall and foot wall slate.

Sphalerite and galena are the main primary sulphides in Dugald River ore but pyrrhotite and pyrite also occur and are likely to be the main sulphide forms in mineralised waste rock. The presence of pyrrhotite and pyrite are a potential concern given that they will be subject to oxidation processes if the rock is exposed to atmospheric conditions. The potential for acidification of sulphidic rock will depend on both the sulphide content and the magnitude of any inherent neutralising capacity within the rock. Sulphidic rock that has little acid neutralising capacity (ANC) could be a potential source of *acid rock drainage* (ARD) and it is essential that such waste is identified and managed in a manner that limits the potential for sulphide oxidation and/or formation of acid conditions.

It is expected that drainage from non-acid forming rock should remain circum-neutral, nevertheless assessment of the potential to generate drainage with elevated salinity is necessary, as calcium and magnesium sulphates may be mobilised from non-acid forming rock by the combination of oxidation and neutralisation reactions. Such drainage, commonly referred to as *Neutral Mine Drainage* may also have measurable concentrations of trace elements (*e.g.* metals and metalloids) that are sparingly soluble at circum-neutral pH.

In recognition of the likelihood of some PAF waste rock and also the potential for generation of sulphate-rich neutral mine drainage, EGi was commissioned by MMG to review the findings of previous geochemical studies and to undertake further detailed assessment of the geochemical characteristics of samples representing waste rock that will be produced during the development of the Dugald River underground

mine. The main objectives of the geochemical testing program carried out on these samples were as follows:

- To determine the range of acid forming characteristics of the major waste rock units within the Dugald River deposit and to provide sufficient data for estimating the incidence of acid generating waste rock types within the proposed mine.
- To assess the forms and reactivity of the sulphide mineralisation within major waste rock units under controlled laboratory conditions, and to make preliminary estimates of the likely geochemical behaviour and lag times for acidification to occur under field conditions.
- To assess the reactivities of any carbonate mineralisation within major rock units that might delay or mitigate the generation of ARD.
- To identify any elemental enrichments within major rock units that might be environmentally significant and assess the potential for mobilisation of environmentally important elements which could impact on the quality of pit water and waste dump seepage.
- To assess the leaching potential of environmentally important elements from both PAF and NAF waste rock types and to assess the geochemical implications for mine water chemistry and the need for long term management of ARD from the waste dump and the final pit.

This report presents the results of the laboratory testing program carried out by EGi on drill core samples supplied by MMG and presents the main findings and implications of the current and previous geochemical investigations in relation to geochemical characteristics of waste rock and need for the selective handling and disposal of materials that could be problematic in respect of acid generations or metals leaching.

2.0 Previous Geochemistry Studies

There have been two previous geochemical studies of waste rock for the Dugald River project.

The first study was of a preliminary nature carried out by AGC Woodward-Clyde[1] as part of the pre-feasibility baseline environmental studies commissioned by Minenco Pty Limited in 1991. This study involved the assessment of the acid forming potential of 18 drill core samples representing waste rock and another five samples representing ore grade material within the Zn/Pb lode. The samples were taken from seven drill holes and the lithologies represented by the waste samples were hanging wall slate (6 samples), footwall slate (8) and limestone (4).

A second more detailed investigation of waste rock geochemistry was commissioned by OZ Minerals Australia Limited in 2008. This study was carried out by AARC[2] and included static geochemical analysis of 121 drill core samples and also establishment of a series of kinetic leach column tests. The samples were taken from 12 diamond drill holes and were representative of the following lithologies: calc-silicate (23 samples), mafic feldspar porphyry (3), white mica schist (13), hanging wall slate (38), lode waste (10), footwall slate (16) and foot wall limestone (18).

The acid forming characteristics of drill core samples assessed in the 1991 and 2008 studies are summarised in Appendix A. The testing programs for both studies involved measurements of existing pH, total sulphur content, acid neutralising capacity (ANC), and net acid producing potential (NAPP). The 2008 study also included measurement of net acid generation (NAG) capacity. Overall, a total of 139 samples representing waste rock were assessed for acid forming potential.

Multi-element assays were also carried out on all samples in the 1991 study and half the samples in the 2008 study. Samples in both the 1991 and 2008 studies were analysed for As, Cd, Co, Cu, Hg, Pb, S and Zn. The 1991 samples were also assayed for Bi and Sb, whilst the 2008 samples were also assayed for Ba, Be, Cr, Mn, Ni and V. The multi-element data for the previous studies are given in Appendix B.

The preliminary findings of previous geochemical investigations were as follows:

- The initial pHs of the majority of samples were circum-neutral, suggesting that drainage from freshly mined rock will likely be neutral to alkaline.
- Most samples were enriched to some extent with sulphur, but most samples also had high to very high ANCs and were classified as non-acid forming.

1 AGC Woodward Clyde (1971). Preliminary Waste Characterisation. Report prepared for Minenco Pty Limited as part of the Dugald River Project - Prefeasibility Environmental Baseline Studies, July 1991.

2 AustralAsian Resource Consultants (2008). Waste Rock Characterisation Report, Dugald River Project. Prepared for OZ Minerals Australia Limited, September 2008.

- Sulphur contents were distributed as follows:
    - 30% low (<0.01 to 0.3 %S)
    - 20% low to moderate (0.3 to 1.0 %S)
    - 50% high to very high (> 1%S)
- ANCs were distributed as follows:
    - 14% low (<10 kg H_2SO_4/t)
    - 28% low-moderate (10 to 50 kg H_2SO_4/t)
    - 58% high to very high (>50 kg H_2SO_4/t)
- Based on the NAPP and (when available) NAG test results, 95 samples (68%) were classified as non-acid forming and 40 samples (29%) were classified as potentially acid forming. The classifications of the other four samples were uncertain, but it is EGi's evaluation of the results that two of the four were more likely to be NAF and the other two more likely PAF.
- The main lithologies in which PAF samples occurred were lode waste (8 samples), hanging wall slate (22 samples), and pyritic foot wall slate (3 samples).
- In addition to elevated sulphur contents, many of the lode, hanging wall slate and footwall slate samples were significantly enriched to varying extents in one or more environmentally important elements that include arsenic, cadmium, copper, lead, mercury and zinc.
- Based on the results of the static testing program and the expected lithological distribution of waste rock at that time it was estimated by AARC (2008) that about one-quarter of total waste mined could be PAF. AARC(2008) recommended that, where possible, PAF waste should be prioritised for disposal to underground voids, whilst PAF waste rock remaining on the surface at closure would need to be fully encapsulated within NAF waste rock with high to very high ANC (*e.g*. limestone, calc-silicate and white mica schist).

3.0 Testing Program

3.1 Sample Selection

Seventy-two drill core samples were selected by MMG for the current geochemical program. Figure 1 shows the sample locations on a long-section through the proposed underground mining area.

When combined with samples from the two previous geochemical investigations carried out by AGC-Woodward Clyde (1991) and AARC (2008) there were 211 samples representing Dugald River waste rock. The samples were distributed between the seven lithologies as follows:

	AGC-WC (1991)	AARC (2008)	EGI (2010)	Combined
• Calc-silicate	0	23	8	31
• Mafic feldspar porphyry	0	3	4	7
• White mica schist	0	13	4	17
• Hanging wall slate	6	38	8	52
• Lode waste	0	10	8	18
• Footwall slate	8	16	20	44
• Footwall limestone	4	18	20	42

The guideline on *Assessment and Management of Acid Drainage* prepared by the Queensland Government, Department of Environment and Resource Management (DERM)[3] provides minimum numbers of samples that should be collected from each rock type based on the tonnage that will be mined. The tonnages of the various waste rock units generated by the Dugald River zinc/lead underground development will be 0.46 Mt of hanging wall slate, 0.66 Mt of lode waste, 2.88 Mt of footwall slate, and 3.11 Mt of footwall limestone. The corresponding minimum sample numbers for these tonnages based on interpolation of the DERM guideline are 18, 21, 43 and 45, respectively. Therefore, over the three geochemical assessment programs the numbers of samples tested were comparable to the DERM guideline.

[3] DERM (1995). Assessment and Management of Acid Drainage. Queensland Department of Environment and Resource Management, January 1995.

The guideline indicates the minimum number of samples collected from each rock/overburden type during initial sampling should generally be as follows; <0.01 Mt = minimum of 3, <0.1 Mt = minimum of 8, < 1 Mt = minimum of 26, and <10 Mt = minimum of 80. These discrete values can be interpolated using the formula $y=25.9x^{0.48}$, where y is the minimum number of samples and x is the tonnage (Mt) of the particular rock unit.

3.2 Sample Preparation

The samples for the current geochemical program were supplied as drill core pieces, with each sample typically weighing 1-2 kg. Following inspection of the samples they were forwarded to Sydney Environmental and Soil Laboratory Pty Ltd where sample preparation was carried out. Sample preparation included crushing to less than 4 mm size by conventional jaw crusher, then milling of a 200g split to less than 75 micron using a zirconia pulverising bowl. The crushed and pup samples were subsequently returned to EGi's laboratory for geochemical analysis.

3.3 Static Testing Program

The static testing program for the 72 drill core pulps included assessment of the same range of parameters as were determined in the 1991 and 2008 geochemical studies. They were:

- Existing pH and conductivity
- Total sulphur content
- Maximum potential acidity (MPA)
- Acid neutralising capacity (ANC)
- Net acid producing potential (NAPP)
- Net acid generation (NAG) capacity

The NAPP and NAG test results were reviewed then some samples were selected for more detailed analysis to either clarify the ARD classifications, assess sulphide or carbonate reactivity, and identify elemental enrichments and their potential leachability. The detailed testing of selected drill core samples included one or more of the following:

- Sulphur forms - 15 samples
- Sequential NAG test - 2 samples
- Kinetic NAG tests - 5 samples
- Acid buffer characteristic curves - 5 samples
- Solids multi-element analyses - 15 samples
- Water extractable elements - 15 samples
- Acid extractable elements - 15 samples
- Peroxide extractable elements - 15 samples

In addition to the static testing reported herein, MMG is currently assessing commissioning long-term column leach tests involving some waste rock samples discussed in this report.

3.4 Laboratory Procedures

Existing pH and Conductivity

The pH and electrical conductivity of each sample were measured on a suspension comprising 30 g of crushed (minus 4 mm) sample in 60 mL of deionised water (*i.e.* 1:2 solid:water ratio), following at least 1 hour of equilibration.

Total Sulphur Analyses

The total sulphur content of each sample was determined by the Leco furnace method. Sulphur assays were carried out by Sydney Environmental & Soil Laboratory Pty Ltd under a quality assurance system certified as complying with ISO 9002.

Maximum Potential Acidity

The maximum potential acidity (MPA) is the amount of acid that theoretically could be generated by a sample if all the sulphur occurred as reactive pyrite and there was complete oxidation of the pyrite according to the following reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

The MPA of each sample, expressed as kg H_2SO_4/t, and was calculated from the %S content using a conversion factor of 30.6.

Acid Neutralising Capacity

The acid neutralising capacity (ANC) of each sample was determined using the Sobek Method. The method provides a direct measurement of the amount of acid that can be consumed by carbonate and other minerals within a rock sample, and involves reacting a sample with a known amount of acid at between pH 1 to 2 for approximately 1 to 2 hours. The residual acidity after reaction was back-titrated to determine the amount of acid consumed by the sample, expressed in terms of kg H_2SO_4/t.

Net Acid Producing Potential

The NAPP is the amount of acid that potentially can be produced by a sample after allowance for the ANC. It is calculated by subtracting the ANC value from the MPA value. If the NAPP is negative then it is likely that the material has sufficient inherent buffer capacity to prevent acid generation. Conversely, if the NAPP is positive then the material may be acid generating.

Net Acid Generation

NAG is a direct oxidation procedure for estimating the acid forming potential of a sample. The NAG test involved reaction of 2.5 g sample with 250 mL of 15% hydrogen peroxide to rapidly oxidise any sulphide minerals present. Both acid generation and acid neutralisation occur simultaneously during the NAG test,

hence the end result represents a direct measurement of the net amount of acid that a sample can generate. If the sample after reaction had a pH less than 4.5 (*i.e.* NAGpH<4.5) then it was considered to be acid forming and the actual amount of acidity generated was subsequently determined by titration of the mixture.

Sequential NAG Tests

With high sulphur samples the oxidation of sulphides is often not completed in a single stage NAG test, and a sequential multi-stage procedure is needed to ensure all sulphides are fully oxidised. In the sequential NAG test a 2.5 g sub-sample of tailings is reacted several times with 250 mL aliquots of 15% hydrogen peroxide. At the end of each stage, the sample is filtered to separate the solids and NAG liquor. The NAG liquor is assayed for pH and acidity, as per a standard NAG test. The solids are recovered and the oxidation process continued using another aliquot of hydrogen peroxide. The overall NAG capacity of the tailings is determined by summing the individual acid capacities from each stage.

Kinetic NAG Tests

Kinetic NAG tests were also carried out on selected tailings samples to assess the reactivity of the sulphides present and to provide an indication of the likely lag period for acid generation to occur under oxidising conditions. The kinetic NAG test is an accelerated oxidation procedure wherein a sample is reacted with hydrogen peroxide (as per the standard NAG test described in Section 2.2) and the reaction kinetics are continuously monitored by measuring the pH and temperature of the NAG solution.

Acid Buffer Characteristic Curve

An acid buffer characteristic curve was produced by slowly titrating of a sample with dilute HCl acid over a period of 16 to 24 hours. This titration method provides a far less aggressive treatment of a sample than that applied in the ANC method and hence provides a measure of the buffering provided by more soluble carbonates within a sample.

Multi-Element Analysis of Solids

The multi-element analysis of solids was carried out by Australian Laboratory Services (ALS) in Brisbane using NATA registered procedures. Mercury was assayed using an aqua regia digestion to ensure minimal volatilisation followed by analysis using inductively coupled plasma mass spectrometry. A suite of 34 other elements were assayed using a multi-acid digestion (*i.e.* hydrofluoric, nitric, perchloric and hydrochloric acids) followed by analysis using inductively coupled plasma optical spectrometry.

Water Extractable Elements

The water-soluble components within a sample were determined by extraction of 25 g of crushed (minus 4 mm) sample in 500 mL of deionised water (*i.e.* a solid:liquor ratio of 1:20) for 24 hours in accordance with the Australian Standard Leaching Procedure (ASLP). The extraction containers were agitated on an end-over-end shaker throughout the equilibration period, and at completion the pH and electrical conductivity of each

extract were recorded. The liquor fraction was then filtered through a 0.45 micron membrane filter, preserved with a few drops of high purity HNO_3 acid, then despatched to Australian Laboratory Services (ALS) in Sydney for multi-element analysis.

Acid Extractable Elements

The acid-soluble components within a sample were determined in accordance with the ASLP but using dilute sulphuric acid as the extractant. The extraction involved equilibration of 25 g of crushed (minus 4 mm) sample in 500 mL of 0.05 M H_2SO_4 (*i.e.* a solid:liquor ratio of 1:20) for 24 hours with constant agitation. The pH and electrical conductivity of each extract were recorded, then the liquor fraction was filtered through a 0.45 micron membrane filter, preserved with a few drops of high purity HNO_3 acid, then despatched to Australian Laboratory Services (ALS) in Sydney for multi-element analysis.

Peroxide Extractable Elements

Elements that may be mobilised as a consequence of sulphide oxidation were determined by reacting 2.5 g of sample with 250 mL of 15% hydrogen peroxide, as per the NAG test procedure described above. Following reaction of the sample the NAG liquor was re-adjusted to 250 mL with deionised water, then a sub-sample was filtered through a 0.45 micron membrane filter, preserved with a few drops of high purity HNO_3 acid, then despatched to Australian Laboratory Services (ALS) in Sydney for multi-element analysis. A second sub-sample was titrated as per the normal NAG procedure to determine the amount of any acidity generated during the test.

4.0 Acid Forming Potential of Dugald River Waste Rock

The acid forming characteristics of the 72 drill core samples assessed by EGi are summarised in Table 1 with the samples sorted according to the drill hole number. The same data are also presented in Table 2 with the samples sorted according to lithology and ARD classification.

As the procedures used to assess these samples were the same as those used in previous geochemical investigations by AGC-Woodward Clyde (1991) and AARC (2008), the three datasets were combined to allow a more comprehensive review. This provided an overall total of 211 samples representing waste rock that were distributed between the seven lithologies as follows:

	Sample Count	Percent of Total
• Calc-silicate	31	~ 15%
• Mafic feldspar porphyry	7	~ 3%
• White mica schist	17	~ 8%
• Hanging wall slate	52	~ 25%
• Lode waste	18	~ 9%
• Footwall slate	44	~ 21%
• Footwall limestone	44	~ 20%

4.1 Sulphur Content

The sulphur content distributions for each of the seven lithologies are shown graphically in Figure 2. The sulphur content range and median content for each lithology were as follows:

	%S Median	%S Range
• Calc-silicate	<0.01	<0.01 - 1.57
• Mafic feldspar porphyry	<0.01	<0.01 - 0.77
• White mica schist	0.03	<0.01 - 0.29
• Hanging wall slate	1.8	<0.01 - 14.4
• Lode waste	6.4	1.2 - 16.6
• Footwall slate	1.1	0.45 - 14.6
• Footwall limestone	1.0	0.1 - 2.12

The sulphur contents of samples representing calc-silicate, mafic feldspar porphyry and white mica schist were generally low, with 87% of the samples from these three lithologies containing less than 0.1 %S, and only a few samples exceeding 0.3 %S.

In contrast, the sulphur contents of samples representing lode waste, hanging wall and footwall slate, and footwall limestone were typically in the moderate to high range. Not surprisingly, sulphur enrichment is particularly high in lode waste. The median sulphur content for lode waste samples was 6.4 %S. Furthermore, one-third of the lode samples had sulphur contents exceeding 10 %S.

On average, the extent of sulphur enrichment in hanging wall and footwall slate was less than for lode waste but nevertheless still significant. The median sulphur contents for the two slate lithologies were 4.1 and 1.8 %S, respectively and approximately one-third of the slate samples had sulphur contents exceeding 2 %S.

Almost all of the footwall limestone samples were also enriched but concentrations were typically confined to between 0.5 to 1.5 %S. The median sulphur content for limestone samples was 1.0 %S.

4.2 Acid Neutralising Capacity

The ANC distributions for each of the seven lithologies are shown graphically in Figure 3. The median, range and percentage of samples with ANCs in the high to very high range (*i.e.* ANC exceeding 100 kg H_2SO_4/t) were as follows:

	Median (kg H_2SO_4/t)	Range (kg H_2SO_4/t)	Percent with ANC>100 kg H_2SO_4/t
• Calc-silicate	169	9 - 688	81 %
• Mafic feldspar porphyry	79	21 - 401	43 %
• White mica schist	32	9 - 252	24 %
• Hanging wall slate	31	5 - 455	27 %
• Lode waste	13	5 - 398	28 %
• Footwall slate	108	11 - 548	55 %
• Footwall limestone	235	10 - 552	90 %

The results indicate wide ranging ANC values for all lithologies. As might be expected, the majority of footwall limestone samples had high to very high ANCs, as did most of the calc-silicate samples and more than half of the footwall slate samples.

The neutralising capacities of the hanging wall slate and the white mica schist samples were, on average, noticeably lower with median ANCs for the two lithologies of 31 and 32 kg H_2SO_4/t, respectively. Nevertheless around one-quarter of the samples from each lithology had ANCs exceeding 100 kg H_2SO_4/t.

The ANCs of lode waste samples were bi-modal in distribution. Thirteen of the 18 lode waste samples had low ANCs in the range 5 to 34 kg H_2SO_4/t. The other five lode waste samples had very high ANCs between 208 and 398 kg H_2SO_4/t.

4.3 Net Acid Producing Potential

The calculation of NAPP represents the balance between a samples acid potential and neutralisation capacity. This balance is sometimes also referred to as an acid-base account. The acid potential is related to the presence of sulphides, and in this study was indirectly determined from the total sulphur content, assuming that all sulphur occurred as pyrite. This is a conservative assumption, hence the acid potential can be regarded as the maximum potential acidity (MPA) that could be produced by a sample.

The NAPP represents the net acidity after allowance for the neutralising capacity within a sample, as determined directly using the standard Sobek method (as discussed Section 3.4). The difference between the two components represents the net acid producing potential or NAPP, which. The NAPP is expressed in terms of weight of acid generation per unit weight of rock (kg H_2SO_4/t) and may be positive or negative depending on the relative magnitudes of the respective acid and neutralising potentials.

The NAPP distributions for each of the seven lithologies are shown graphically in Figure 4. The median, range and percentage of samples with positive NAPPs were as follows:

	Median (kg H_2SO_4/t)	Range (kg H_2SO_4/t)	Percent with +ve NAPP
• Calc-silicate	-161	-688 to -9	0 %
• Mafic feldspar porphyry	-72	-401 to -21	0 %
• White mica schist	-31	-246 to 0	0 %
• Hanging wall slate	10	-423 to 421	58 %
• Lode waste	104	-187 to 500	78 %
• Footwall slate	-71	-512 to 390	20 %
• Footwall limestone	-195	-513 to 18	2 %

The results indicate that with samples representing calc-silicate, mafic feldspar porphyry, white mica schist and footwall limestone the neutralising capacity exceeds the acid potential of contained sulphides, in many cases by a large amount (*i.e.* samples were strongly NAPP negative).

The NAPPs of samples representing lode waste and hanging wall and footwall slate varies widely from strongly negative through to strongly positive. The majority of footwall slate samples were NAPP negative, lode waste samples were predominantly NAPP positive, whilst hanging wall slate samples relatively evenly divided.

Figure 5 shows an acid-base account plot for the combined data set. The acid-base account plot illustrates the relationship between the sulphur content (and hence MPA) of a sample and its ANC. This type of plot not only provides an indication of the acid forming potential of a sample but also illustrates the relative balance between the two parameters.

4.4 ARD Classification

The ARD classifications of the 18 waste rock samples previously tested by AGC-Woodward Clyde (1991) were based solely on NAPP values. For all other samples, the ARD classifications were assigned on the basis of both the NAPP value (as discussed above) and the sample's net acid generation (NAG) capacity. The latter was determined directly by reaction of the sample with hydrogen peroxide. A sample is considered to have a positive NAG capacity if it acidifies to pH 4.5 or less, in which case the amount of acid generated[4] is determined by titration. Because the NAPP and NAG values are determined independently of each other, the combination of the NAPP and NAG results provides greater certainty to the classification.

The ARD classification criteria were as follows:

- ***Non-Acid Forming*** *(NAF)* - A sample was considered to be NAF if it had a negative NAPP and the sample did not acidify to any significant extent when oxidised with peroxide in the NAG test (*i.e.* NAG=0 or NAGpH≥4.5). Although sulphides may be present in such samples, the inherent ANC is generally sufficient to neutralise any acid that might have been produced by sulphide oxidation.

- ***Potentially Acid Forming*** *(PAF)* - A sample was considered to be PAF if the NAPP and NAG were both positive. The exposure of such rock to atmospheric conditions is likely to result in sulphide oxidation, which in turn could result in tailings acidification.

- **Uncertain** *(UC)* - With some samples there was a disparity between the NAPP and NAG test results, and in such cases an *uncertain* (UC) classification was assigned. A disparity may occur if the NAPP is negative but the sample acidifies to less than pH 4.5 in the NAG test, or when the NAPP is positive but it does not acidify under NAG test conditions. The former may occur when the ANC within a sample is not readily available, and the latter may occur when some sulphur occurs as sulphate or as sulphides that do not generate acid when oxidised. The ARD classification considered most likely was indicated in brackets *e.g.* UC(NAF) or UC(PAF).

Figure 6 shows an ARD classification plot for the combined dataset, excluding the 18 samples from the AGC-Woodward Clyde (1991) study which did not include NAG testing. The ARD classification plot illustrates the concurrence of the NAPP and NAG test results. Clearly, the majority of samples plot either in the upper left quadrate *(i.e.* negative NAPP and NAGpH≥4.5) signifying samples were NAF, or in the lower right quadrate (positive NAPP and NAGpH<4.5) signifying samples were PAF. There were only five samples (four from the AARC study and one sample in the current EGi study) that could not be definitively classified due to conflicting NAPP and NAG test results. Tentative classifications were assigned as follows:

- AARC (2008) White mica schist (DR342, 272.5-273m) likely PAF (*but low capacity only*)
- AARC (2008) Hanging wall slate (DR346, 410-410.5m) likely NAF
- AARC (2008) Hanging wall slate (DR315, 84.5-85m) likely PAF
- AARC (2008) Footwall slate (DR342, 424-425m) likely PAF
- EGi (2010) Lode waste (DR379 631-631.5m) likely NAF (*based on seq NAG test*)

[4] Note: A sample may have a positive, zero or negative NAPP, but the NAG value can only be positive if acidification (i.e. NAGpH≤4.5) occurs, or zero if there is no acidification in the NAG test.

The last three samples on this list typically had high sulphur contents, high ANCs and strong positive NAPPs but they did not acidify when oxidised with peroxide in the NAG test. With the two AARC (2008) samples it is possible that the absence of acidification in the single-stage NAG tests was associated incomplete sulphide oxidation, which is a common occurrence with samples where the sulphur content and ANC are both high. As this possibility could not be confirmed, both samples were conservatively classified as PAF based on the positive NAPP results.

In the case of the one *uncertain* sample in the current study a follow-up sequential NAG test was carried out by EGi to verify the classification. Ten sequential stages of oxidation were carried to ensure complete sulphide oxidation. In all stages the pH of the NAG liquor remained circum-neutral. Therefore, although the classification remains uncertain, the results of the sequential NAG test suggest that the sample was more likely to be NAF.

After allowing for these tentative classifications, the NAF/PAF distributions for each of the seven lithologies were as follows:

	Total	PAF	NAF
• Calc-silicate	31	0 (0 %)	31 (100 %)
• Mafic feldspar porphyry	7	0 (0 %)	7 (100 %)
• White mica schist	17	2 (12 %)	14 (88 %)
• Hanging wall slate	52	28 (54 %)	24 (46 %)
• Lode waste	18	13 (72 %)	5 (28 %)
• Footwall slate	44	9 (20 %)	35 (80 %)
• Footwall limestone	42	1 (2 %)	41 (98 %)

The main points to note in relation to acid forming characteristics are as follows:

Calc-silicate
- negligible sulphur and high to very high ANC
- virtually all likely to be NAF and most will have a large excess of neutralising capacity due to high carbonate content.

Mafic feldspar porphyry
- low sulphur and moderate to high ANC
- a relatively small number of samples tested but results suggest waste rock from this lithology will be NAF, most with a considerable excess of neutralising capacity.

White mica schist
- low sulphur and variable ANC (from low to high)
- results suggest waste rock from this lithology will predominantly be devoid of sulphur and hence will be NAF, but there is a possibility of some material with low ANC (<10 kg H2SO4/t) which has slightly elevated sulphur (~0.3 %S) that could be PAF, albeit with a low capacity for acid generation.

Hanging wall slate

- moderate to high sulphur content and variable ANC
- results indicate a major portion of waste rock from this lithology will be PAF, some with a very high capacity for acid generation. There will also be some NAF rock, which is primarily distinguished by having high to very high ANC.

Lode waste

- high to very sulphur content and variable ANC
- majority of mineralised waste within the lode will be PAF with a very high capacity for acid generation. Only lode waste with very high ANC (*i.e.* >200 kg H_2SO_4/t) will be NAF.

Footwall slate

- moderate to high sulphur content and moderate to high ANC
- results suggest that footwall slate will be predominantly NAF but some footwall slate with low ANC is likely to be PAF.

Footwall limestone

- moderate sulphur content and moderate to high ANC
- results suggest virtually all footwall limestone is likely to be NAF and will have a large excess of neutralising capacity.

5.0 Reactivity of Carbonate Mineralisation within Dugald River Waste Rock

Many of drill core samples tested had high acid neutralising capacities. This was particularly the case for samples representing calc-silicate and footwall limestone, but also included samples from each other lithologies. Overall, approximately 54% of samples had ANCs greater than 100 kg H_2SO_4/t, and around half of these had ANCs exceeding 200 kg H_2SO_4/t.

In this study and the previous geochemical studies of Dugald River waste rock the ANCs of drill core samples were determined using the Sobek method. As described in Section 3.4, the Sobek method involves measurement of acid consumption by a sample under relatively strong acid conditions, typically around pH 1 to 2. The method therefore represents an aggressive treatment of the sample and accounts for buffer capacity provided not only by the more readily-available carbonate minerals such as calcite and dolomite but also less reactive forms such as ferroan dolomite, siderite, and some clay minerals.

The following five samples were selected for further testing to define the reactivity of the mineralisation responsible for the ANC under circum-neutral and weak acid conditions:

MMG / EGi Codes	Lithology	Sulphur (%S)	ANC (kg H_2SO_4/t)
80448 / 40886	Calc-silicate	1.57	210
80424 / 40862	Mafic feldspar porphyry	0.77	79
80478 / 40916	Lode waste	2.38	219
80430 / 40868	Footwall slate	1.15	120
80436 / 40874	Footwall limestone	1.06	462

Each sample was slowly titrated with dilute H_2SO_4 over a period of about 18 to 24 hours to produce an acid buffer characteristic curve (ABCC). The slow acid addition represents a milder treatment of a sample than that applied in the standard Sobek method. One advantage of the buffer curve is that it can be used to identify if there is any carbonate mineralisation that can buffer the sample at around neutral pH, which is usually required to produce a substantial lag phase and which is essential for maintaining low metal solubilities.

The buffer curves for the five samples are given in Figures 7(a) to 7(e), respectively. All five samples produced well defined plateaus indicating strong pH buffering at near neutral pH, and confirming the presence of readily available carbonates[5] as the dominant source of the high ANC. In each case, the starting

[5] As a general rule, calcite and limestone are typically readily available for neutralisation and can maintain pH-neutral conditions up until almost all the ANC is consumed. Dolomite is also usually reactive, however the reactivity may decline when there is significant iron substitution, such as with ferroan dolomite. In contrast, magnesite and siderite are usually poorly reactive at circum-neutral pH, and significant dissolution of these carbonates often only occurs under laboratory conditions when the pH drops below about 4. Furthermore, iron carbonate (siderite) does not

pH was greater than pH 8, indicating that fresh rock similar to the test samples should be a potential source of alkaline drainage.

The readily-available buffer capacity was quantified as the amount of acid required to lower the pH of a unit weight of sample to 4.5, which generally marks the end of the buffer plateau and is the pH used in the NAG test to differentiate NAF and PAF materials. The readily-available buffer capacities were as follows:

MMG / EGi Codes	Lithology	Start pH	ANC (kg H_2SO_4/t)	Readily Available (kg H_2SO_4/t)	% Readily Available
80448 / 40886	Calc-silicate	8.6	210	208	99%
80424 / 40862	Mafic feldspar porphyry	8.4	79	100	100%
80478 / 40916	Lode waste	9.4	219	210	96%
80430 / 40868	Footwall slate	9.5	120	116	97%
80436 / 40874	Footwall limestone	9.4	462	475	100%

This comparison confirms that virtually all of the ANCs of the five samples resulted from carbonate forms that were readily-available under circum-neutral to weak acidic conditions. Such forms could be expected to provide effective buffering of sulphide derived acidity if such material were exposed to atmospheric conditions.

contribute to the ANC of a sample. This is because the dissolution of $FeCO_3$ during the acidification stage of the ANC method is negated by the re-precipitation of iron hydroxide during the back-titration step of the method.

6.0 Sulphur Speciation and Reactivity within Dugald River Waste Rock

6.1 Sulphur Speciation

In this study the calculation of NAPP was based on total sulphur assays, assuming that the sulphur occurs as pyrite. This represents a conservative approach in that some sulphur can occur as sulphate, which is non-acid generating, and/or as other metal-sulphides that generate less acidity than pyrite when oxidised. For example, monosulphides such as sphalerite (ZnS) and galena (PbS) typically do not contribute significantly to the acid forming potential as both sulphides generate little or no free acid when oxidised. The oxidation of sphalerite by oxygen occurs without generating hydrogen ions according to the reaction:

$$ZnS + 2\,O_2 \Rightarrow Zn^{2+} + SO_4^{2-}$$

Consequently, sphalerite and galena (which would be expected to occur mainly within mineralised lode waste) are generally not regarded as acid generating, although the oxidation of these sulphide minerals does release zinc and lead, respectively.

A preliminary assessment of sulphur forms within Dugald River waste rock was carried out based on selective extraction methods. Fifteen samples with elevated sulphur contents were selected by EGi and analysed by ALS (Brisbane) for the following:

- Total sulphur - Measured using a Leco sulphur analyser.
- Sulphate-sulphur - Sample leached with hot HCl to remove acid-soluble sulphates. The amount of sulphate within the leachate is then determined by ICPAES. The acid leachable fraction is generally considered to be sulphate, although the method isn't always specific as some mono-sulphides can dissolve to varying extents.
- Sulphide-sulphur - Calculated as the difference between Total-S and Sulphate-S values.
- Cr Reducible S - Sample reacted with hot acidic $CrCl_2$ to reduce (non-sulphate) inorganic sulphur forms to H_2S which are trapped in zinc acetate solution for assay. Chromium reducible sulphur is generally deemed to occur specifically as pyritic-S forms but may include some elemental-S if present in a sample.

The sulphur speciation results are given in Table 3 and shown graphically in Figure 8. The samples included:

- 6 lode waste samples (5 PAF / 1 UC),
- 2 hanging wall slate (1 PAF / 1 NAF),
- 6 footwall slate (3 PAF / 3 NAF), and
- 1 footwall limestone sample (NAF)

Overall, the results indicate that sulphate-S typically represents a relatively small fraction of the total sulphur content in Dugald River waste rock. There was one lode waste sample where sulphate-S was 35% of total sulphur, but in most other cases sulphate-S represented less than 10% of total sulphur. This means that sulphide-sulphur, indirectly calculated as the difference between the total and sulphate-S values, accounted for the vast majority of the sulphur present in Dugald River waste samples tested.

As a further check, measurements were also made of chromium reducible sulphur, which directly quantifies sulphidic-sulphur forms. The chromium reducible sulphur contents of the 15 samples were essentially the same as the sulphide-S contents calculated by difference from the total-S and sulphate-S assays. This similarity adds veracity to the finding that sulphur is most likely to occur as sulphide.

6.2 Sulphur Reactivity

The kinetic NAG procedure was used to gain an insight into the reactivity of sulphides within Dugald River waste rock and to obtain a quick, qualitative assessment of the likely lag time for acidification of PAF waste rock to occur under field conditions. The kinetic NAG test is similar to the standard NAG test where a sample is oxidised with hydrogen peroxide, except that the pH and temperature of the NAG liquor are constantly recorded during the reaction phase of the test. The reaction kinetics are then extrapolated to the field situation using correlations previously derived from an extensive database comprising results of kinetic NAG tests, leach column tests, and field observations across a wide range of rock types.

Although kinetic NAG testing is not a replacement for column leach tests where reactions occur at real time, the profiles obtained by the accelerated procedure provide a qualitative estimate of the lag period to the extent that acidification of PAF rock is likely to occur rapidly (weeks to months), within the short term (many months to one or two years), or medium to long term (several years).

Five PAF samples were selected for kinetic NAG testing as follows:

MMG / EGi Codes	Lithology	%S	ANC	NAPP	ARD Class
80454 / 40892	Lode waste	10.46	34	286	PAF
80429 / 40867	Lode waste	3.32	19	83	PAF
80443 / 40881	Footwall slate	7.88	21	220	PAF
80438 / 40876	Footwall slate	1.66	11	40	PAF
80483 / 40921	Hanging wall slate	1.99	9	52	PAF

The kinetic NAG test reaction profiles for the five samples are given in Figures 9(a) to 9(e), respectively.

Lode Waste Rock –High Sulphur

The two lode waste samples (Figures 9a and 9b) exhibited similar reactivities under NAG test conditions. The pH profiles for both samples were indicative of high rates of sulphide oxidation and there was no evidence of any circum-neutral buffering which normally indicates a lag. The starting pHs were relatively low at 4.0 and 4.8, respectively, and both liquors rapidly acidified to around pH 3 within 8 and 9 minutes,

respectively. There was some buffering between pH 3 to 2 (as indicated by a small plateau in the pH curve) presumably associated with their respective ANCs of 34 and 19 kg H_2SO_4/t, but with ongoing oxidation both samples eventually acidified to less than pH 1 within about one and a half hours. The pH minimums corresponded with rapid increases in temperature, with the NAG liquors effectively boiling primarily as a consequence of catalytic decomposition[6] of the peroxide.

Overall, the acidification patterns exhibited by the two high sulphur lode waste samples under NAG test conditions are consistent with such material exhibiting high reactivity and, based on previous laboratory and field testing of waste rock at other sites with similar reaction profiles, it is likely that lode waste similar to the two test samples would exhibit little, if any, lag period if exposed to atmospheric conditions in the field. The results suggest that acidification would likely occur within months rather than years[7].

Footwall Slate –High Sulphur

The high sulphur footwall slate sample also reacted strongly in the kinetic NAG test (Figure 9c). As was the case with the high sulphur lode waste samples there was no initial circum-neutral pH plateau that normally signifies a significant lag, but the rate of acidification was slower than for the lode waste samples even though the sulphur content was equally high at 7.88 %S. It took approximately 49 minutes for the pH of the NAG liquor to acidify to pH 3 from a starting point of pH 5.2, roughly 5-times longer than for the lode waste samples. There was again some buffering between pH 3 to 2, and the pH minimum of less than 1 occurred after about 100 minutes (similar to the lode samples) corresponding with a sharp increase in temperature.

The reason for the slower rate of acidification of the footwall slate sample is not clear. The ANC of the slate sample was relatively low at 21 kg H_2SO_4/t and comparable to the neutralization capacities of the two lode waste samples. It is possible that the slower rate of acidification relate to differences in the forms of sulphides present. This aspect will be examined further when the sulphur speciation data become available.

The reaction kinetics exhibited by the footwall slate sample under NAG test conditions suggests that such material might respond slower than the lode waste in the field if exposed to atmospheric conditions. However, given the high sulphide content and the limited availability of inherent neutralisation capacity it is expected that any lag period would be relatively short. Based on the reaction kinetics exhibited in the NAG test it is expected that any field lag would be less than a year, and possibly no more than several months.

6 The temperature of the NAG solution also provides an insight into sulphide reactivity. Some of the initial temperature rise may be attributed to the oxidation of pyrite, which is an exothermic (heat generating) process. However, as the oxidation process continues and soluble metals are released, there is an increasing tendency for the hydrogen peroxide to catalytically decompose, a process that is also exothermic. This markedly accelerates the heating of the NAG solution. The main catalyst for peroxide decomposition is likely to be dissolved iron that is released during pyrite oxidation.

7 The lag times provided in this report should be used as a guide only and are based on correlations previously derived by EGi from comparison of kinetic NAG profiles with results from real time testing of the same materials (*e.g.* leach column tests) and field observations at actual mine sites.

Footwall and Hanging Wall Slate – Moderate to High Sulphur

The kinetic NAG test results for the hanging wall and footwall slate samples with moderate to high sulphur contents are given in Figures 9d and 9e, respectively. The profiles for the two samples were very similar, reflecting the fact that they also had similar acid forming characteristics. As noted above, the respective sulphur contents were moderately high at 1.66 and 1.99 %S, the ANCs were relatively low at 11 and 9 kg H_2SO_4/t, and the NAPPs were comparable at 40 and 52 kg H_2SO_4/t.

The pHs were initially between above 5 but again there were no pH plateaus to suggest that such materials could produce circum-neutral drainage for any length of time if exposed to atmospheric conditions. The pHs of both NAG liquors decreased steadily with time, reaching pH 3 within 83 and 36 minutes, respectively. This rate of pH decrease would suggest a field lag of the order of months to a year, rather than several years. The initial rapid pH decreases were followed by more gradual declines to around pH 1.5, but unlike the high sulphur samples discussed above, there accompanying temperature rises were relatively modest, peaking at around 40 ^{o}C after nearly 5 to 6 hour of reaction time.

Summary of Implications for Field Behaviour

Overall, the results of the kinetic NAG tests suggest that sulphidic lode waste and PAF slate from the hanging wall and footwall adjoining the lode which has a low ANC and a sulphur content exceeding 1.5 %S will be highly reactive and could acidify within several months of exposed to atmospheric conditions.

However, it should be noted that only a limited number of samples with moderate to very high sulphur contents were subjected to kinetic NAG testing. The lag period for PAF waste rock that contains substantially less than 1.5 %S and/or has an ANC substantially above the ANCs of the test samples could extend for much longer, with the onset of acidic conditions delayed beyond a year and possibly for several years.

Some long-term column leach tests were carried out as apart of the AARC (2008) geochemical study (see Section 9) and further column testing is planned for samples from the current study. These column tests will provide more information on sulphide reactivity and lag time under real-time condition.

7.0 Elemental Composition of Dugald River Waste Rock

Multi-element scans were run on 15 drill core samples from the current study. They included three samples representing hanging wall slate and two samples from each of the other lithologies. As a general rule, one of the chosen samples from each lithology had a sulphur content towards the top of the concentration range for that lithology, whilst the other sample had a sulphur content that was typically around mid-range. The samples selected were as followed:

MMG / EGi Codes	Lithology	%S	ANC	NAPP	NAG	ARD Class
80466 / 40904	Calc-silicate	0.47	62	-48	0	NAF
80448 / 40886	Calc-silicate	1.57	210	-161	0	NAF
80442 / 40880	Mafic feldspar porphyry	0.01	72	-72	0	NAF
80424 / 40862	Mafic feldspar porphyry	0.77	79	-56	0	NAF
80467 / 40905	White mica schist	0.05	11	-9	0	NAF
80449 / 40887	White mica schist	0.29	9	0	6	PAF
80428 / 40866	Hanging wall slate	0.94	158	-129	0	NAF
80483 / 40921	Hanging wall slate	1.99	9	52	43	PAF
80437 / 40875	Hanging wall slate	4.81	286	-139	0	NAF
80478 / 40916	Lode waste	2.38	219	-146	0	NAF
80454 / 40892	Lode waste	10.46	34	286	138	PAF
80430 / 40868	Footwall slate	1.15	120	-84	0	NAF
80438 / 40876	Footwall slate	1.66	11	40	37	PAF
80436 / 40874	Footwall limestone	1.06	462	-429	0	NAF
80486 / 40924	Footwall limestone	1.69	107	-55	0	NAF

The elemental compositions of the 15 Dugald River waste rock samples are given in Table 4. The samples were assayed for a suite of 35 elements that included: Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, S, Sb, Se, Sn, Sr, Th, Ti, U, V, and Zn.

Multi-element assays were also carried out as part of AGC-Woodward Clyde (1991) and AARC (2008) geochemical studies of Dugald River waste rock. All samples in the 1991 study and half the samples in the 2008 studies were assayed for a limited range of elements of environmental significance which included: As, Cd, Co, Cu, Hg, Pb, S and Zn. The 2008 samples were also assayed for Ba, Be, Cr, Mn, Ni and V, whilst the 1991 samples were also assayed for Bi[8] and Sb. The assay data from previous studies are given in Appendix B-1.

To provide some relativity to the multi-element data, the compositions of the rock solids were compared to typical background compositions reported for soil. The ratios of the concentrations in Dugald River rock relative to background soil are presented graphically in Figure 10. Those elements that occur substantially

8 The bismuth contents of all of the samples in the AGC-Woodward Clyde (1991) study were at or below the analytical detection limit of 5 mg/kg, which is relatively high in comparison to concentrations typically found in background soils. As such, the Bi results were not included in this review of elemental enrichments in Dugald waste rock.

above the ratio=1 line in Figure 10 are elevated in comparison to typical soil, whilst elements that occur below the line are deficient relative to typical soil

Geochemical Abundance Indices (GAIs) were also calculated for each sample to provide an indication of elemental enrichments that may have environmental significance. Each GAI was calculated as follows:

$GAI = \log_2 [C / (1.5*S)]$

where C is the concentration of the element in the sample and S is the median soil[9] content for that element. The GAI are truncated to integer increments (0 through to 6, respectively) where a GAI of 0 indicates the element is present at a concentration similar to, or less than, median soil abundance and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above median soil abundance. The enrichment ranges for the GAI are as follows:

Little or No Enrichment

GAI=0	< 3 times median soil

Slightly Enrichment

GAI=1	3 to <6 times median soil
GAI=2	6 to <12 times median soil

Significant Enrichment

GAI=3	12 to <24 times median soil
GAI=4	24 to <48 times median soil
GAI=5	48 to <96 times median soil
GAI=6	≥ 96 times median soil

The GAIs for the 15 Dugald River waste rock samples assayed in the current study are given in Table 5, and GAIs for samples from previous studies are given in Appendix B-2. The main purpose of the GAI is to provide an indication of any elemental enrichments that may be of environmental importance. As a general rule, a GAI of 3 or above is considered significant and such an enrichment may warrant further examination.

Samples representing calc-silicate, mafic feldspar porphyry and white mica schist were relatively free of significant (GAI≥3) enrichments. For these lithologies, the only significant enrichment identified was sulphur in one calc-silicate sample.

However, many samples representing hanging wall slate, footwall slate and lode waste were significantly (GAI≤3) enriched with one or more of a range of environmentally important elements. In addition to sulphur, the implications of which have already been discussed in Section 4, many samples from these lithologies were significantly enriched with arsenic, cadmium and zinc, and there were small numbers of samples enriched with copper, lead, mercury, and selenium.

[9] References for median soil data were: (1) Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, London. (2) Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Parkville, Victoria, Australia

A summary of the significant enrichments in each lithology (apart from sulphur) is given below:

- Calc-silicate none
- Mafic feld. porphyry none
- White mica schist none
- Hanging wall slate As (11/28) Zn (6/28) Cd (5/28) Hg (3/28) Cu (9/28) Se (1/3)
- Lode waste As (4/6) Zn (2/6) Cd (5/6) Hg (4/6) Pb (2/6) Se (1/2), Mn (1/6), Bi (1/2)
- Footwall slate As (8/21) Zn (4/21) Cd (6/21) Hg (1/21) Pb (2/21) Cu (1/21)
- Footwall limestone As (3/14) Zn (2/4)

(ratios shown are the number samples significantly enriched compared to the total assayed)

The enriched elements listed above form an elemental association that is commonly reported for a hydrothermal base metal deposit, hence their occurrence within the lode waste and the hanging wall and footwall slate adjoining the lode is expected. However, they are all regarded as environmentally important because of their potential toxicological effects on humans and/or aquatic life. Biological systems are particularly sensitive to metals such as zinc and copper, and there are obvious health implications in relation to elevated concentrations of mercury, cadmium and lead.

Zinc, copper and cadmium are usually highly mobile under acidic conditions and it is likely that significant concentrations of these metals would occur in any acidic drainage produced by PAF waste that is exposed to atmospheric conditions.

There may also be potential for leaching of arsenic, although the solubility of arsenic is often difficult to predict as its solubility and geochemical behaviour in geological systems is often controlled by adsorption or co-precipitation reactions involving other elements (*e.g.* iron at lower pHs and calcium at higher pHs).

The potential for leaching of environmentally important elements from Dugald River waste rock is considered further in Section 8.

8.0 Solute Leaching from Dugald River Waste Rock

Batch extraction tests were carried out on the 15 samples selected for multi-element analysis (see Section 7) to assess the potential for mobilisation of potentially hazardous elements from Dugald River waste rock. Three extractants were used, namely deionised water, 0.05M sulphuric acid, and hydrogen peroxide. The extractions with water and sulphuric acid were based on the Australian Standard leaching Procedure (ASLP) and involved leaching of crushed (≤4 mm) material at a solid:liquor ratio of 1:20 on an end-over-end shaker for a period of 18 hours. The peroxide extractions were based on the single-stage NAG test and involved over-night oxidation and leaching of pulverised sample at a solid:liquor ratio of 1:100.

The main objectives of the extraction tests were as follows:

- Deionised water - To provide an indication of the likely solubility of elements in freshly mined rock at the existing pH of the material.
- Dilute Acid - To assess the potential for elemental release from NAF waste rock that may be subject to acidic conditions imposed from some other source (*i.e.* overlying PAF rock).
- Peroxide - To assess elements that could potentially be released from the same rock following an extended period of exposure to atmospheric conditions resulting in significant sulphide oxidation. Depending on the particular rock type, the oxidation process may result in formation of *acidic rock drainage* (*e.g.* PAF lode waste) or generation of *neutral mine drainage* (*e.g.* NAF calc-silicate or footwall limestone with elevated sulphur and high to very high ANC).

The compositions of extracts from tests involving deionised water, dilute acid and peroxide are given in Tables 6 to 8, respectively. A statistical summary of the results for elements that are generally regarded as environmentally important is also presented graphically in Figure 11. This figure illustrates the concentration range, 20-80 percentile band, and average concentrations for Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Se, Sn, and Zn. Because the peroxide extractions were carried out at one-fifth the solid:liquor ratio than was used for the water and acid extractions, a five-times adjustment factor was applied to peroxide results to provide a more realistic comparison of extraction methods in Figure 11.

Water Extractions

Regardless of the ARD classifications, the water extracts of all 15 waste rock samples were circum-neutral to alkaline, with pHs of 7.4 to 8.5, respectively. The pH values are consistent with the samples containing some reactive carbonate, and in most cases having moderate to high ANCs.

Overall, there was little difference in the chemical compositions of the water extracts. The only differences of any substance was that the two NAF calc-silicate samples produced extracts with markedly higher concentrations of calcium (48 and 221 mg/L) and sulphate (113 and 549 mg/L) compared to extracts from

other samples. The elevated calcium and sulphate concentrations suggests the presence of some readily-soluble gypsum or anhydrite within the calc-silicate.

One of the hanging wall slate samples also had slightly elevated concentrations of calcium (22 mg/L) and sulphate (49 mg/L), but for all other extracts the concentrations were relatively low, with calcium ranging from <1 to 11 mg/L and sulphate ranging from <1 to 20 mg/L. There was also minimal release of magnesium (<1 to 2 mg/L), potassium (<1 to 4 mg/L) or sodium (<1 to 2 mg/L).

Overall, the concentrations of environmentally important elements in the water extracts were consistently low and commonly less than the analytical detection limits. Mercury and cadmium were consistently below the detection limit of 0.0001 mg/L, cobalt, chromium, copper, lead, nickel, antimony and tin were below or close to the 0.001 mg/L detection limit, and selenium was below the 0.01 mg/L detection limit. Arsenic was also low, with all but two extracts containing less than 0.006 mg/L.

Only the lode waste samples exhibited some minor leaching of metals. The water extract of one of the load samples contained 0.42 mg/L of zinc and 0.33 mg/L of barium. There were also traces of nickel (0.006 mg/L) and lead (0.004 mg/L), whilst the other lode extract had a trace of arsenic (0.016 mg/L).

Such results from the water extractions suggest that the potential for leaching by natural rainfall of environmentally important elements such as As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Se, Sn, and Zn will be inconsequential for freshly mined rock similar to the samples tested.

Acid Extractions

The dilute acid extraction involved 0.05M H_2SO_4. This strength has a pH of 1.6, an acidity equivalent to 5000 mg $CaCO_3$/L, and a sulphate concentration of approximately 4,800 mg/L. From an ARD perspective, a pH of 1.6 represents an extreme case but the acidity[10] and sulphate concentration are of a magnitude commonly observed in ARD from actively oxidising PAF rock. The total amount of acid added to each sample was equivalent to 98 kg H_2SO_4/t.

As expected, there was some neutralisation of acid by some of the samples, in particular those with high ANCs. Three of the four samples with ANCs exceeding 200 kg H_2SO_4/t produced extracts of pH 5.3 to 5.4, while the fourth sample raised the pH to 3.3. It is expected that some neutralisation would also have occurred with most of the other 11 samples that had lower ANCs, but overall pHs remained low at between pH 1.5 to 2.1.

A defining feature of the acid extractions was that there was significant release of calcium as a direct consequence of the neutralisation processes. Calcium concentrations ranged from 20 to 164 mg/L in the acid extracts for samples with relatively low ANCs (i.e. ≤34 kg H2SO4/t), and from 393 to 874 mg/L for the higher ANC samples. The latter range equates to ANC equivalent of 19 to 43 kg H_2SO_4/t if it is assumed that

[10] In most cases the acidity of ARD predominantly results from dissolved iron and aluminium, with free acid (H_2SO_4) usually a minor contributor.

the calcium was derived from calcite[11] dissolution and there was no re-precipitation[12] of the calcium into other forms.

In addition to calcium, there was significant release of iron, aluminium and manganese from most samples. The concentrations of iron in the acid extracts ranged from 4 to 60 mg/L (average 25 mg/L), aluminium from 0.3 to 22 mg/L (average 8 mg/L), and manganese from 2.8 to 137 mg/L (average24 mg/L). Concentrations of iron and aluminium were greatest in extracts of low pH, which is consistent with the solubilities of both these elements being highly pH-dependent.

Mercury, tin and selenium remained below their respective detection limits of 0.0001, 0.001 and 0.1 mg/L. The concentration ranges for most of the environmentally important elements were generally higher in the acid extracts compared to the water extraction results, typically by an order-of-magnitude as illustrated in Figure 11.

Notwithstanding this general increase, the concentrations in most cases were still comparatively low and indicative of only limited elemental release despite the low pH condition imposed on the samples. For example, concentrations of cadmium and antimony were less than 0.01 mg/L, and the concentrations of arsenic, cobalt, chromium, copper and nickel were less than 0.1 mg/L.

However, there was a significant release of zinc from one of the lode waste samples (as per the water extract) producing concentration of 5.8 mg/L in the acid extract. For all other samples the zinc concentrations were much lower, typically around 0.1 to 0.3 mg/L.

Peroxide Extractions

As noted above, the results of the water leach tests provide an indication of the initial solubility of elements in freshly mined rock. However geochemical changes are likely to occur if sulphidic rock is exposed to conditions in which oxidation can occur, which could alter the potential for leaching of metals and other environmentally important elements. The purpose of the peroxide extractions, which followed the same procedure as the NAG test, was to highlight those elements that could potentially be released from Dugald River waste rock during an extended period of exposure to atmospheric conditions.

It should be noted that only four of the samples tested were classified as PAF. They included lode waste sample, one white mica schist, one hanging wall slate and one footwall slate. The pHs of these samples after reaction ranged from 2.3 to 3.5. Some of the NAF samples also had significant sulphide contents, but the ANCs were generally high to very high and the pH of the peroxide extracts were invariably circum-neutral at between pH 6.2 to 9.2.

[11] In the case of calc-silicate it is likely that some of the calcium derived from other sources (*e.g*. dissolution of gypsum or anhydrite) as calcium concentration was also relatively high in the corresponding water extracts.

[12] It is likely that some calcium re-precipitated as gypsum in some extracts given that the sulphate concentrations at the end of the test where generally lower than at the start, particularly in the case of samples with higher ANCs where carbonate dissolution was greatest. This being the case, the amounts of ANC dissolution would have been higher than those indicated by dissolved calcium.

It should also be noted that the composition of a peroxide extract at the end of the 18 hour reaction period should not be regarded as necessarily representative of the drainage quality that might be produced by such a material under field conditions as the concentrations of various elements are fundamentally influenced by the configuration of the test procedure, including the soil:liquor ratio, the extent of oxidation, and the degree of any acidification that might occur. Rather, the intent of the peroxide test was to highlight elements that might be released in significant amounts as a consequence of sulphide oxidation. To this end, and to provide a more apt comparison of the peroxide, water and acid leach results in Figure 11, the elemental concentrations in the peroxide extracts were multiplied by five to adjust for the different solid:liquor ratio that was used in the peroxide (NAG test) extraction.

This comparison suggests that the elements which had a higher propensity for release under oxidising conditions included zinc, lead, nickel, manganese, copper, cobalt, and to a lesser extent arsenic. However, significant releases of these elements were almost exclusively confined to the four PAF samples that acidified during the peroxide extraction. With the NAF samples the concentrations in the peroxide extracts were typically at trace values only. Elements that showed little or no propensity for release regardless of pH included mercury, tin, chromium, selenium and antimony.

9.0 Column Leach Testing of Dugald River Waste Rock

MMG is currently assessing commissioning long-term column leach tests involving some waste rock samples discussed in this report. The results of such testing would complement the findings of previous column leach tests that were commissioned by AARC in August 2008 and operated for either 44 weeks or 68 weeks.

The main objective of the column tests is to quantify the longer-term geochemical behaviour of different waste rock lithologies at real time under conditions that are conducive to sulphide oxidation and metals leaching. The column leach testing program will also provide data on rates of sulphide oxidation and acidification of PAF waste rock such as occurs within the vicinity of the lode and in the adjoining hanging wall and footwall slate, and more accurate water quality data for drainages that could emerge from PAF and NAF waste rock stockpiled at the surface.

The column tests commissioned by AARC involved composites of drill core samples representing the following waste rock types:

- Column 1 - hanging wall slate (uncertain),
- Column 2 - footwall limestone (NAF),
- Column 3 - PAF waste mixture (comprising lode waste and pyritic/mineralised footwall slate)
- Column 4 - footwall slate (NAF),
- Column 5 - calc-silicate (NAF),
- Column 6 - calc-silicate & mafic feldspar porphyry mix (NAF),
- Column 7 - mica schist (NAF),

The acid forming characteristics of the samples are detailed in Appendix C-1. Briefly, the samples exhibited the following characteristics:

- The PAF waste mixture had a very high acid forming potential. The sulphur content was 9.47 %S, and the NAPP was corresponding high at 254 kg H_2SO_4/t.
- The hanging wall slate was borderline with respect to ARD potential and the ARD classification was uncertain. It contained 2.39 %S and had a small positive NAPP of 2 kg H2SO4/t, but it did not acidify when reacted in the NAG test.
- All other samples were classified as NAF They had substantially lower sulphur contents (0.02 to 0.96 %S) and high to very high ANCs (80 to 222 kg H_2SO_4/t).

The column tests were undertaken by ALS Brisbane, generally in accordance with the *Free Draining Leach Column Procedure* outlined in the AMIRA P387A Project ARD Test Handbook[13]. Each column comprised 2.5 kg of crushed core (nominally less than 10 mm[14]) and was leached under free-draining conditions with deionised water on a monthly leach cycle.

The monthly leachate collections were assayed for pH, EC, alkalinity/acidity and sulphate concentration. A multi-element scan was also run on every second collection. The leachate assay results for the column tests are tabulated in Appendix C. Plots of leachate pH, sulphate and calcium concentration through time are also given in Figures 12 to 14, respectively.

NAF Waste Samples

The five NAF samples produced circum-neutral leachates (Figure 12) throughout the 44 week test period and the major ion chemistries were dominated by sulphate (Figure 13) and calcium (Figure 14). The average pH, alkalinity, sulphate concentration and calcium concentration for the five NAF columns during the test period were as follows:

Column Test	Lithology	Average pH	Average Alk (mg/L)	Average SO_4 (mg/L)	Average Ca (mg/L)
Column 2	Footwall limestone	7.8	30	44	17
Column 4	Footwall slate	7.6	21	46	18
Column 5	HW Calc-silicate	8.7	54	6	7
Column 6	HW Calc-sil / Mafic porphyry	8.6	39	8	7
Column 7	HW Mica schist	8.4	27	4	7

Figure 15 shows a statistical summary of the combined leachate quality results for the five NAF leach column tests. The results are consistent with the findings of the water extraction tests reported in Section 8. Apart from occasional trace concentrations of zinc (up to 0.2 mg/L) and manganese (up to 0.35 mg/L) there was no evidence of significant release of environmentally important elements from any of the NAF waste rock samples during the 12 month period. Mercury and cadmium were consistently below or close to the analytical detection limit of 0.0001 mg/L, antimony, arsenic, chromium, cobalt, copper, lead nickel and tin were below or close to the 0.001 mg/L detection limit, and selenium was below the 0.01 mg/L detection limit.

The concentrations reported for zinc ranged up to 0.2 mg/L but around half of leachate collections contained less than the 0.005 mg/L detection limit and the average zinc concentration across all of the NAF samples

[13] EGi was a contributing author of the AMIRA handbook and the column leach procedure described was developed by EGi and is currently used in EGi's laboratory. This column set-up will also be employed for the planned new column tests involving Dugald waste rock.

[14] The nominal minus 10 mm size material used by ALS for the 2.5 kg column tests was larger than the nominal minus 4 mm specified in the handbook.

was less than 0.02 mg/L. Similarly for manganese, concentrations ranged up to 0.35 mg/L but the average overall was only 0.06 mg/L.

PAF Waste Mixture

Column 3 contained a mixture of drill core samples representing PAF lode waste and PAF mineralised and pyritic footwall slate. The acid forming characteristics of the sample were typical of the lode waste samples included in the current study in that it had a high sulphur content (9.47 %S), a low to moderate ANC (36 kg H_2SO_4/t) and a high NAPP (254 kg H_2SO_4/t). The static NAG test also confirmed that the sample had a high acid potential under oxidising conditions.

The initial leachate draining from the column was pH neutral, similar to what was observed in the water extraction tests that were carried out on this type of waste rock. Leachate pH remained neutral for the first 12 weeks, but thereafter steadily decreased with time (see Figure 12). When the column test was stopped at 68 weeks the pH of leachate had decreased to 4.4.

There was considerable variability in the concentration of sulphate in column leachate during the test, but overall there was a general upward trend with time. The average concentration for the 68 week test period was 99 mg/L. This average is around twice that recorded for leachates from the columns containing the footwall slate (Column 2) and footwall limestone (Column 3), and more than an order-of-magnitude greater than for leachates from the other NAF columns. However, the sulphate concentrations *per se* were relatively low in comparison to what often occurs in acid rock drainage from highly pyritic rock. With such materials it is not uncommon to find sulphate concentrations in the order of several thousand mg/L. Indeed, sulphate concentrations of that magnitude were recorded in an identical column leach test involving process tailings from the Dugald River project that was carried out by EGi[15] in 2008-9. The reason for the relatively low sulphate concentrations in leach from the PAF waste sample is not known, but it is probable that the particle size and rock strength of the test material (nominally < 10 mm) were factors affecting the exposed surface area of sulphides.

The acidification of the PAF waste mix was accompanied by increased leaching of iron, zinc, manganese and aluminium as illustrated in Figure 16. The maximum concentrations recorded during the column test were 18.1, 9.4, 6.3, and 0.47 mg/L, respectively.

However, there was only trace leaching of other environmentally important elements, with many elements occurring in leachate at concentrations below or close to the limits of analytical detection. For example, mercury was less than the detection limit of 0.0001 mg/L, arsenic, chromium, lead antimony and tin were less than 0.001 mg/L, and selenium was less than 0.01 mg/L. The average and range of concentrations recorded for environmentally important elements were as follows:

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15 EGi (2009). Geochemistry and column leach testing of tailings. Dugald River Zinc Project, Queensland. Final Report. Prepared for Oz Minerals Australia Limited by Environmental Geochemistry International Pty Ltd. Document No. 6412/877, July 2009.

The Dugald tailings sample had a sulphur content of 7.9 %S and was strongly acid generating with a NAG capacity of 86 kg H_2SO_4/t. Under column leach testing the tailings acidified to around pH 3.5 within the first few months of leaching and over the course of the 52 week column test the concentration of sulphate in leachate ranged from 1640 to 5720 mg/L and averaged 3080 mg/L.

Element	Average	Range
Al	0.19	(0.02 - 0.47)
As	<0.001	
Cd	0.005	(0.0002 - 0.009)
Co	0.015	(0.003 - 0.04)
Cr	<0.001	
Cu	0.01	(<0.001 - 0.03)
Fe	8.3	(<0.05 - 18.1)
Hg	<0.0001	(<0.0001 - 0.0004)
Mn	2.4	(0.41 - 6.3)
Ni	0.06	(0.01 - 0.14)
Pb	0.015	(<0.001 - 0.03)
Sb	<0.001	
Se	<0.01	
Sn	<0.001	
Zn	4.02	(0.10 - 9.4)

Hanging Wall Slate

Column 1 contained a composite of drill core interval representing both NAF and PAF hanging wall slate. Static testing of the sample indicated a sulphur content of 2.39 %S (which equates to a maximum acid potential of 73 kg H_2SO_4/t), and an ANC of 71 kg H_2SO_4/t. These results mean that the acid-base characteristics of the sample were evenly balanced, with a NAPP of only 2 kg H_2SO_4/t. The sample didn't acidify when reacted in a single addition NAG test, but the acid-base account denotes it was borderline with respect to ARD potential.

The overall pH profile for the hanging wall slate sample (see Figure 12) was comparable to that profile exhibited by the PAF waste mix, despite having a much lower sulphur content (albeit still relatively high) and about double the ANC. The initial leachate from the column was circum-neutral but after the first few months there was an overall downward trend in pH, with values less than 5 recorded for the last two collections at weeks 64 and 68. A lag period of only a few months is unusual for rock which has an ANC of 71 kg H_2SO_4/t, which normally would be considered to be in the moderate to high range and would normally be expected to provide a lag of at least a year and probably several years. The absence of such an extended lag suggests that the ANC within the slate was not readily available for reaction with acid produced by sulphide oxidation.

The decrease in pH was again accompanied by increases in the concentrations of iron, zinc, manganese and aluminium, but not to the same extent as reported for the PAF waste mix. By the end of the test the concentrations of these metals had increased to 10.4, 0.50, 0.51 and 0.19 mg/L, respectively. Other environmentally important elements were either below detection or occurred at trace concentrations only.

10.0 Summary and Implications for Dugald River Waste Rock Management

This report presents the results and findings of geochemical analysis of drill core samples representing waste rock lithologies that will be mined during development and operation of the Dugald River project. The geochemical program involved static testing of 72 drill core samples selected by MMG to assess their potential for generation of acid rock drainage, and also the potential for metals leaching under both acidic and neutral drainage conditions. In addition to the 72 samples tested by EGi, data from previous geochemical studies carried out by AARC (2008) and AGC-Woodward Clyde (1991) were compiled into a single geochemical database to enhance the evaluation of acid generation and metals leaching characteristics of the different waste rock types.

Main Findings

Overall, results for 211 samples were assessed. They included 31 samples representing calc-silicate, 7 mafic feldspar porphyry, 17 white mica schist, 52 hanging wall slate, 18 lode waste, 44 footwall slate, and 42 footwall limestone. The results for these samples suggest that:

- Waste rock from the calc-silicate, mafic feldspar porphyry, white mica schist lithologies associated with the mining of copper ore, and also waste rock from the footwall limestone lithology will be non-acid forming (NAF), with the calc-silicate and footwall limestone likely to have high to very high neutralisation capacity.
- Waste rock from within the lode zone will almost invariably be potentially acid forming (PAF) and have a high to very high capacity for acid generation if exposed to atmospheric conditions. It is also likely that some slate waste rock from the adjoining hanging wall and footwall will be pyritic and strongly PAF. Approximately 54% of the hanging wall slate samples tested, and 20% of the footwall slate samples tested were classified as PAF.

Elemental analyses of selected samples were also carried out to identify any enrichments that might be environmentally significant in terms of impacting on the quality of mine water and waste dump seepage. No significant metal or metalloid enrichments were identified in the calc-silicate, mafic feldspar porphyry and white mica schist but many of the hanging wall slate, footwall slate and lode waste samples were highly enriched with one or more of a range of environmentally important elements on comparison to concentrations typically occurring in background soils. The most prevalent enrichments were arsenic, cadmium and zinc. There was also less frequent enrichment with copper, lead, mercury, and selenium.

The enriched elements listed above form an elemental association that is commonly reported for a hydrothermal base metal deposit, hence their occurrence within the lode waste and the hanging wall and footwall slate adjoining the lode is expected. However, they are all regarded as environmentally important in terms of water quality, human health and/or aquatic life.

A series of batch extraction tests were carried out on selected samples to assess the potential for mobilisation of environmentally important elements under both acidic and neutral mine drainage conditions. Also, the results of column leach tests previously commissioned by AARC were reviewed to identify elements that might be released from different waste rock lithologies when exposed to atmospheric conditions. Elements that exhibited a higher propensity for release under oxidising conditions included zinc, lead, nickel, manganese, copper, cobalt, and to a lesser extent arsenic. However, significant releases of these elements were almost exclusively confined to PAF waste once acidification had occurred. With the NAF rock producing neutral drainage, the concentrations of environmentally important elements were typically at trace values only. Elements that showed little or no propensity for release regardless of pH included mercury, tin, chromium, selenium and antimony.

Implications for Waste Rock Management

The results of this and previous studies suggest that most lode waste and some pyritic slate in the hanging wall and footwall adjoining the lode will have a high acid generating potential and consequently a high level of management will be required to limit sulphide oxidation and minimise the risk of ARD generation occurring if such material is brought to the surface and exposed to atmospheric conditions. Clearly, highly PAF waste should be preferentially used as underground fill where possible. For PAF waste that needs to be stockpiled temporarily at the surface, or permanently placed within a dump, it is recommended that mining and handling procedures are developed that will allow selective placement of PAF waste in a manner that minimises rainfall infiltration (to limit leaching) and oxygen ingress (to limit oxidation). Prevention or control of acid rock drainage within stockpiles or dumps of pyritic waste rock will require adoption of strategies that involve one or more of the following:

- In-situ neutralisation of acid generation via blending of PAF rock with other materials that are non-acid forming, in particular high carbonate materials such as the footwall limestone or hanging wall calc-silicate;
- Minimisation of pyrite oxidation processes within dumped PAF waste via:
    - isolation and encapsulation of PAF rock within cells within the core of a dump or stockpile,
    - prevention of convective air movement by constructing dumps in small, compacted lifts,
    - construction of intermediate or final barrier layers which limit oxygen diffusion;
- Minimisation of acid drainage migration via:
    - controls on surface drainage,
    - incorporation of layers of low hydraulic conductivity.

The two key ingredients for pyrite oxidation are water and oxygen. Whilst it is generally best practice to divert surface waters away from dumps, and to place final cappings that minimise rainwater ingress, such measures are unlikely to produce a dump in which the moisture content is low enough to prevent sulphide oxidation. In the wet-dry climatic setting that occurs at the Dugald River site, the only practical mechanism for controlling sulphide oxidation will be to limit the movement of atmospheric oxygen into stockpiled material. This can generally be achieved by either burial and isolation of PAF rock within cells within the core of a

dump, or by construction of an outer cover that incorporates a layer with a low air-filled porosity which will act as a barrier to inward gaseous movement.

It is essential that all PAF rock is excluded from the area under the outer slope of dumps where convective air movement tends to be greatest. PAF rock should also be excluded from the base layer and from existing drainage lines so that the under-drainage is not in contact with sulphidic mineralised rock. To the extent possible, limestone or calc-silicate should be placed in drainage lines to impart some alkalinity to drainage prior to emergence at the dump toe.

As it is expected that PAF waste will be a relatively small percentage of total waste, there should also be opportunities for blending with high carbonate NAF rock prior to encapsulation within cells within the dump core. Ideally, blending would involve co-dumping of high carbonate rock such as limestone or calc-silicate with PAF rock to create an overall blend that is non-acid forming. Even if a NAF blend cannot be achieved, the high ANC of the blend would be expected to provide a very long lag which would prevent acidification pending possible future use as underground fill.

It is essential that no PAF rock is unduly exposed to atmospheric conditions, and intermediate barrier layers of NAF rock should be used to encapsulate PAF lifts prior to the wet season. Progressive encapsulation of PAF rock using intermediate cover layers would reduce leaching of PAF rock during dump construction, and in the longer term such layers would also provide a source of alkalinity to any pore water moving down into PAF rock zones within a dump.

It is essential that any stockpiled waste rock remaining at the surface at mine closure has a final cover layer comprising only NAF material. Such a cover would serve as a revegetation layer and provide circum-neutral surface runoff. The design of the final cover can be developed as mining proceeds and the NAF/PAF schedule for waste rock is refined, but under the climatic conditions prevailing at the River site a *Store and Release* cover system would likely provide the necessary level of control on rainfall infiltration to prevent significant leaching of any PAF rock encapsulated within cells within the dump core.

Tables

TABLE 1: Acid Forming Characteristics of Dugald River waste rock - Samples arranged by drill hole

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80421	40859	DR315	284.0	284.5	0.5	Footwall slate	331	8.3	0.90	28	220	8	-193	0	7.8	NAF
80422	40860	DR315	304.0	304.5	0.5	Footwall limestone	216	8.1	0.68	21	456	22	-435	0	8.3	NAF
80423	40861	DR322	104.0	104.5	0.5	Calc-silicate	221	8.4	0.01	0	261	853	-261	0	8.8	NAF
80424	40862	DR322	150.0	150.5	0.5	Mafic feldspar porphyry	315	8.5	0.77	24	79	3	-56	0	8.9	NAF
80425	40863	DR322	288.0	288.5	0.5	Footwall slate	416	8.3	0.80	24	82	3	-57	0	7.9	NAF
80426	40864	DR322	310.0	310.5	0.5	Footwall limestone	239	8.2	0.88	27	467	17	-440	0	8.5	NAF
80427	40865	DR324	300.0	300.5	0.5	Hanging wall slate (Si Ab alt)	325	8.5	0.42	13	81	6	-68	0	7.8	NAF
80428	40866	DR324	405.0	405.5	0.5	Hanging wall slate (non sulphide)	176	8.4	0.94	29	158	5	-129	0	8.1	NAF
80429	40867	DR324	423.0	423.5	0.5	Lode (mineralised waste)	212	7.8	3.32	102	19	0.2	83	73	2.2	PAF
80430	40868	DR324	456.0	456.5	0.5	Footwall slate	245	7.9	1.15	35	120	3	-84	0	9.3	NAF
80431	40869	DR324	485.0	485.5	0.5	Footwall limestone	335	8.6	1.53	47	307	7	-260	0	8.2	NAF
80432	40870	DR330	101.5	102.0	0.5	Calc-silicate	346	8.4	0.01	0	134	437	-133	0	8.7	NAF
80433	40871	DR331	197.0	197.5	0.5	Footwall slate	512	8.5	1.18	36	170	5	-134	0	8.3	NAF
80434	40872	DR331	240.0	240.5	0.5	Footwall limestone	146	8.2	1.06	32	451	14	-418	0	9.6	NAF
80435	40873	DR336	382.0	382.5	0.5	Footwall limestone	235	8.3	0.71	22	215	10	-194	0	8.1	NAF
80436	40874	DR337	401.0	401.5	0.5	Footwall limestone	315	8.2	1.06	32	462	14	-429	0	8.9	NAF
80437	40875	DR339	188.0	188.5	0.5	Hanging wall slate (Si Ab alt)	142	8.1	4.81	147	286	1.9	-139	0	8.1	NAF
80438	40876	DR339	241.0	241.5	0.5	Footwall slate	117	8.9	1.66	51	11	0.2	40	37	2.4	PAF
80439	40877	DR339	248.0	248.5	0.5	Lode (mineralised waste)	145	8.2	2.05	63	237	4	-175	0	8.1	NAF
80440	40878	DR339	271.0	271.5	0.5	Footwall limestone	129	7.9	1.28	39	363	9	-323	0	8.0	NAF
80441	40879	DR343	133.0	133.5	0.5	Calc-silicate	139	7.8	0.01	0	82	268	-82	0	9.4	NAF
80442	40880	DR343	416.0	416.5	0.5	Mafic feldspar porphyry	146	8.4	0.01	0	72	235	-72	0	8.6	NAF
80443	40881	DR343	521.0	521.5	0.5	Footwall slate	235	7.6	7.88	241	21	0.1	220	260*	2.0	PAF
80444	40882	DR343	544.0	544.5	0.5	Footwall limestone	246	7.8	0.82	25	229	9	-204	0	7.7	NAF
80445	40883	DR345	351.0	351.5	0.5	Footwall slate	415	7.7	0.57	17	60	3	-42	0	7.8	NAF
80446	40884	DR345	364.0	364.5	0.5	Footwall limestone	329	8.6	0.85	26	199	8	-173	0	7.9	NAF
80447	40885	DR346	449.0	449.5	0.5	Footwall slate	346	8.7	1.61	49	119	2.4	-70	0	7.6	NAF
80448	40886	DR355	435.0	435.5	0.5	Calc-silicate	352	8.5	1.57	48	210	4	-161	0	9.5	NAF

TABLE 1: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80449	40887	DR355	501.0	501.5	0.5	Schist	146	8.2	0.29	9	9	1	0	6	3.5	PAF
80450	40888	DR355	576.0	576.5	0.5	Lode (mineralised waste)	216	8.4	11.75	360	7	0	352	297*	2.0	PAF
80451	40889	DR355	636.0	636.5	0.5	Footwall slate	315	8.0	2.18	67	148	2	-82	0	7.5	NAF
80452	40890	DR355	660.0	660.5	0.5	Footwall limestone	429	7.8	0.39	12	152	13	-140	0	7.6	NAF
80453	40891	DR356	52.0	52.5	0.5	Hanging wall slate (Si Ab alt)	276	7.9	0.38	12	392	34	-380	0	7.9	NAF
80454	40892	DR356	181.0	181.5	0.5	Lode (mineralised waste)	186	7.4	10.46	320	34	0	286	348*	2.0	PAF
80455	40893	DR356	215.0	215.5	0.5	Footwall slate	345	7.6	0.87	27	136	5	-109	0	7.8	NAF
80456	40894	DR356	261.0	261.5	0.5	Footwall limestone	329	8.4	1.87	57	435	8	-377	0	7.9	NAF
80457	40895	DR356	263.0	263.5	0.5	Hanging wall slate (non sulphide)	307	7.8	1.07	33	455	14	-423	0	7.5	NAF
80458	40896	DR364	150.0	150.5	0.5	Schist	212	8.3	0.08	2	15	6	-13	0	4.7	NAF
80459	40897	DR364	278.0	278.5	0.5	Footwall slate	246	8.5	0.59	18	140	8	-122	0	7.8	NAF
80460	40898	DR364	306.0	306.5	0.5	Footwall limestone	197	8.6	0.89	27	462	17	-435	0	7.9	NAF
80461	40899	DR366	178.0	178.5	0.5	Footwall limestone	176	8.7	1.32	40	385	10	-345	0	7.6	NAF
80462	40900	DR368	245.0	245.5	0.5	Footwall limestone	203	8.5	0.77	24	516	22	-492	0	8.2	NAF
80463	40901	DR373	338.0	338.5	0.5	Calc-silicate	211	8.3	0.04	1	143	117	-141	0	7.8	NAF
80464	40902	DR373	638.0	638.5	0.5	Footwall slate	242	8.7	1.11	34	111	3	-77	0	8.9	NAF
80465	40903	DR373	671.0	671.5	0.5	Footwall limestone	403	8.6	0.83	25	302	12	-276	0	8.2	NAF
80466	40904	DR379	531.0	531.5	0.5	Calc-silicate	179	8.5	0.47	14	62	4	-48	0	8.4	NAF
80467	40905	DR379	575.0	575.5	0.5	Schist	245	8.7	0.05	2	11	7	-9	0	6.3	NAF
80468	40906	DR379	584.0	584.5	0.5	Hanging wall slate (non sulphide)	225	8.9	0.89	27	159	6	-132	0	7.6	NAF
80469	40907	DR379	631.0	631.5	0.5	Lode (mineralised waste)	312	8.1	13.94	427	398	0.9	28	0*	7.3	UC (NAF)
80470	40908	DR379	671.0	671.5	0.5	Footwall slate	345	8.4	1.56	48	40	0.8	7	3*	3.6	PAF
80471	40909	DR379	715.0	715.5	0.5	Footwall limestone	332	8.3	0.92	28	192	7	-163	0	8.0	NAF
80472	40910	DR388	478.0	478.5	0.5	Footwall slate	199	8.5	0.84	26	103	4.0	-77	0	7.6	NAF
80473	40911	DR388	513.0	513.5	0.5	Footwall limestone	227	8.6	1.22	37	446	12	-409	0	7.7	NAF
80474	40912	DR393	335.0	335.5	0.5	Calc-silicate	235	8.3	0.74	23	212	9	-189	0	7.8	NAF
80475	40913	DR393	358.0	358.5	0.5	Mafic feldspar porphyry	246	8.2	0.01	0	187	612	-187	0	7.5	NAF
80476	40914	DR393	698.0	698.5	0.5	Footwall slate	255	8.9	0.91	28	60	2.2	-32	0	7.6	NAF

TABLE 1: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80477	40915	DR395	674.0	674.5	0.5	Mafic feldspar porphyry	142	8.4	0.01	0	169	551	-168	0	7.7	NAF
80478	40916	DR395	769.0	769.5	0.5	Lode (mineralised waste)	222	8.3	2.38	73	219	3	-146	0	7.8	NAF
80479	40917	DR395	932.0	932.5	0.5	Footwall slate	315	8.5	1.13	35	144	4	-109	0	7.6	NAF
80480	40918	DR405	212.0	212.5	0.5	Footwall slate	329	8.4	0.66	20	43	2.1	-23	0	7.9	NAF
80481	40919	DR405	234.0	234.5	0.5	Footwall limestone	276	7.6	0.10	3	127	41	-123	0	7.2	NAF
80482	40920	DR406	216.0	216.5	0.5	Calc-silicate	155	7.7	0.01	0	196	642	-196	0	7.4	NAF
80483	40921	DR406	481.0	481.5	0.5	Hanging wall slate (non sulphide)	242	7.8	1.99	61	9	0.1	52	43	2.4	PAF
80484	40922	DR408	839.0	839.5	0.5	Lode (mineralised waste)	235	7.9	6.12	187	5	0.0	182	219*	2.3	PAF
80485	40923	DR408	889.0	889.5	0.5	Footwall slate	246	8.7	2.12	65	94	1.5	-30	0	7.5	NAF
80486	40924	DR412	36.0	36.5	0.5	Footwall limestone	196	8.3	1.69	52	107	2.1	-55	0	7.6	NAF
80487	40925	DR414	337.0	337.5	0.5	Hanging wall slate (Si Ab alt)	331	8.4	0.01	0	190	621	-190	0	7.3	NAF
80488	40926	DR414	421.0	421.5	0.5	Schist	342	8.2	0.05	2	10	6	-8	0	7.2	NAF
80489	40927	DR414	564.5	565.0	0.5	Lode (mineralised waste)	309	8.6	1.90	58	16	0.3	42	38	2.4	PAF
80490	40928	DR414	599.5	600.0	0.5	Footwall slate	311	8.7	0.98	30	88	2.9	-58	0	7.8	NAF
80491	40929	DR417	58.0	58.5	0.5	Footwall slate	316	8.6	1.18	36	548	15	-512	0	7.7	NAF
80492	40930	DR417	123.0	123.5	0.5	Footwall limestone	321	8.5	0.97	30	444	15	-414	0	7.2	NAF

KEY

Existing pH = pH of 1:2 extract
EC = Electrical Conductivity of 1:2 extract (µS/cm)
MPA = Maximum Potential Acidity (kg H_2SO_4/t)
ANC = Acid Neutralising Capacity (kg H_2SO_4/t)

NAPP = Net Acid Producing Potential (kg H_2SO_4/t)
NAG = Net Acid Generation capacity to pH 7.0 (kg H_2SO_4/t)
NAGpH = pH of NAG liquor
** note: NAG values with asterisk are from sequential NAG tests*

NAF = Non-Acid Forming
PAF = Potentially Acid Forming
UC = Uncertain Classification
(likely classification given in brackets)

TABLE 2: Acid Forming Characteristics of Dugald River waste rock - Samples arranged by lithology

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80423	40861	DR322	104.0	104.5	0.5	Calc-silicate	221	8.4	0.01	0	261	853	-261	0	8.8	NAF
80482	40920	DR406	216.0	216.5	0.5	Calc-silicate	155	7.7	0.01	0	196	642	-196	0	7.4	NAF
80474	40912	DR393	335.0	335.5	0.5	Calc-silicate	235	8.3	0.74	23	212	9	-189	0	7.8	NAF
80448	40886	DR355	435.0	435.5	0.5	Calc-silicate	352	8.5	1.57	48	210	4	-161	0	9.5	NAF
80463	40901	DR373	338.0	338.5	0.5	Calc-silicate	211	8.3	0.04	1	143	117	-141	0	7.8	NAF
80432	40870	DR330	101.5	102.0	0.5	Calc-silicate	346	8.4	0.01	0	134	437	-133	0	8.7	NAF
80441	40879	DR343	133.0	133.5	0.5	Calc-silicate	139	7.8	0.01	0	82	268	-82	0	9.4	NAF
80466	40904	DR379	531.0	531.5	0.5	Calc-silicate	179	8.5	0.47	14	62	4	-48	0	8.4	NAF
80475	40913	DR393	358.0	358.5	0.5	Mafic feldspar porphyry	246	8.2	0.01	0	187	612	-187	0	7.5	NAF
80477	40915	DR395	674.0	674.5	0.5	Mafic feldspar porphyry	142	8.4	0.01	0	169	551	-168	0	7.7	NAF
80442	40880	DR343	416.0	416.5	0.5	Mafic feldspar porphyry	146	8.4	0.01	0	72	235	-72	0	8.6	NAF
80424	40862	DR322	150.0	150.5	0.5	Mafic feldspar porphyry	315	8.5	0.77	24	79	3	-56	0	8.9	NAF
80458	40896	DR364	150.0	150.5	0.5	White mica schist	212	8.3	0.08	2	15	6	-13	0	4.7	NAF
80467	40905	DR379	575.0	575.5	0.5	White mica schist	245	8.7	0.05	2	11	7	-9	0	6.3	NAF
80488	40926	DR414	421.0	421.5	0.5	White mica schist	342	8.2	0.05	2	10	6	-8	0	7.2	NAF
80449	40887	DR355	501.0	501.5	0.5	White mica schist	146	8.2	0.29	9	9	1.0	0	6	3.5	PAF
80457	40895	DR356	263.0	263.5	0.5	Hanging wall slate (non sulphide)	307	7.8	1.07	33	455	14	-423	0	7.5	NAF
80453	40891	DR356	52.0	52.5	0.5	Hanging wall slate (Si Ab alt)	276	7.9	0.38	12	392	34	-380	0	7.9	NAF
80487	40925	DR414	337.0	337.5	0.5	Hanging wall slate (Si Ab alt)	331	8.4	0.01	0	190	621	-190	0	7.3	NAF
80437	40875	DR339	188.0	188.5	0.5	Hanging wall slate (Si Ab alt)	142	8.1	4.81	147	286	1.9	-139	0	8.1	NAF
80468	40906	DR379	584.0	584.5	0.5	Hanging wall slate (non sulphide)	225	8.9	0.89	27	159	6	-132	0	7.6	NAF
80428	40866	DR324	405.0	405.5	0.5	Hanging wall slate (non sulphide)	176	8.4	0.94	29	158	5	-129	0	8.1	NAF
80427	40865	DR324	300.0	300.5	0.5	Hanging wall slate (Si Ab alt)	325	8.5	0.42	13	81	6	-68	0	7.8	NAF
80483	40921	DR406	481.0	481.5	0.5	Hanging wall slate (non sulphide)	242	7.8	1.99	61	9	0.1	52	43	2.4	PAF

TABLE 2: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80439	40877	DR339	248.0	248.5	0.5	Lode (mineralised waste)	145	8.2	2.05	63	237	4	-175	0	8.1	NAF
80478	40916	DR395	769.0	769.5	0.5	Lode (mineralised waste)	222	8.3	2.38	73	219	3	-146	0	7.8	NAF
80469	40907	DR379	631.0	631.5	0.5	Lode (mineralised waste)	312	8.1	13.94	427	398	0.9	28	0*	8.4	UC (NAF)
80489	40927	DR414	564.5	565.0	0.5	Lode (mineralised waste)	309	8.6	1.90	58	16	0.3	42	38	2.4	PAF
80429	40867	DR324	423.0	423.5	0.5	Lode (mineralised waste)	212	7.8	3.32	102	19	0.2	83	73	2.2	PAF
80484	40922	DR408	839.0	839.5	0.5	Lode (mineralised waste)	235	7.9	6.12	187	5	0.0	182	219*	2.0	PAF
80454	40892	DR356	181.0	181.5	0.5	Lode (mineralised waste)	186	7.4	10.46	320	34	0.1	286	348*	2.0	PAF
80450	40888	DR355	576.0	576.5	0.5	Lode (mineralised waste)	216	8.4	11.75	360	7	0.0	352	352*	2.0	PAF
80491	40929	DR417	58.0	58.5	0.5	Footwall slate	316	8.6	1.18	36	548	15	-512	0	7.7	NAF
80421	40859	DR315	284.0	284.5	0.5	Footwall slate	331	8.3	0.90	28	220	8	-193	0	7.8	NAF
80433	40871	DR331	197.0	197.5	0.5	Footwall slate	512	8.5	1.18	36	170	5	-134	0	8.3	NAF
80459	40897	DR364	278.0	278.5	0.5	Footwall slate	246	8.5	0.59	18	140	8	-122	0	7.8	NAF
80455	40893	DR356	215.0	215.5	0.5	Footwall slate	345	7.6	0.87	27	136	5	-109	0	7.8	NAF
80479	40917	DR395	932.0	932.5	0.5	Footwall slate	315	8.5	1.13	35	144	4	-109	0	7.6	NAF
80430	40868	DR324	456.0	456.5	0.5	Footwall slate	245	7.9	1.15	35	120	3	-84	0	9.3	NAF
80451	40889	DR355	636.0	636.5	0.5	Footwall slate	315	8.0	2.18	67	148	2.2	-82	0	7.5	NAF
80464	40902	DR373	638.0	638.5	0.5	Footwall slate	242	8.7	1.11	34	111	3	-77	0	8.9	NAF
80472	40910	DR388	478.0	478.5	0.5	Footwall slate	199	8.5	0.84	26	103	4	-77	0	7.6	NAF
80447	40885	DR346	449.0	449.5	0.5	Footwall slate	346	8.7	1.61	49	119	2.4	-70	0	7.6	NAF
80490	40928	DR414	599.5	600.0	0.5	Footwall slate	311	8.7	0.98	30	88	3	-58	0	7.8	NAF
80425	40863	DR322	288.0	288.5	0.5	Footwall slate	416	8.3	0.80	24	82	3	-57	0	7.9	NAF
80445	40883	DR345	351.0	351.5	0.5	Footwall slate	415	7.7	0.57	17	60	3	-42	0	7.8	NAF
80476	40914	DR393	698.0	698.5	0.5	Footwall slate	255	8.9	0.91	28	60	2.2	-32	0	7.6	NAF
80485	40923	DR408	889.0	889.5	0.5	Footwall slate	246	8.7	2.12	65	94	1.5	-30	0	7.5	NAF
80480	40918	DR405	212.0	212.5	0.5	Footwall slate	329	8.4	0.66	20	43	2.1	-23	0	7.9	NAF
80470	40908	DR379	671.0	671.5	0.5	Footwall slate	345	8.4	1.56	48	40	0.8	7	2	3.6	PAF
80438	40876	DR339	241.0	241.5	0.5	Footwall slate	117	8.9	1.66	51	11	0.2	40	37	2.4	PAF
80443	40881	DR343	521.0	521.5	0.5	Footwall slate	235	7.6	7.88	241	21	0.1	220	260*	2.0	PAF

TABLE 2: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80462	40900	DR368	245.0	245.5	0.5	Foot wall limestone	203	8.5	0.77	24	516	22	-492	0	8.2	NAF
80426	40864	DR322	310.0	310.5	0.5	Foot wall limestone	239	8.2	0.88	27	467	17	-440	0	8.5	NAF
80422	40860	DR315	304.0	304.5	0.5	Foot wall limestone	216	8.1	0.68	21	456	22	-435	0	8.3	NAF
80460	40898	DR364	306.0	306.5	0.5	Foot wall limestone	197	8.6	0.89	27	462	17	-435	0	7.9	NAF
80436	40874	DR337	401.0	401.5	0.5	Foot wall limestone	315	8.2	1.06	32	462	14	-429	0	8.9	NAF
80434	40872	DR331	240.0	240.5	0.5	Foot wall limestone	146	8.2	1.06	32	451	14	-418	0	9.6	NAF
80492	40930	DR417	123.0	123.5	0.5	Foot wall limestone	321	8.5	0.97	30	444	15	-414	0	7.2	NAF
80473	40911	DR388	513.0	513.5	0.5	Foot wall limestone	227	8.6	1.22	37	446	12	-409	0	7.7	NAF
80456	40894	DR356	261.0	261.5	0.5	Foot wall limestone	329	8.4	1.87	57	435	8	-377	0	7.9	NAF
80461	40899	DR366	178.0	178.5	0.5	Foot wall limestone	176	8.7	1.32	40	385	10	-345	0	7.6	NAF
80440	40878	DR339	271.0	271.5	0.5	Foot wall limestone	129	7.9	1.28	39	363	9	-323	0	8.0	NAF
80465	40903	DR373	671.0	671.5	0.5	Foot wall limestone	403	8.6	0.83	25	302	12	-276	0	8.2	NAF
80431	40869	DR324	485.0	485.5	0.5	Foot wall limestone	335	8.6	1.53	47	307	7	-260	0	8.2	NAF
80444	40882	DR343	544.0	544.5	0.5	Foot wall limestone	246	7.8	0.82	25	229	9	-204	0	7.7	NAF
80435	40873	DR336	382.0	382.5	0.5	Foot wall limestone	235	8.3	0.71	22	215	10	-194	0	8.1	NAF
80446	40884	DR345	364.0	364.5	0.5	Foot wall limestone	329	8.6	0.85	26	199	8	-173	0	7.9	NAF
80471	40909	DR379	715.0	715.5	0.5	Foot wall limestone	332	8.3	0.92	28	192	7	-163	0	8.0	NAF
80452	40890	DR355	660.0	660.5	0.5	Foot wall limestone	429	7.8	0.39	12	152	13	-140	0	7.6	NAF
80481	40919	DR405	234.0	234.5	0.5	Foot wall limestone	276	7.6	0.10	3	127	41	-123	0	7.2	NAF
80486	40924	DR412	36.0	36.5	0.5	Foot wall limestone	196	8.3	1.69	52	107	2.1	-55	0	7.6	NAF

KEY

Existing pH = pH of 1:2 extract
EC = Electrical Conductivity of 1:2 extract (µS/cm)
MPA = Maximum Potential Acidity (kg H_2SO_4/t)
ANC = Acid Neutralising Capacity (kg H_2SO_4/t)
NAPP = Net Acid Producing Potential (kg H_2SO_4/t)
NAG = Net Acid Generation capacity to pH 7.0 (kg H_2SO_4/t)
NAGpH = pH of NAG liquor
** note: NAG values with asterisk are from sequential NAG tests*
NAF = Non-Acid Forming
PAF = Potentially Acid Forming
UC = Uncertain Classification
(likely classification given in brackets)

TABLE 3: Speciation of sulphur forms in Dugald River waste rock

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Lithology	SESL Lab	ALS Lab				ARD Class
						Total-S (%S)	Total-S (%S)	Sulphate-S (%S)	Sulphide-S (%S)	Cr Reducible-S (%S)	
80429	40867	DR324	423.0	423.5	Lode (mineralised Waste)	3.32	3.95	0.05	3.90	3.41	PAF
80437	40875	DR339	188.0	188.5	Hanging Wall Slate	4.81	4.47	0.29	4.18	4.33	NAF
80438	40876	DR339	241.0	241.5	Footwall Slate	1.66	1.62	0.16	1.46	1.64	PAF
80443	40881	DR343	521.0	521.5	Footwall Slate	7.88	7.67	1.46	6.21	6.81	PAF
80447	40885	DR346	449.0	449.5	Footwall Slate	1.61	2.11	0.07	2.04	1.88	NAF
80450	40888	DR355	576.0	576.5	Lode (mineralised Waste)	11.75	11.5	1.64	9.86	8.94	PAF
80451	40889	DR355	636.0	636.5	Footwall Slate	2.18	2.13	0.17	1.96	1.76	NAF
80454	40892	DR356	181.0	181.5	Lode (mineralised Waste)	10.46	9.48	1.42	8.06	8.42	PAF
80469	40907	DR379	631.0	631.5	Lode (mineralised Waste)	13.94	21.1	0.28	20.82	19.7	UC (NAF)
80470	40908	DR379	671.0	671.5	Footwall Slate	1.56	1.55	0.12	1.43	1.32	PAF
80483	40921	DR406	481.0	481.5	Hanging Wall Slate	1.99	2.16	0.13	2.03	1.92	PAF
80484	40922	DR408	839.0	839.5	Lode (mineralised Waste)	6.12	6.55	2.31	4.24	5.97	PAF
80485	40923	DR408	889.0	889.5	Footwall Slate	2.12	1.86	0.09	1.77	1.88	NAF
80486	40924	DR412	36.0	36.5	Footwall Limestone	1.69	1.72	0.02	1.70	1.68	NAF
80489	40927	DR414	564.5	565.0	Lode (mineralised Waste)	1.90	2.03	0.22	1.81	1.64	PAF

KEY

Total-S: by Leco furnace
Sulphate-S: by HCl leach method
Sulphide-S: by difference of total-S and SO4-S
Cr-Reducible-S: by reaction with hot acidic CrCl2

NAF = Non-Acid Forming
PAF = Potentially Acid Forming
UC = Uncertain Classification
(likely classification given in brackets)

TABLE 4: Elemental composition of Dugald River waste rock

MMG Code		80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486
EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF
S	%	0.53	2.52	0.01	0.65	0.05	0.26	0.93	1.51	4.12	2.32	8.22	0.94	1.34	1.48	2.04
Al	%	6.16	5.34	7.12	7.41	11.05	8.69	6.3	7.61	4.33	6.58	5.65	5.46	7.17	3.19	5.66
Ca	%	3.59	9.09	2.29	2.09	0.35	0.25	4.48	0.39	9.01	9.21	0.14	4.86	0.82	10.55	3.52
Fe	%	3.84	5.63	10.15	6.05	4.85	0.86	2.41	3	8.07	5.36	7.26	2.68	2.31	1.85	3.52
K	%	2.64	4.16	2.39	1.41	4.09	4.34	4.75	5.02	2.86	5.4	4.49	3.93	4.93	1.12	2.26
Mg	%	0.96	1.14	2.48	4.38	1.28	0.61	2.08	0.78	4.14	0.98	0.35	1.19	0.96	4.84	3.11
Na	%	0.57	0.19	2.79	2.28	0.34	0.25	0.2	0.59	0.17	0.28	0.13	0.28	0.79	0.77	0.3
Ti	%	0.332	0.222	0.747	0.295	0.54	0.356	0.198	0.243	0.11	0.313	0.124	0.232	0.155	0.078	0.169
As	mg/kg	1.3	0.4	1.5	4.9	3.7	0.7	234	72.3	11	572	167.5	80.2	683	19	1.2
Ba	mg/kg	510	840	370	180	850	1030	500	1300	480	350	80	750	1110	540	360
Be	mg/kg	2.5	1.1	1.06	4.26	2.44	5.43	1.77	1.84	1.38	4.23	1.66	1.91	2.79	1.04	2.23
Bi	mg/kg	0.22	0.08	0.08	0.06	0.1	0.24	0.33	0.55	0.88	0.08	3.55	0.61	0.26	0.29	0.32
Cd	mg/kg	0.17	0.02	0.02	0.02	0.08	0.02	0.19	0.13	0.06	0.24	62.4	0.68	0.08	1.74	0.08
Co	mg/kg	14.2	17	21.2	23.8	14	3.3	6.9	11.1	8.5	12	44.4	12.5	12.8	6.1	25.5
Cr	mg/kg	47	37	17	51	77	57	37	78	35	49	44	38	49	20	36
Cu	mg/kg	159	2	9.1	4.2	25.3	8.5	24.1	44.8	324	25.8	39.9	52.4	33.4	13.2	162.5
Ga	mg/kg	19.2	15	21.6	24.1	29.3	27.9	17.9	21.2	11.9	14.85	15.05	15.95	21.8	8.36	16.5
Hg	mg/kg	0.005	0.005	0.005	0.017	0.005	0.005	0.018	0.012	0.009	0.005	1.055	0.009	0.006	0.072	0.005
In	mg/kg	0.079	0.041	0.063	0.025	0.077	0.061	0.026	0.02	0.006	0.012	0.144	0.053	0.01	0.042	0.012
La	mg/kg	84	31.4	42	132	46.9	66.6	45.5	68.5	23.7	34.4	19.9	31	81.2	27.1	81.8
Li	mg/kg	31.8	25.7	40.8	43.1	42.2	57.1	31.3	21.2	32.8	51.3	34.4	64.8	46.8	62.1	54.2
Mn	mg/kg	989	2100	824	1450	875	289	3380	336	5190	13600	1060	1560	1780	649	1020
Mo	mg/kg	1.26	3.52	0.84	0.4	0.54	0.59	7.7	4.67	8.92	5.48	8.4	4.11	8.5	4.07	3.22
Nb	mg/kg	11.8	7.1	6.6	10.9	17.4	7.7	7.3	7	3.9	10.2	3.1	9	5.7	2.1	4.3
Ni	mg/kg	21.4	22.6	35.5	31.7	40.7	27.8	17.7	43.1	82.9	32.3	30.3	21.6	25.3	14.8	36.9
P	mg/kg	790	470	680	650	850	650	830	620	740	1490	620	1150	1020	370	1020
Pb	mg/kg	4.8	5.1	0.7	3.2	5.7	5.8	22.4	39.6	17.6	51.7	433	23.5	73.4	73.3	6.7
Sb	mg/kg	0.52	0.53	0.74	0.46	0.27	0.6	3.48	2.4	1.04	0.42	8.69	0.51	0.26	1.62	0.79
Se	mg/kg	2	2	3	2	2	2	2	4	5	3	5	2	2	1	2
Sn	mg/kg	3.8	2.8	3.7	7.1	3.5	4.7	1.6	1.3	1.3	0.8	1.7	4.7	1.6	1.2	0.6
Sr	mg/kg	119.5	132.5	87.3	36.5	31.1	46.8	77.4	123	44.6	1405	48	156.5	108.5	236	34.4
Th	mg/kg	19.4	11.7	2.2	16.1	20.7	19.1	13.4	18.8	8.2	9.4	13.1	12.4	19.5	7.1	12.7
U	mg/kg	4.7	6.9	0.6	6.2	5.1	19	7	12.5	8.9	15.2	8.6	5.9	11.1	4.3	6.4
V	mg/kg	80	84	309	88	104	82	90	117	79	103	77	57	84	35	62
Zn	mg/kg	125	39	28	27	61	23	149	87	31	165	4.14%	463	38	520	17

* Underlined values indicate concentration below the analytical detection limit.

TABLE 5: Geochemical abundance indices for Dugald River waste rock

MMG Code	80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486	Median Soil Content
EGi Code	40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924	
Lithology	Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone	
Parameter	NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	
S	2	4	0	2	0	1	3	3	5	4	6	3	3	3	4	0.07 %
Al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1 %
Ca	0	2	0	0	0	0	0	0	2	2	0	1	0	2	0	1.5 %
Fe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4 %
K	0	0	0	0	0	1	1	1	0	1	1	0	1	0	0	1.4 %
Mg	0	0	1	2	0	0	1	0	2	0	0	0	0	2	2	0.5 %
Na	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0.5 %
Ti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5 %
As	0	0	0	0	0	0	4	3	0	5	4	3	6	1	0	6 mg/kg
Ba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500 mg/kg
Be	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6 mg/kg
Bi	0	0	0	0	0	0	0	0	1	0	3	1	0	0	0	0.2 mg/kg
Cd	0	0	0	0	0	0	0	0	0	0	6	0	0	1	0	0.4 mg/kg
Co	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	8 mg/kg
Cr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70 mg/kg
Cu	1	0	0	0	0	0	0	0	2	0	0	0	0	0	1	30 mg/kg
Ga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20 mg/kg
Hg	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0.06 mg/kg
In	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 mg/kg
La	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	40 mg/kg
Li	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25 mg/kg
Mn	0	0	0	0	0	0	1	0	1	3	0	0	0	0	0	1000 mg/kg
Mo	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	2 mg/kg
Nb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10 mg/kg
Ni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50 mg/kg
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	800 mg/kg
Pb	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	35 mg/kg
Sb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5 mg/kg
Se	1	1	2	1	1	1	1	2	3	2	3	1	1	0	1	0.4 mg/kg
Sn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4 mg/kg
Sr	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	250 mg/kg
Th	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9 mg/kg
U	0	1	0	1	0	2	1	2	1	2	1	0	1	0	1	2 mg/kg
V	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	90 mg/kg
Zn	0	0	0	0	0	0	0	0	0	0	6	1	0	1	0	90 mg/kg

Median soil data from:

Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, London.

Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Vic.

* Geochemical Abundance Indices (GAI)

GAI=0 represents <3 times median soil content

GAI=1 represents 3 to 6 times

GAI=2 represents 6 to 12 times

GAI=3 represents 12 to 24 times

GAI=4 represents 24 to 48 times

GAI=5 represents 48 to 96 times

GAI=6 represents more than 96 times

TABLE 6: Water extractable elements in Dugald River waste rock

MMG Code		80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486	
EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924	
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412	
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0	
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5	Blank
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone	
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	
pH		7.7	8.5	7.4	8.4	8.3	8.1	7.9	7.9	7.8	8.4	8.2	8.5	8.3	8.2	8.2	5.9
EC	µS/cm	81	145	213	146	95	86	83	142	107	167	123	115	111	92	107	1
Ag	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Al	mg/L	0.2	0.1	0.3	0.5	0.4	0.6	0.3	0.04	0.2	0.2	0.02	0.3	0.3	0.2	0.2	<0.01
As	mg/L	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	0.006	<0.001	0.002	0.02	<0.001	0.003	0.01	0.002	0.002	<0.001
B	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ba	mg/L	0.003	0.007	0.02	0.002	0.04	0.005	0.02	0.03	0.008	0.3	0.02	0.03	0.02	0.04	0.02	0.002
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ca	mg/L	48	221	5	6	4	5	8	22	6	9	<1	6	5	6	11	<1
Cd	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cl	mg/L	1	2	1	2	2	<1	2	2	2	2	2	1	2	2	2	1
Co	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	mg/L	0.001	0.002	<0.001	0.003	0.002	0.002	0.002	0.001	<0.001	0.003	0.002	0.002	0.003	0.002	0.001	0.004
F	mg/L	<0.1	<0.1	<0.1	0.1	<0.1	0.2	<0.1	<0.1	0.1	0.2	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Fe	mg/L	<0.05	0.1	<0.05	0.3	0.1	0.06	<0.05	<0.05	<0.05	<0.05	0.3	<0.05	<0.05	<0.05	<0.05	<0.05
Hg	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/L	3	2	4	1	3	3	3	3	3	1	<1	2	2	2	3	<1
Mg	mg/L	<1	<1	<1	2	<1	<1	2	2	<1	<1	<1	<1	<1	2	1	<1
Mn	mg/L	0.007	0.04	0.002	0.02	0.02	0.01	0.02	0.2	0.01	0.04	0.03	0.006	0.01	0.002	0.005	<0.001
Mo	mg/L	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Na	mg/L	2	<1	<1	1	1	<1	1	1	2	<1	<1	2	2	1	2	<1
Ni	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001
P	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001
Sb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.002	<0.001	0.001	<0.001	<0.001	0.003	<0.001	<0.001
Se	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Si	mg/L	0.8	0.4	0.9	0.7	1.0	1.2	0.8	0.4	0.9	0.6	0.2	1.2	1.0	0.8	1.2	<0.05
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/L	113	549	<1	4	<1	2	11	49	5	6	5	2	4	3	20	<1
Sr	mg/L	0.2	0.4	0.008	0.006	0.02	0.007	0.03	0.1	0.02	0.09	0.004	0.04	0.01	0.06	0.02	<0.001
Th	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	mg/L	<0.005	<0.005	<0.005	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.4	<0.005	0.009	<0.005	<0.005	<0.005

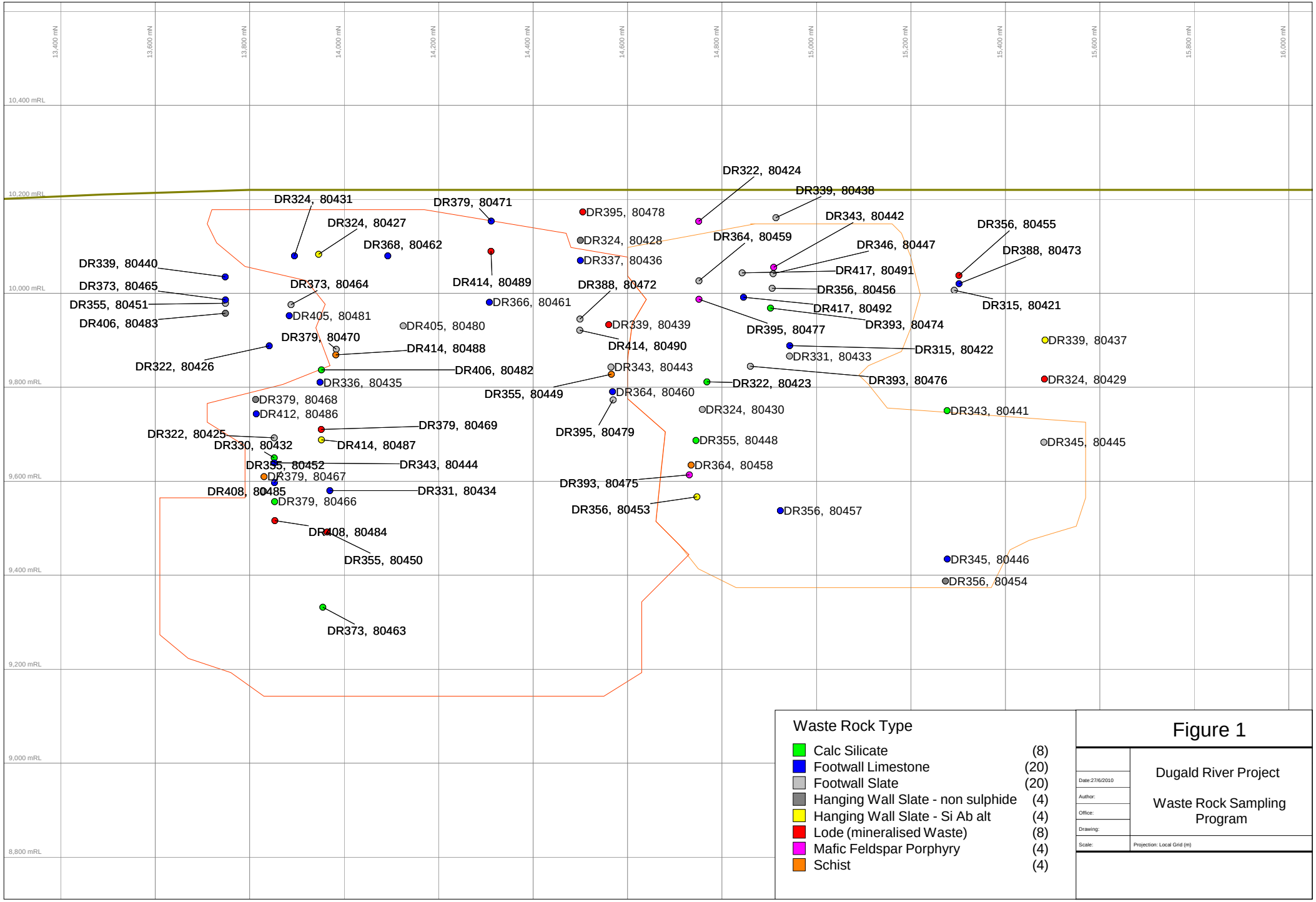
TABLE 7: Acid extractable elements in Dugald River waste rock

MMG Code		80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486	
EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924	
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412	
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0	
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5	Blank
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone	
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	
pH		1.5	5.4	1.8	1.9	1.4	1.6	1.9	1.5	3.3	5.3	1.5	2.1	1.7	5.3	1.6	1.61
EC	µS/cm	18,110	2,410	10,510	11,550	21,020	21,280	9,230	20,620	3,220	2,680	22,210	5,520	21,210	3,510	13,390	23,110
Ag	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Al	mg/L	22	0.6	20	13	10	11	2	8	3	0.5	3	8	11	0.3	8	0.05
As	mg/L	0.008	0.001	0.02	0.01	0.02	0.007	0.03	0.06	0.01	0.03	0.006	0.01	0.04	0.003	0.007	0.01
B	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ba	mg/L	0.05	0.02	0.14	0.05	0.03	0.06	0.02	0.03	0.07	0.04	0.02	0.05	0.03	0.07	0.03	0.001
Be	mg/L	0.005	0.001	0.001	0.008	0.002	0.01	0.001	0.004	0.005	0.002	<0.001	0.008	0.004	<0.001	0.009	<0.001
Ca	mg/L	393	639	874	709	96	84	759	164	653	652	20	707	96	724	782	<1
Cd	mg/L	<0.0001	<0.0001	0.0001	<0.0001	0.0004	<0.0001	0.0002	0.0003	0.0001	0.0003	0.005	0.0004	0.0002	0.0004	0.0003	<0.0001
Cl	mg/L	<1	1	2	3	<1	<1	<1	<1	2	4	<1	1	<1	2	<1	<1
Co	mg/L	0.007	0.004	0.02	0.01	0.02	0.004	0.006	0.03	0.004	0.004	<0.001	0.007	0.004	0.003	0.03	<0.001
Cr	mg/L	0.04	0.002	0.01	0.03	0.02	0.02	0.01	0.08	0.03	0.004	0.004	0.03	0.04	0.003	0.03	0.005
Cu	mg/L	0.04	0.004	0.01	0.08	0.03	0.01	0.01	0.03	0.007	0.002	0.002	0.03	0.02	0.03	0.09	0.01
F	mg/L	1.2	0.3	0.8	0.5	3.7	<5.9	0.4	1.8	0.8	0.9	0.7	1.0	3.3	0.3	0.9	<0.1
Fe	mg/L	23	4	39	59	21	11	60	25	23	11	17	19	15	14	28	1
Hg	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/L	8	2	32	9	7	10	5	6	7	2	1	11	7	5	13	<1
Mg	mg/L	10	6	32	261	7	6	260	11	113	17	2	15	6	225	109	<1
Mn	mg/L	4	31	11	20	1	1	58	4	40	137	3	34	2	6	17	0.001
Mo	mg/L	0.003	0.003	<0.001	0.001	<0.001	<0.001	0.002	0.005	0.003	0.003	<0.001	0.002	0.003	<0.001	0.003	<0.001
Na	mg/L	14	1	2	2	2	<1	1	2	2	1	<1	4	3	1	2	<1
Ni	mg/L	0.01	0.002	0.03	0.02	0.02	0.03	0.01	0.1	0.02	0.009	0.01	0.02	0.02	0.01	0.06	<0.001
P	mg/L	16	<1	27	9	27	20	4	11	8	<1	3	12	23	<1	18	<1
Pb	mg/L	0.01	<0.001	0.005	0.02	0.06	0.04	0.05	0.1	0.05	0.004	0.3	0.04	0.4	0.03	0.03	0.001
Sb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.003	0.002	<0.001	0.002	<0.001	<0.001	0.007	<0.001	<0.001
Se	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Si	mg/L	16	2	27	12	13	12	2	8	3	1	2	8	12	1	10	<0.50
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/L	4880	2640	3870	4400	4830	4770	4270	4950	2420	3120	4770	2600	4930	2610	4370	4870
Sr	mg/L	0.3	0.5	0.4	0.08	0.09	0.05	0.3	0.3	0.2	3.2	0.07	0.4	0.07	1.2	0.3	<0.001
Th	mg/L	0.05	<0.001	0.002	0.04	0.03	0.06	0.02	0.03	0.004	<0.001	0.006	0.02	0.13	<0.001	0.009	<0.001
U	mg/L	0.009	0.004	<0.001	0.01	0.02	0.05	0.004	0.02	0.008	0.001	0.003	0.007	0.05	0.001	0.04	<0.001
Zn	mg/L	0.05	0.03	0.09	0.1	0.2	0.09	0.2	0.2	0.09	0.07	5.8	0.3	0.2	0.2	0.1	<0.005

TABLE 8: Peroxide extractable elements in Dugald River waste rock

MMG Code		80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486
EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF
NAGpH		8.5	9.2	8.5	8.8	6.2	3.5	8.2	2.4	8.3	7.9	2.3	8.9	2.4	8.7	7.6
Ag	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
Al	mg/L	1.31	1.48	1.84	0.11	0.53	6.91	0.15	6.29	0.07	0.31	5.87	0.44	11.4	0.04	0.92
As	mg/L	0.004	<0.001	0.004	<0.001	0.006	<0.001	<0.001	0.016	<0.001	0.001	0.02	0.001	0.146	<0.001	0.002
B	mg/L	0.06	0.06	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.3	<0.05
Ba	mg/L	0.007	0.01	0.011	0.017	0.063	0.152	0.042	0.138	0.037	0.055	0.101	0.081	0.188	0.108	0.063
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.002	<0.001	<0.001	0.001	<0.001	0.004	<0.001	<0.001
Ca	mg/L	63	384	6	40	12	26	94	45	271	101	3	78	31	70	132
Cd	mg/L	0.0107	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0014	<0.0001	<0.0001	0.675	<0.0001	0.0013	<0.0001	<0.0001
Cl	mg/L	<1	<1	<1	1	<1	<1	<1	<1	3	<1	<1	<1	<1	<1	<1
Co	mg/L	0.005	<0.001	0.003	<0.001	0.001	0.038	<0.001	0.166	<0.001	<0.001	0.308	<0.001	0.164	<0.001	0.003
Cr	mg/L	0.005	0.004	0.002	0.007	0.004	0.008	0.002	0.008	<0.001	0.002	0.009	0.003	0.006	0.002	0.002
Cu	mg/L	0.018	0.002	0.019	0.006	0.008	0.118	0.002	0.632	0.003	0.003	0.546	0.002	0.523	0.002	0.019
F	mg/L	<0.1	0.2	<0.1	0.2	0.1	1.8	0.3	0.3	0.4	1	0.3	0.6	0.5	0.2	0.1
Fe	mg/L	5.41	0.09	0.86	0.12	0.72	0.21	0.11	52.6	0.06	0.1	184	<0.05	33.6	0.06	1.75
Hg	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/L	9	5	34	11	9	15	6	8	11	3	6	8	12	8	8
Mg	mg/L	<1	<1	<1	<1	2	2	4	5	8	<1	2	<1	5	2	1
Mn	mg/L	0.158	0.003	0.031	0.007	0.077	0.416	0.024	1.11	0.028	0.059	8.24	0.007	1.29	0.002	0.039
Mo	mg/L	0.008	0.057	<0.001	0.004	0.008	0.009	0.048	<0.001	0.041	0.015	0.001	0.042	<0.001	0.049	0.031
Na	mg/L	2	<1	1	2	<1	<1	<1	1	1	<1	<1	1	3	2	1
Ni	mg/L	0.005	<0.001	0.004	<0.001	0.001	0.339	<0.001	0.598	<0.001	<0.001	0.329	<0.001	0.274	<0.001	0.009
P	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pb	mg/L	0.048	<0.001	0.008	0.002	0.003	0.012	<0.001	0.179	<0.001	<0.001	2.56	<0.001	0.364	<0.001	0.005
Sb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.004	<0.001
Se	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	0.03	<0.01	<0.01	<0.01	<0.01
Si	mg/L	4.91	3.45	6.69	5.06	2.47	10.3	1.18	7.77	0.45	0.93	6.93	1.65	14.5	2.96	1.33
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/L	181	826	10	98	14	129	224	626	652	247	1720	190	540	178	321
Sr	mg/L	0.153	0.667	0.008	0.012	0.016	0.041	0.063	0.106	0.055	0.347	0.01	0.079	0.054	0.223	0.078
Th	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.021	<0.001	<0.001	0.013	<0.001	0.058	<0.001	<0.001
U	mg/L	<0.001	<0.001	0.002	<0.001	<0.001	0.019	<0.001	0.027	<0.001	<0.001	0.019	<0.001	0.099	<0.001	<0.001
Zn	mg/L	6.19	<0.005	0.024	0.01	0.028	0.164	0.016	0.928	0.005	0.018	364	<0.005	0.725	0.006	0.022

Figures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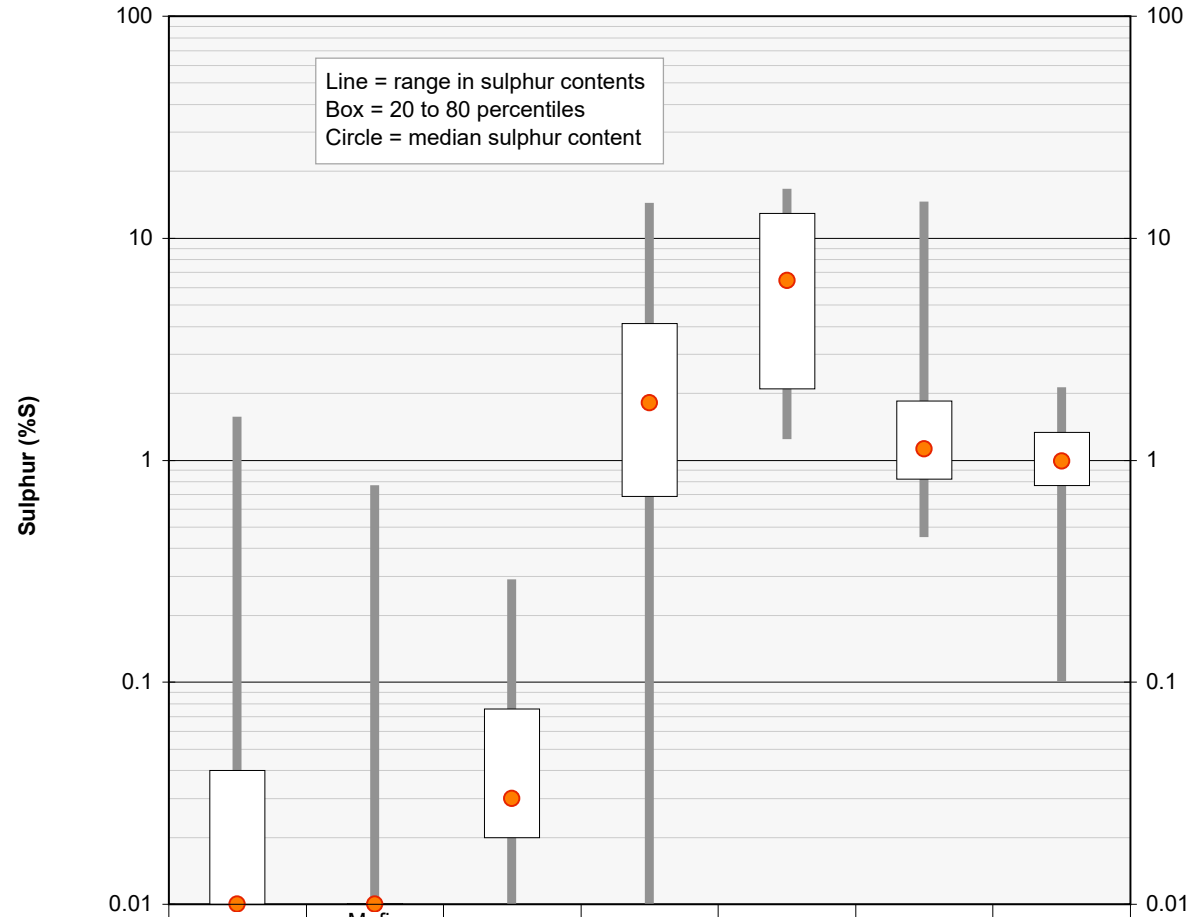
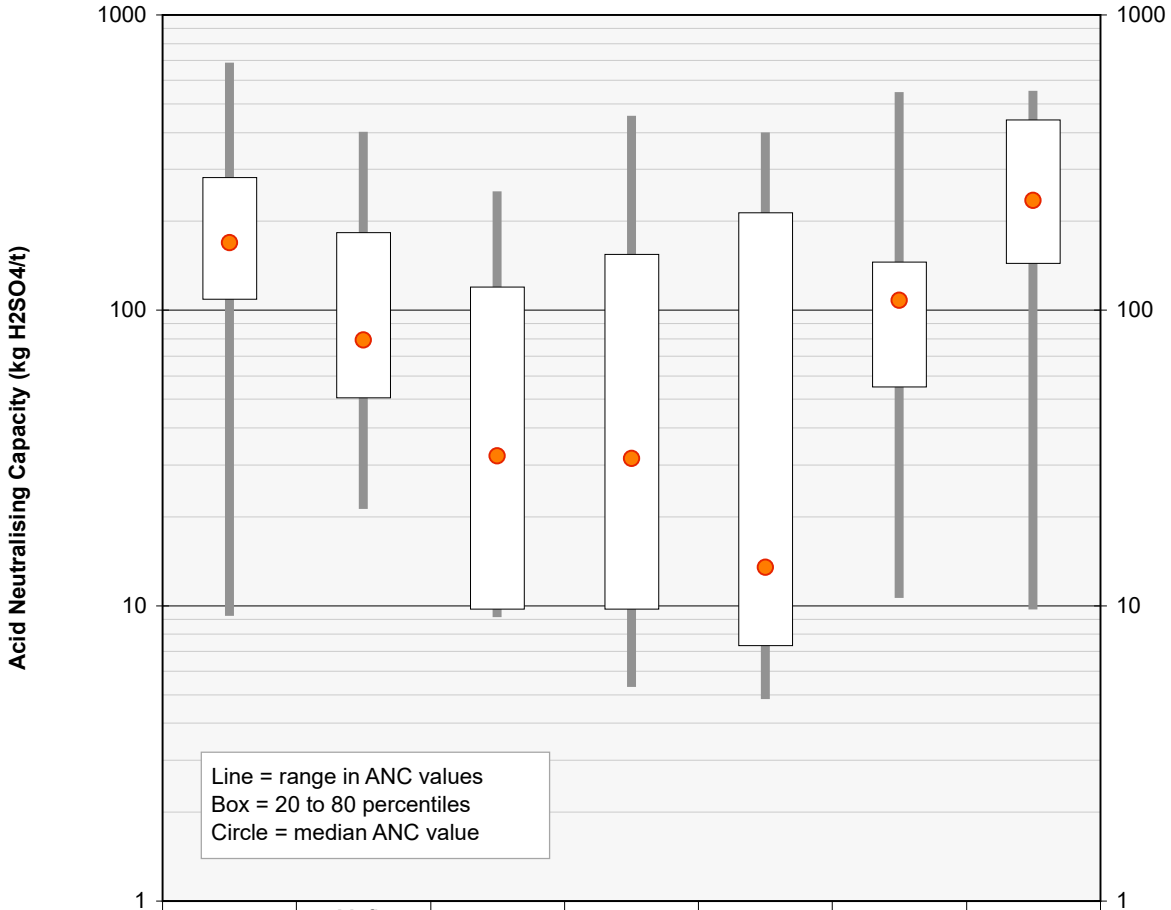
Waste Rock Type
Calc Silicate (8)
Footwall Limestone (20)
Footwall Slate (20)
Hanging Wall Slate - non sulphide (4)
Hanging Wall Slate - Si Ab alt (4)
Lode (mineralised Waste) (8)
Mafic Feldspar Porphyry (4)
Schist (4)
Figure 1
Dugald River Project
Waste Rock Sampling Program
Date:27/6/2010
Author:
Office:
Drawing:
Scale:
Projection: Local Grid (m)



	Calc-silicate	Mafic feldspar porphyry	White mica schist	Hanging wall slate	Lode (waste)	Footwall slate	Footwall limestone
80 percentile	0.04	0.01	0.08	4.13	12.92	1.84	1.34
maximum	1.57	0.77	0.29	14.4	16.6	14.6	2.12
minimum	0.01	0.01	0.01	0.01	1.24	0.45	0.1
20 percentile	0.01	0.01	0.02	0.69	2.10	0.82	0.77
median	0.01	0.01	0.03	1.82	6.44	1.12	0.99

FIGURE 2: Statistical summary of sulphur data for Dugald River waste rock

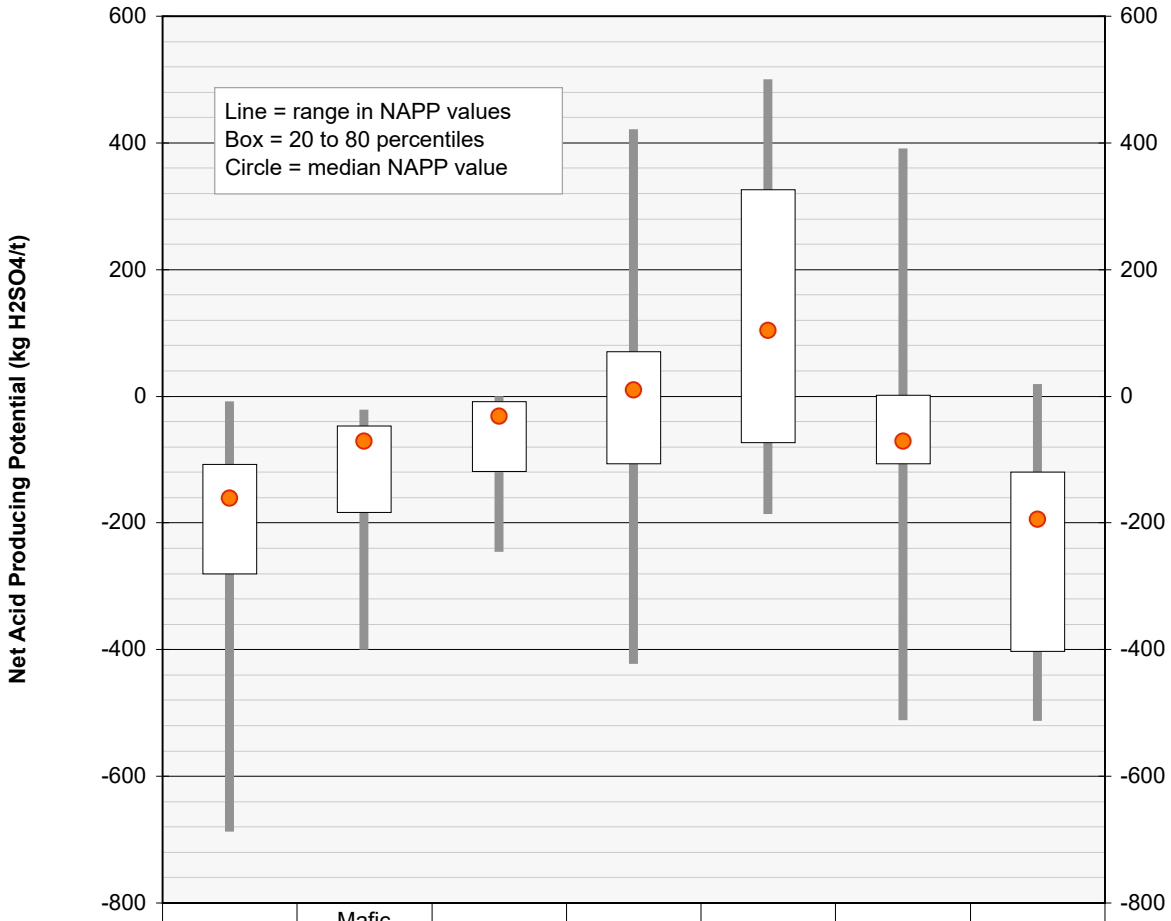
(compliation of results from all geochemical studies)



	Calc-silicate	Mafic feldspar porphyry	White mica schist	Hanging wall slate	Lode (waste)	Footwall slate	Footwall limestone
80 percentile	282	184	120	155	214	145	442
maximum	688	401	252	455	398	548	552
minimum	9	21	9	5	5	11	10
20 percentile	109	51	10	10	7	55	144
median	169	79	32	31	13	108	235

FIGURE 3: Statistical summary of ANC data for Dugald River waste rock

(compliation of results from all geochemical studies)



	Calc-silicate	Mafic feldspar porphyry	White mica schist	Hanging wall slate	Lode (waste)	Footwall slate	Footwall limestone
80 percentile	-108	-47	-9	71	326	2	-120
maximum	-9	-21	0	421	500	390	18
minimum	-688	-401	-246	-423	-187	-512	-513
20 percentile	-281	-183	-119	-107	-74	-106	-403
median	-161	-72	-31	10	104	-71	-195

FIGURE 4: Statistical summary of NAPP data for Dugald River waste rock

(compliation of results from all geochemical studies)

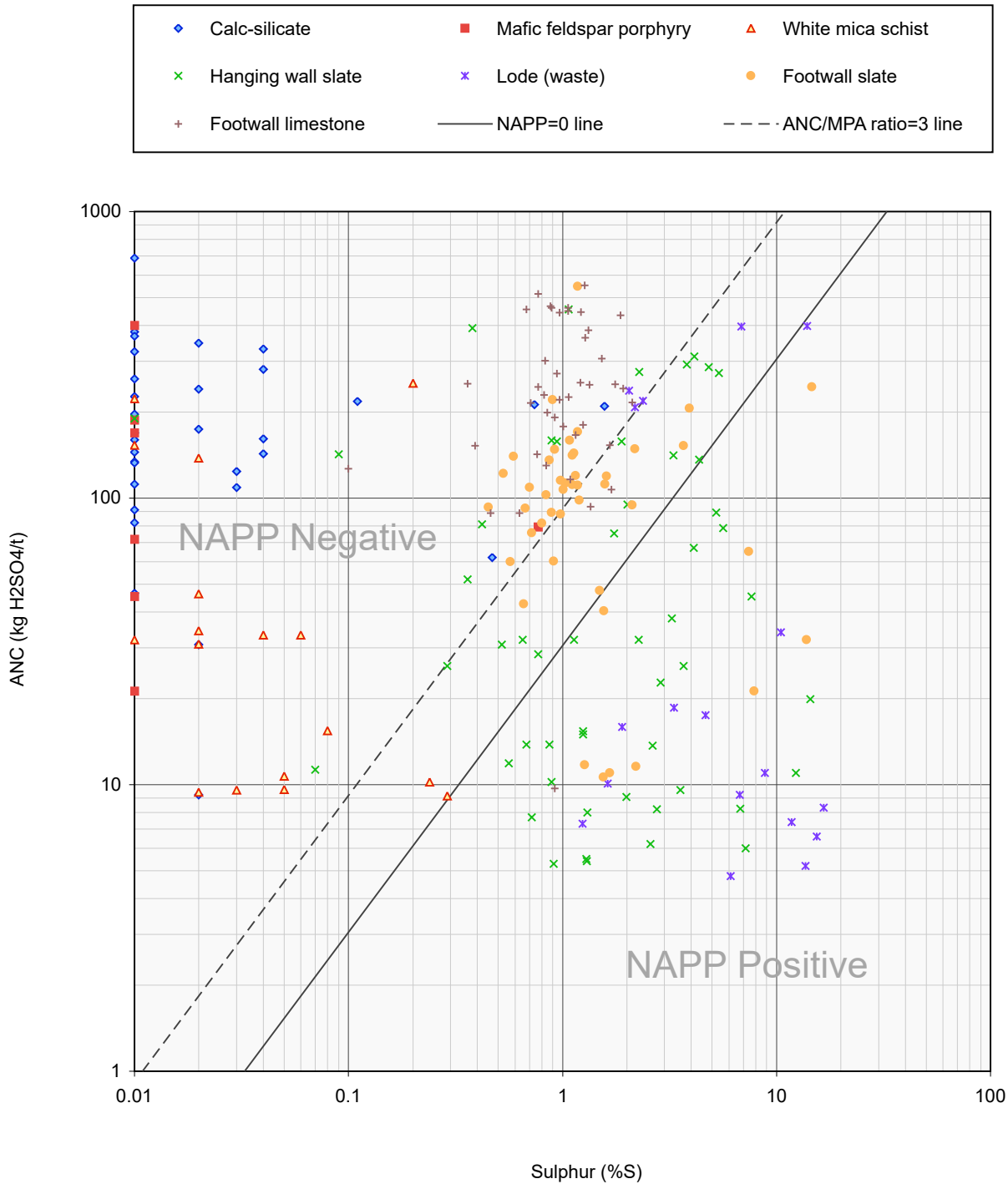


FIGURE 5: Acid-base account plot for Dugald River waste rock

(compliation of results from all geochemical studies)

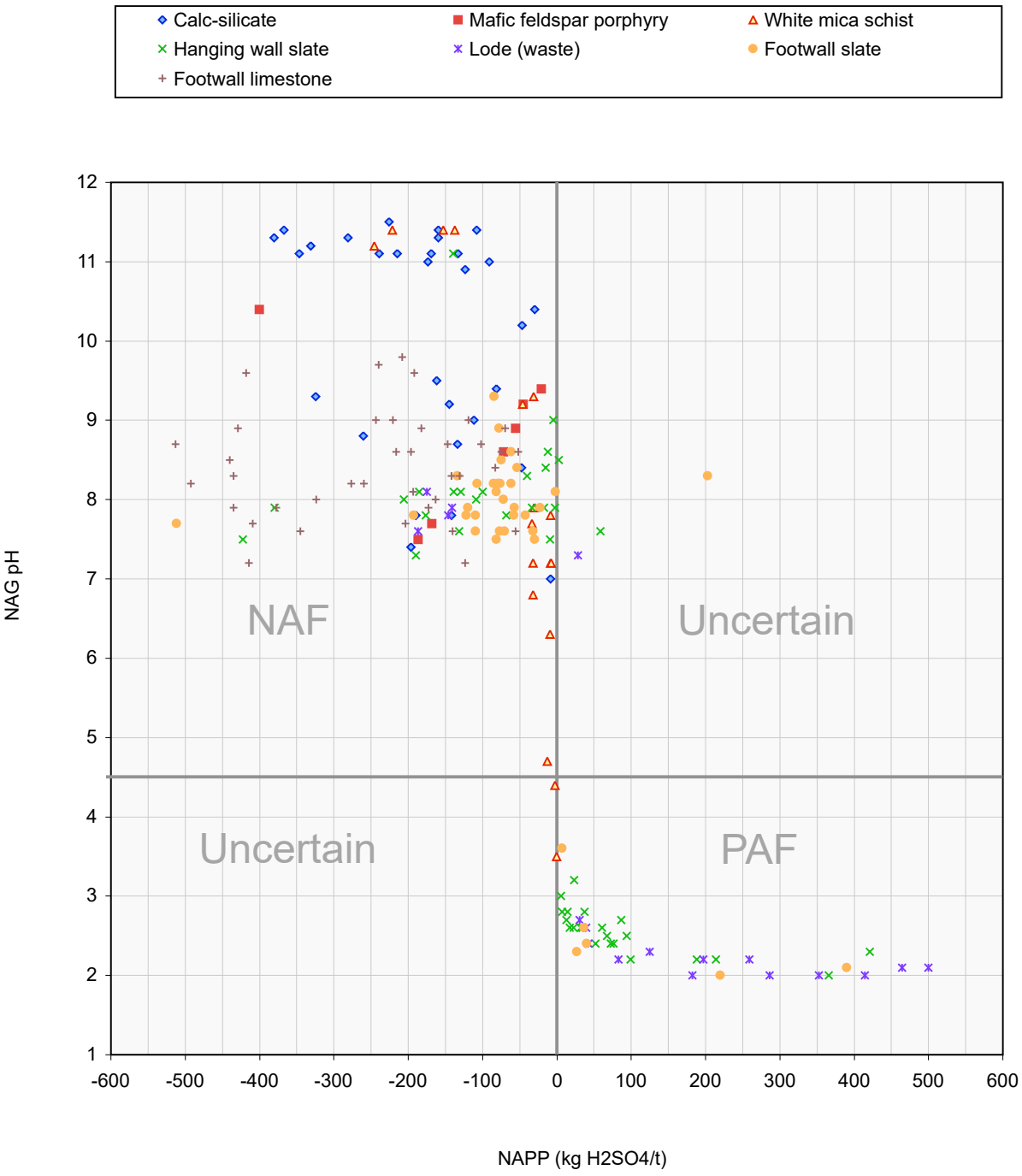
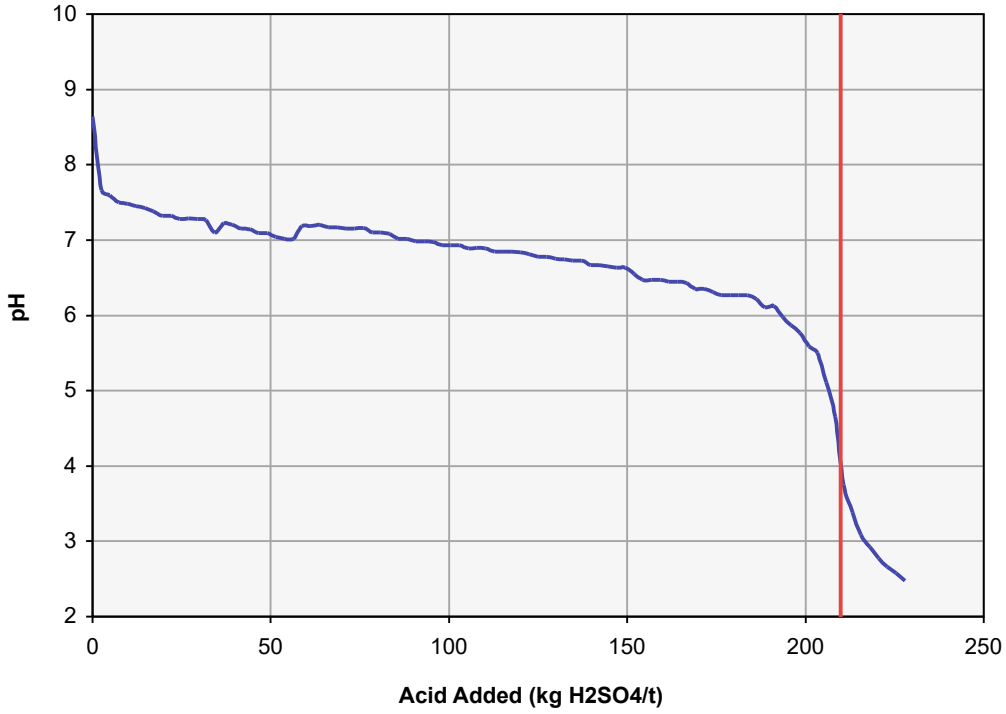


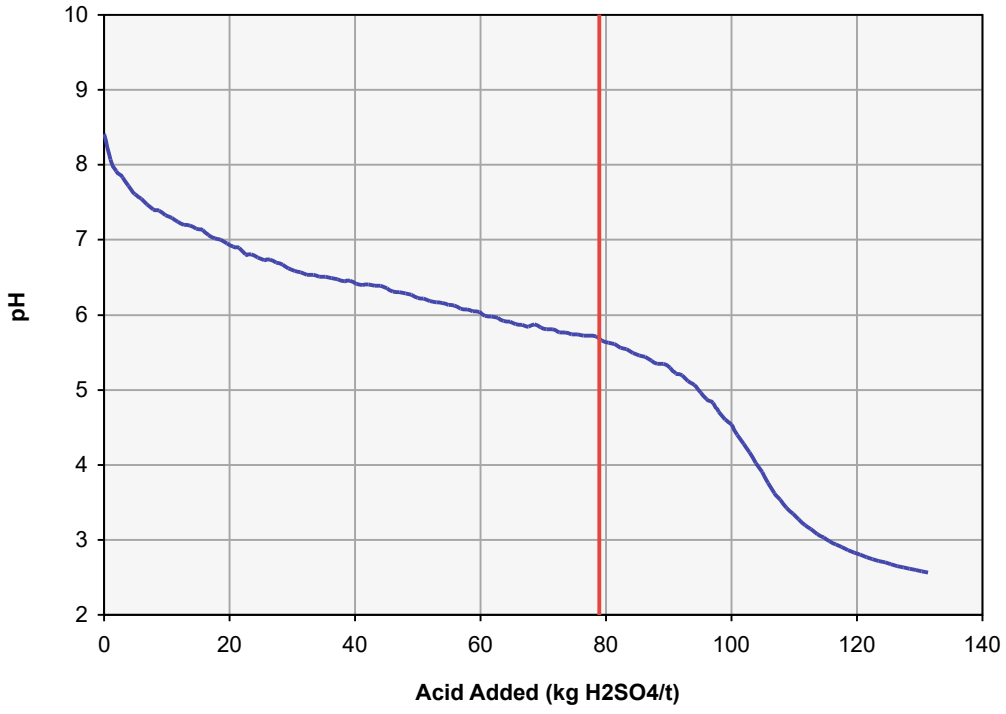
FIGURE 6: ARD classification plot for Dugald River waste rock

(compliation of results from all geochemical studies)



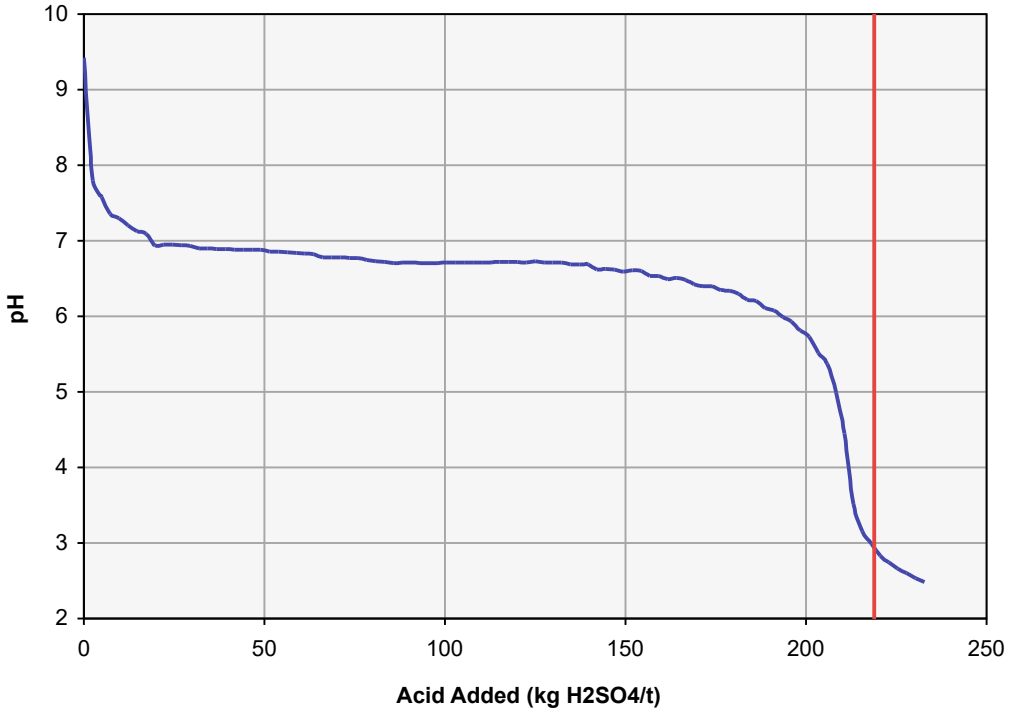
MMG / EGi Codes = 80448 / 40886	ANC = 210 kg H2SO4/t

FIGURE 7(a) - Acid buffer characteristic curve for Dugald River waste rock - Calc-silicate



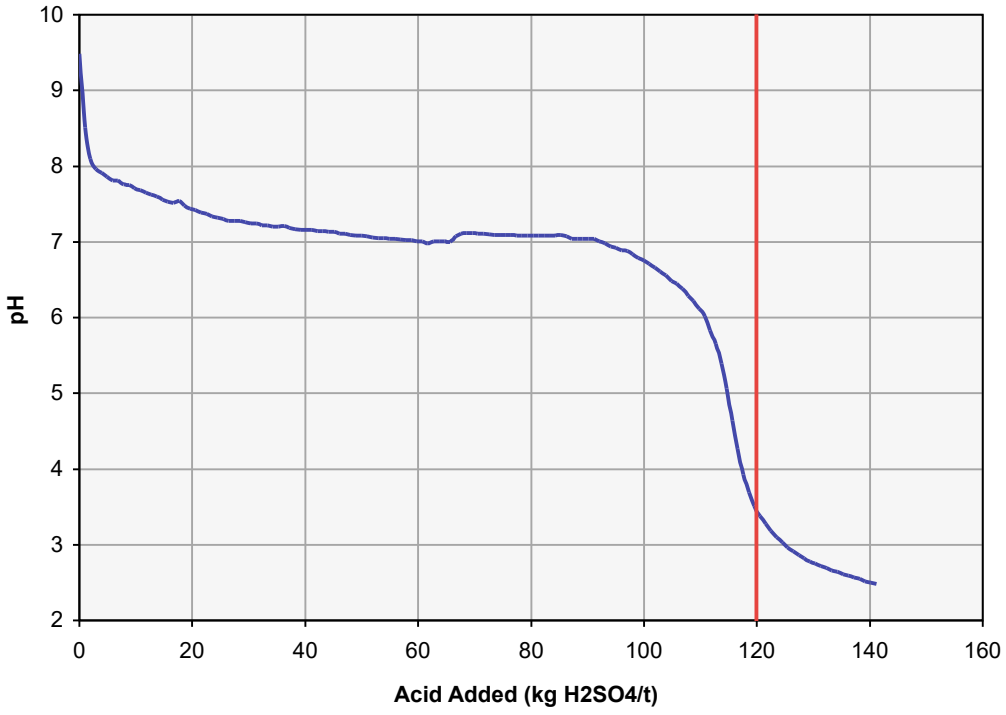
MMG / EGi Codes = 80424 / 40862	ANC = 79 kg H2SO4/t

FIGURE 7(b) - Acid buffer characteristic curve for Dugald River waste rock - Mafic feldspar porphyry



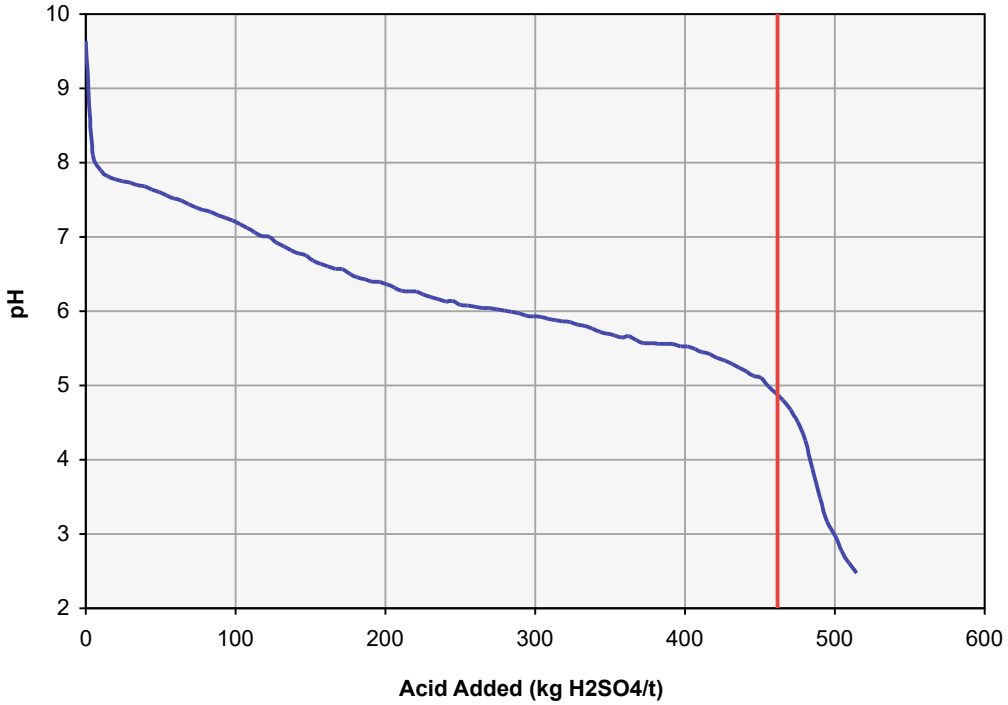
MMG / EGi Codes = 80478 / 40916	ANC = 219 kg H2SO4/t

FIGURE 7(c) - Acid buffer characteristic curve for Dugald River waste rock - Lode waste



MMG / EGi Codes = 80430 / 40868	ANC = 120 kg H2SO4/t

FIGURE 7(d) - Acid buffer characteristic curve for Dugald River waste rock - Foot wall slate



MMG / EGi Codes = 80436 / 40874	ANC = 462 kg H2SO4/t

FIGURE 7(e) - Acid buffer characteristic curve for Dugald River waste rock - Footwall limestone

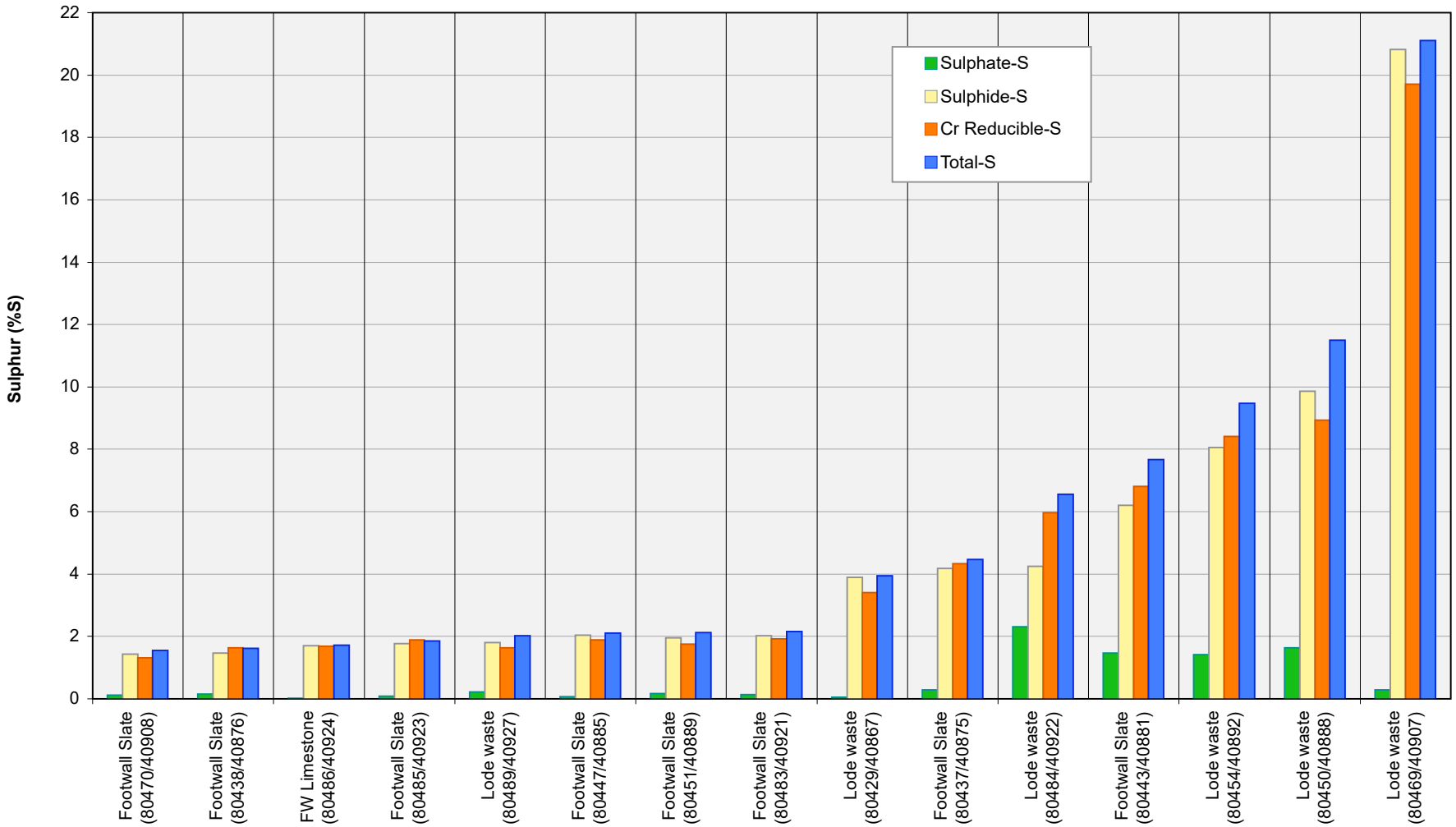
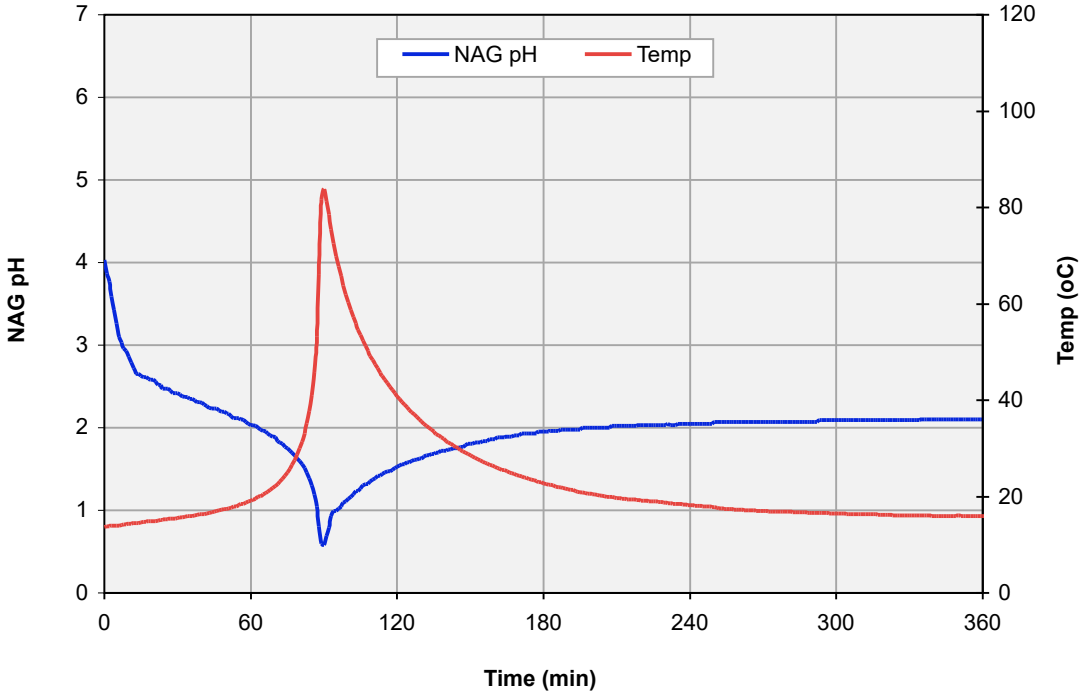
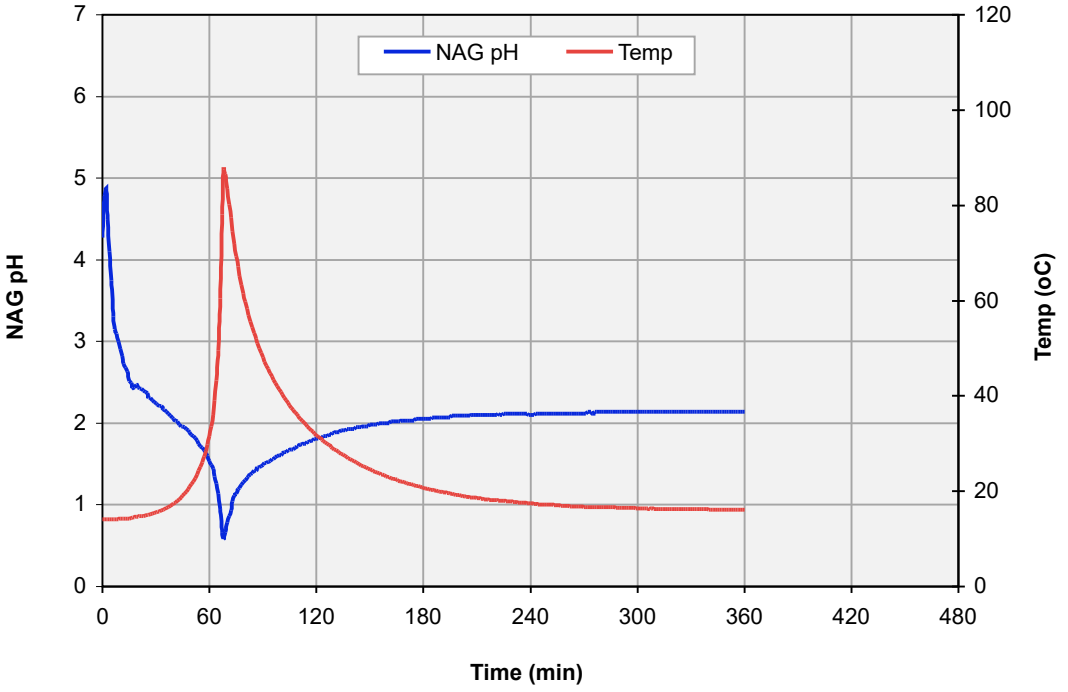


FIGURE 8: Sulphur speciation results for Dugald River waste rock



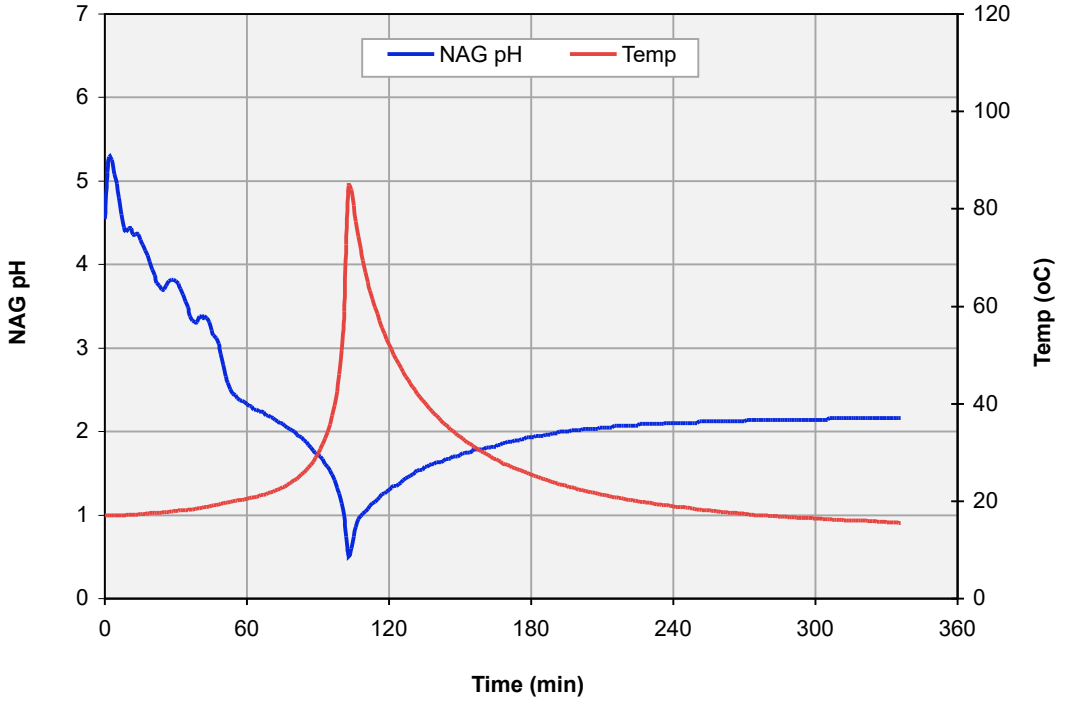
MMG Code = 80454 EGi Code = 40892
10.46%S, ANC = 34 kg H2SO4/t, NAPP = 286 kg H2SO4/t, NAGpH = 2.3

FIGURE 9(a): Kinetic NAG profiles for Dugald River waste rock - Lode waste



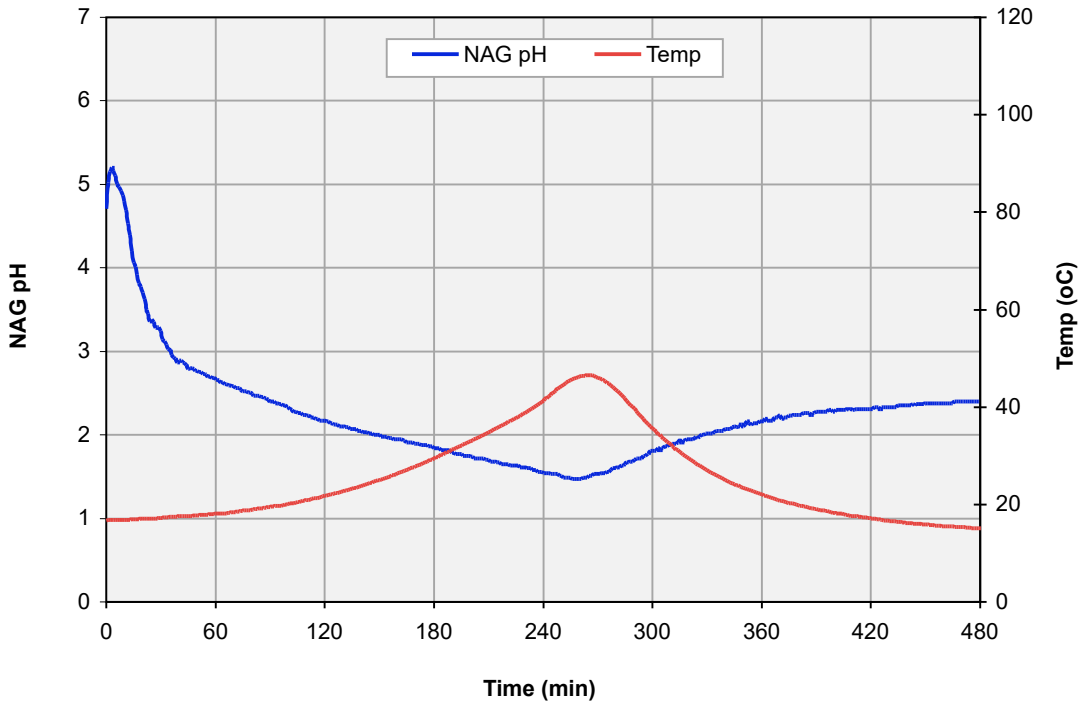
MMG Code = 80429 EGi Code = 40867
3.32%S, ANC = 19 kg H2SO4/t, NAPP = 83 kg H2SO4/t, NAGpH = 2.2

FIGURE 9(b): Kinetic NAG profiles for Dugald River waste rock - Lode waste



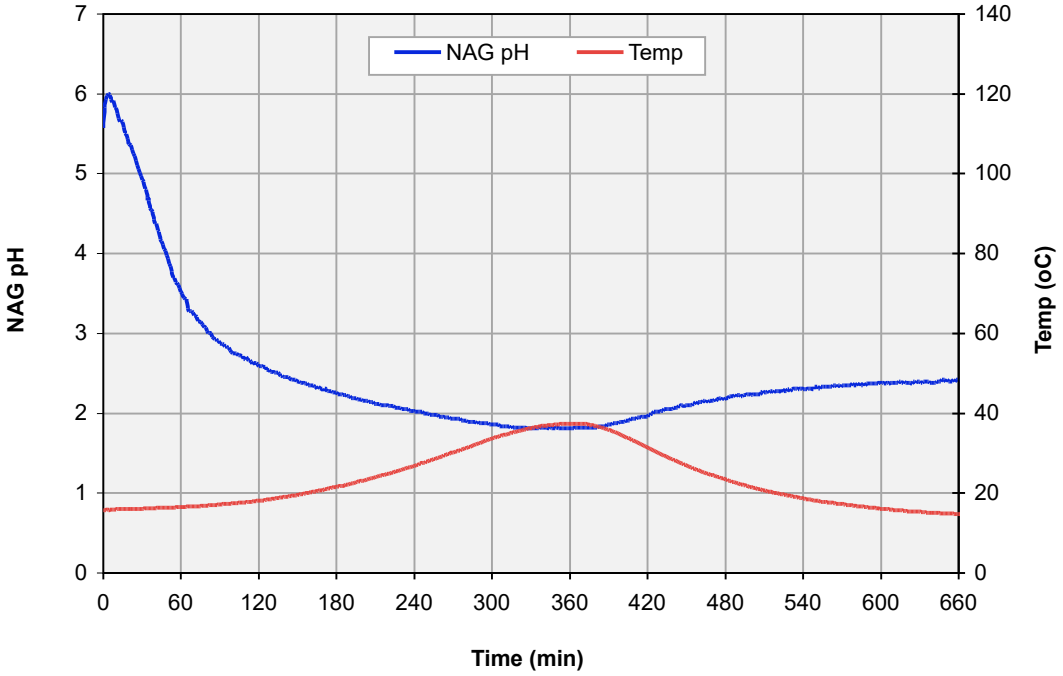
MMG Code = 80443 EGi Code = 40881
7.88%S, ANC = 21 kg H2SO4/t, NAPP = 220 kg H2SO4/t, NAGpH = 2.3

FIGURE 9(c): Kinetic NAG profiles for Dugald River waste rock - Foot wall slate



MMG Code = 80483 EGi Code = 40921
1.99%S, ANC = 9 kg H2SO4/t, NAPP = 52 kg H2SO4/t, NAGpH = 2.4

FIGURE 9(d): Kinetic NAG profiles for Dugald River waste rock - Hanging wall slate



MMG Code = 80438 EGi Code = 40876
1.66%S, ANC = 11 kg H2SO4/t, NAPP = 40 kg H2SO4/t, NAGpH = 2.4

FIGURE 9(e): Kinetic NAG profiles for Dugald River waste rock - Foot wall slate

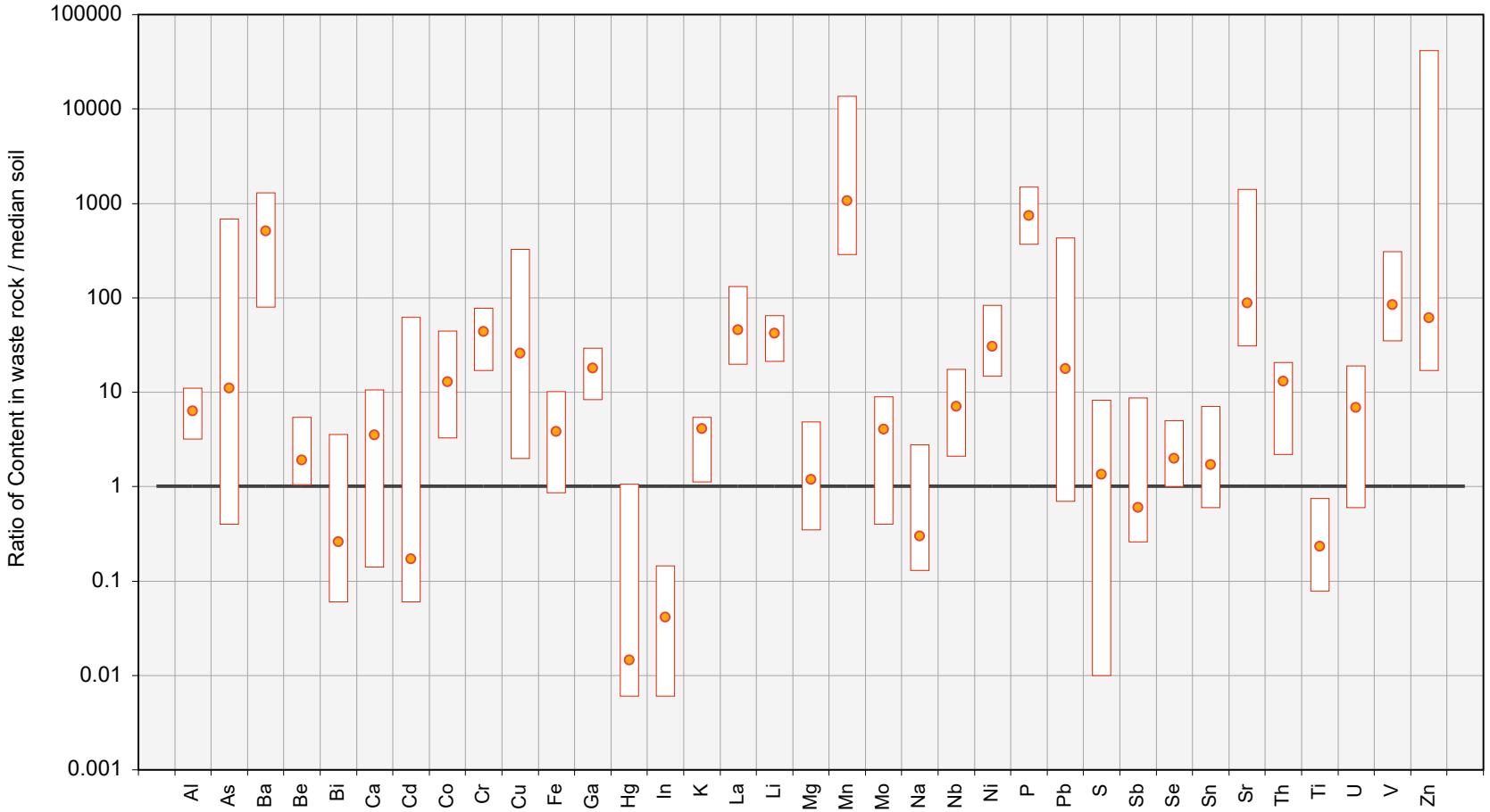


FIGURE 10: Box plot showing the ratios of element concentrations in Dugald River waste rock relative to median soil composition

(Bars = range in ratios Circles = median ratio)

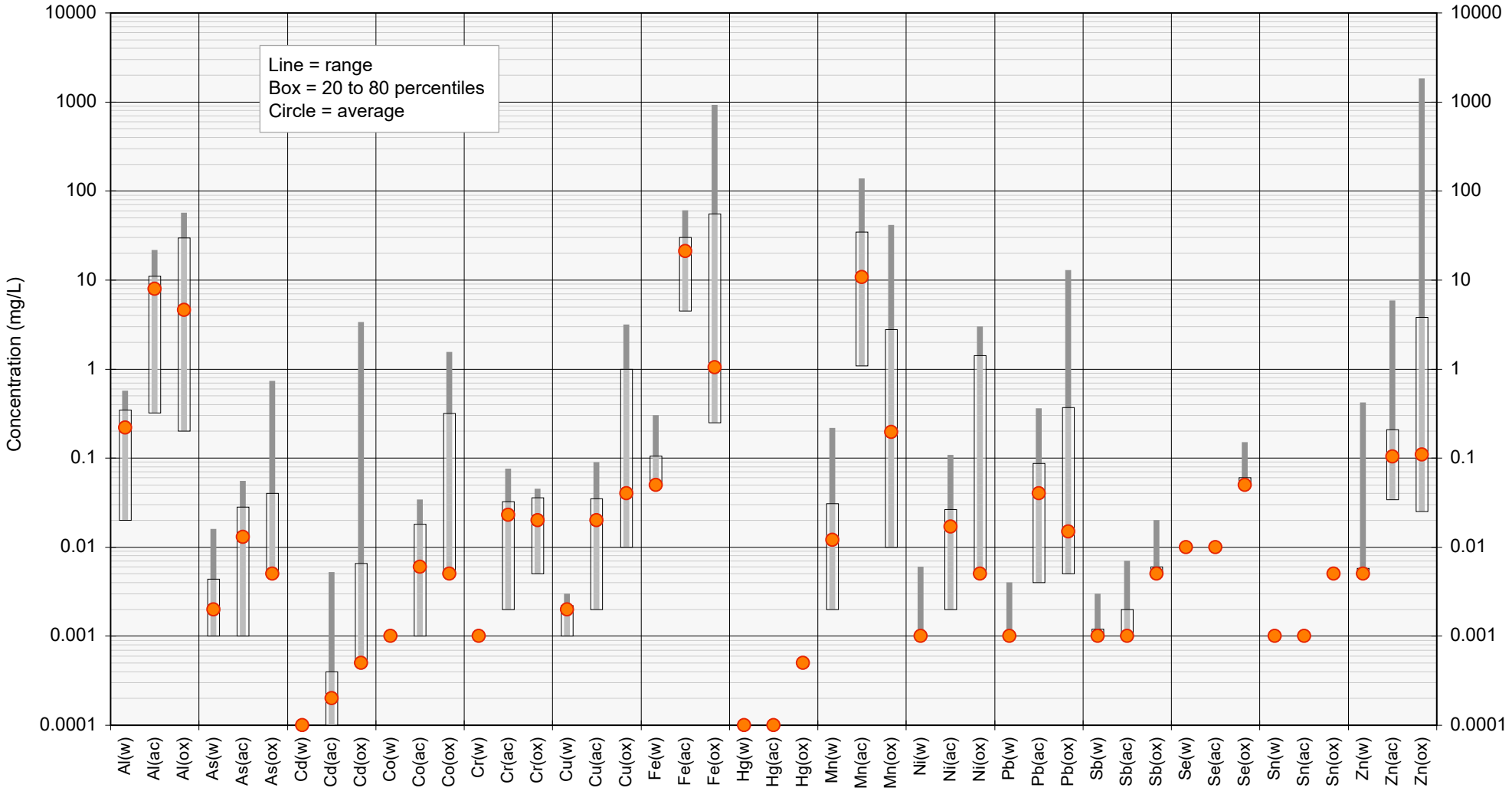


FIGURE 11: Statistical summary of extract assay data for water (w), acid (ac) and peroxide (ox) extraction tests fon Dugald River waste rock

(note: For comparison purposes the peroxide results were multiplied by a factor of 5 to simulate a solid:liquor ratio of 1:20 ratio as used in the water and acid extractions.

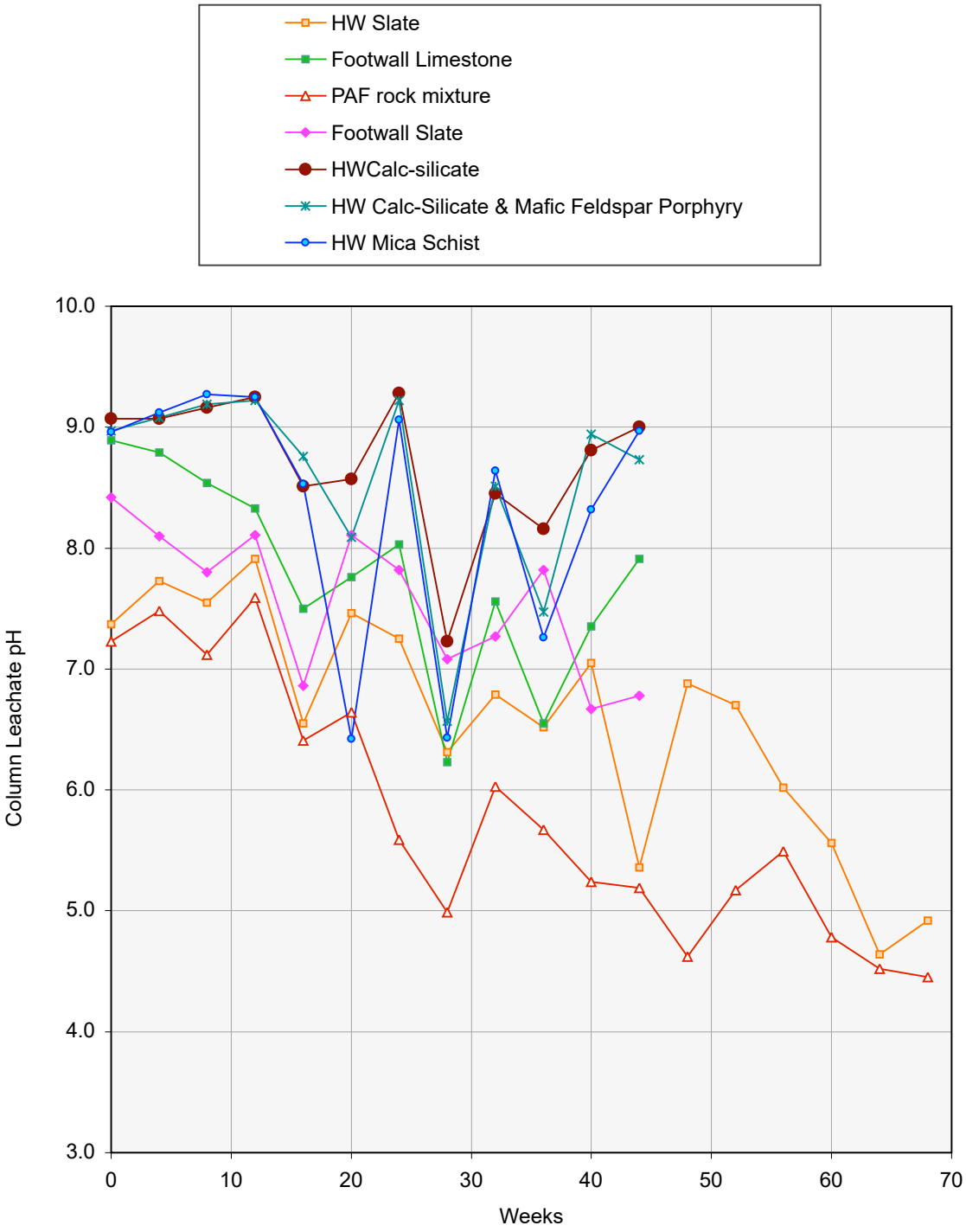


FIGURE 12: Plot of leachate pH for AARC column leach tests on Dugald River waste rock

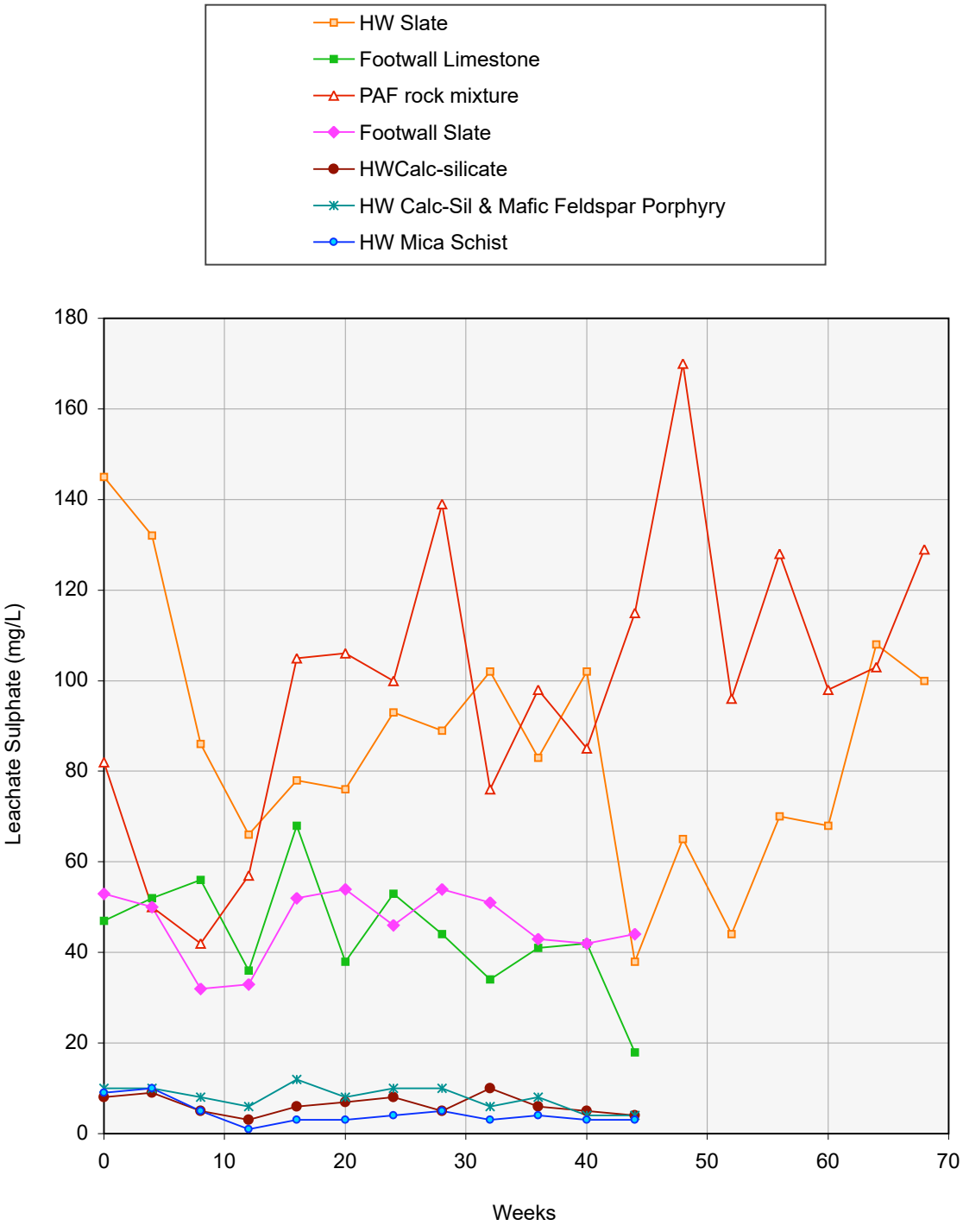


FIGURE 13: Plot of sulphate concentrations in leachates from AARC column leach tests on Dugald River waste rock

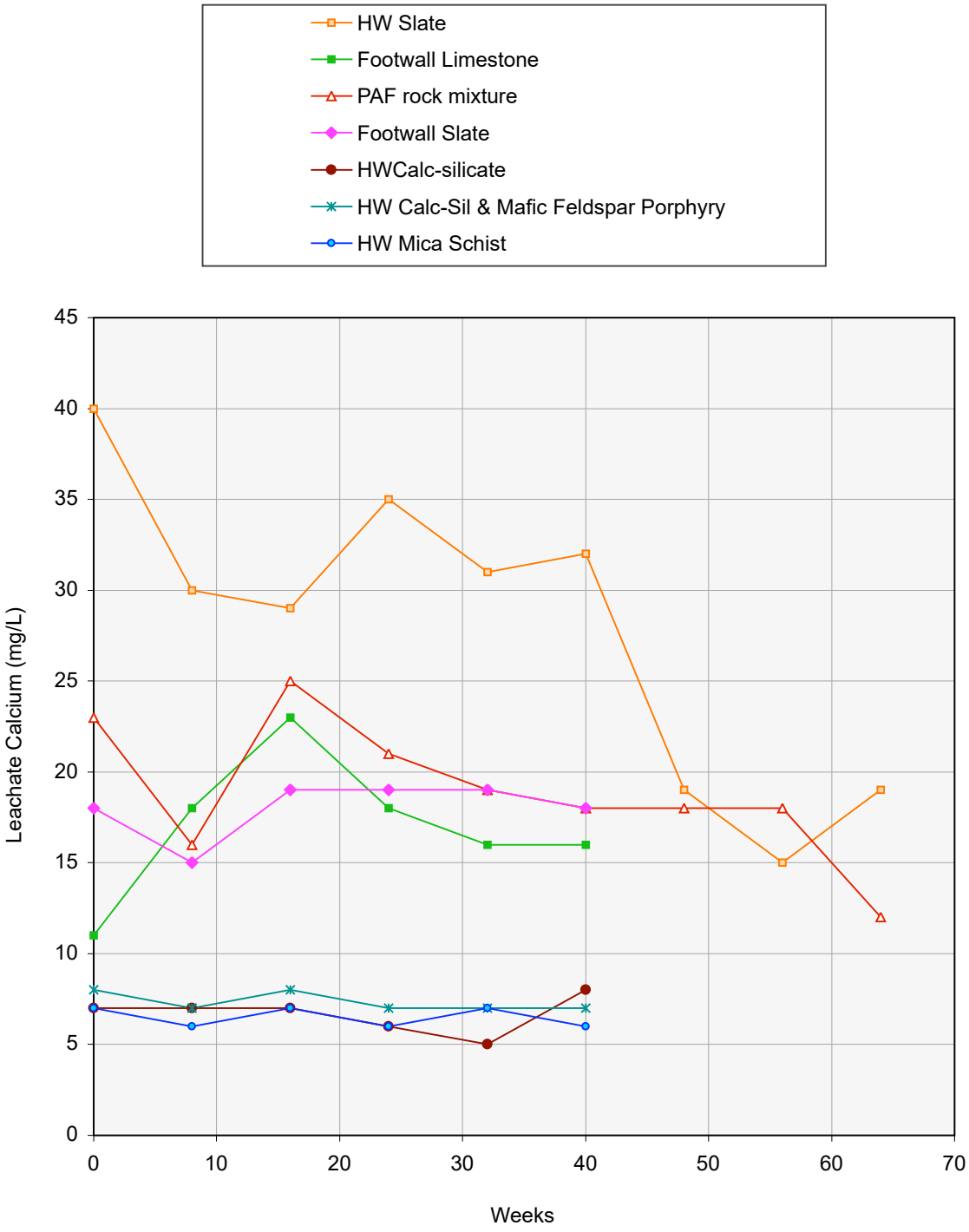


FIGURE 14: Plot of calcium concentrations in leachates from AARC column leach tests on Dugald River waste rock

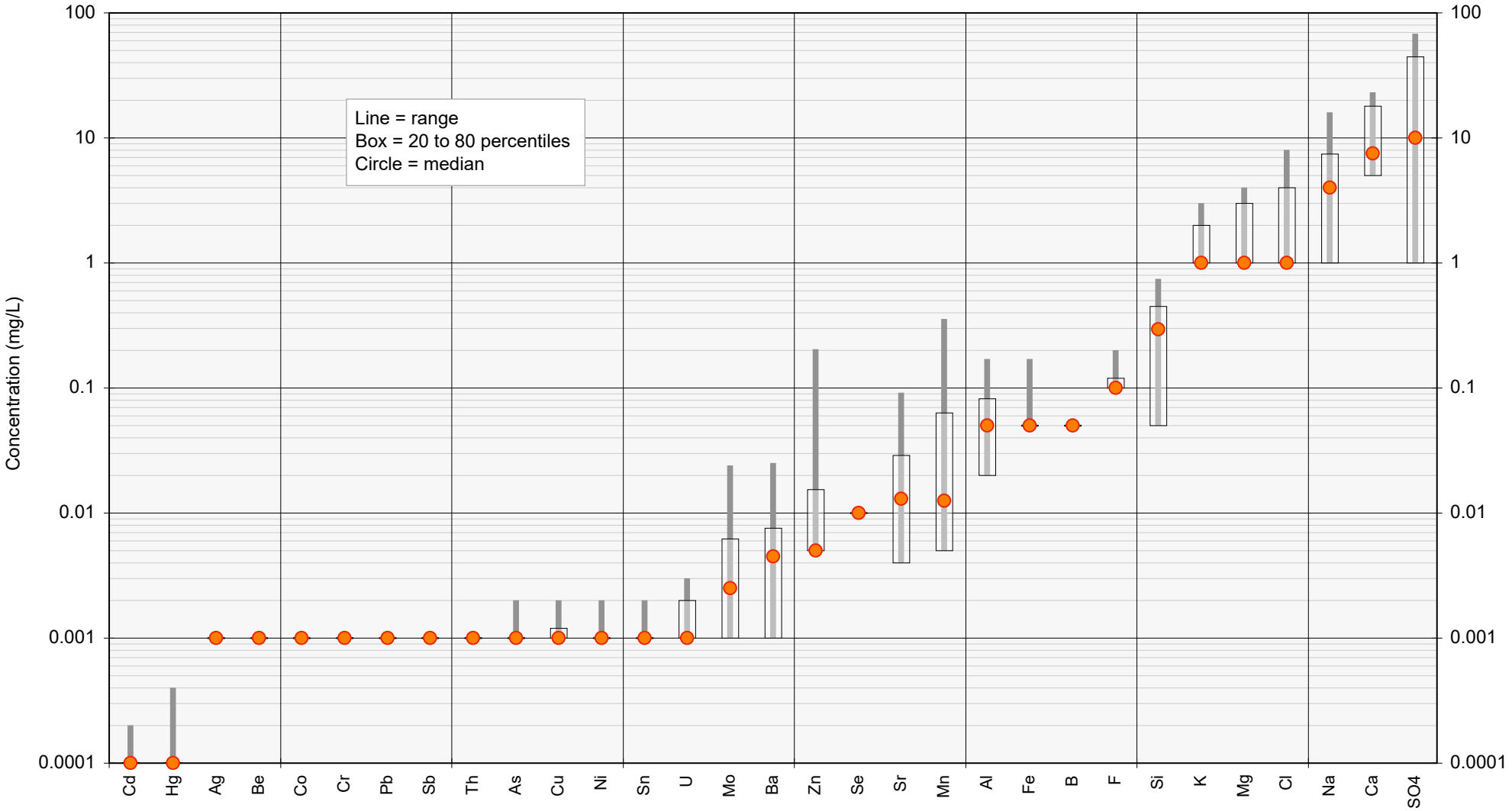


FIGURE 15: Statistical summary of AARC column leach assay data for samples comprising NAF Dugald River waste rock

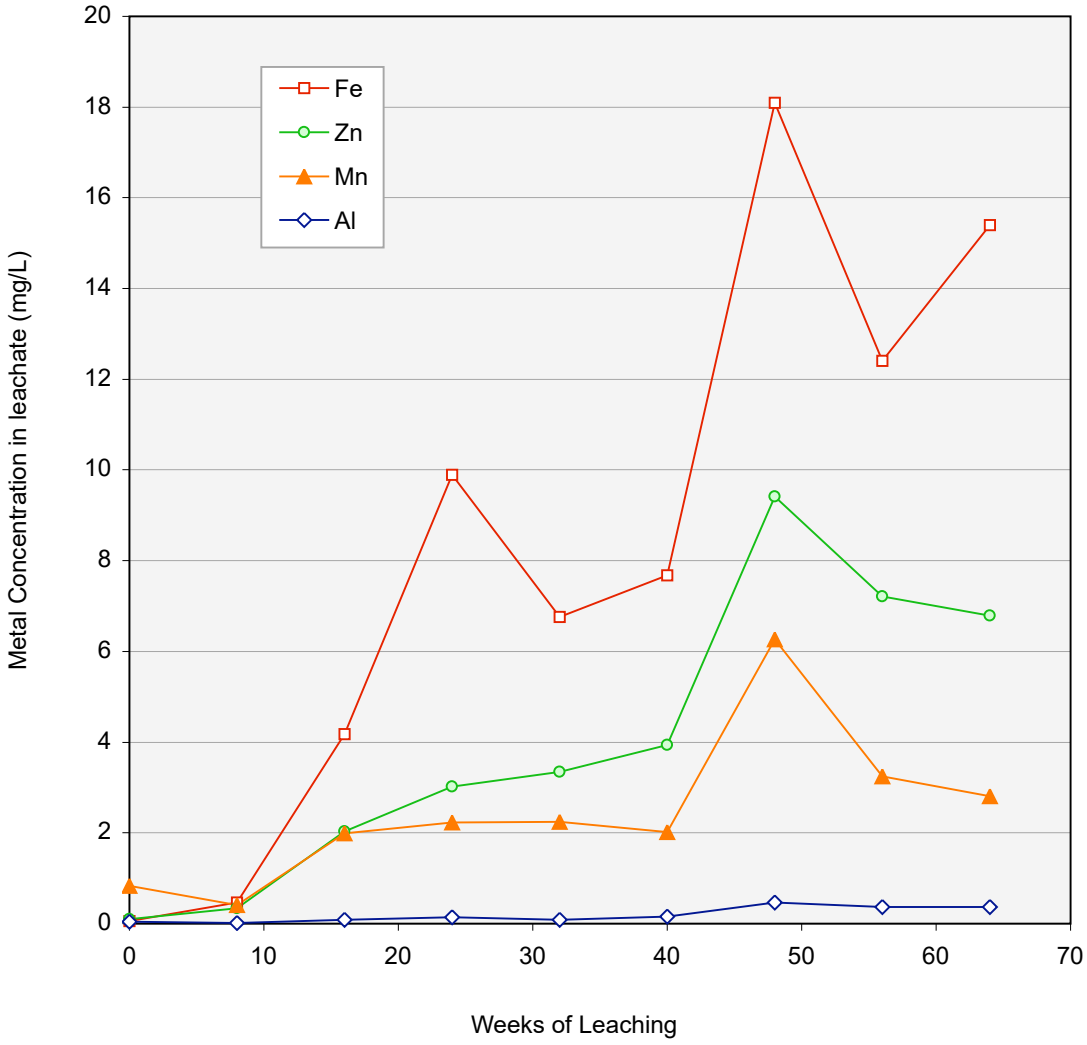


FIGURE 16: Plot of Fe, Zn, Mn and Al concentrations in leachate from Column 3 containing a PAF waste mixture

Appendix A

Acid Forming Characteristics of Drill Core Samples from Previous Geochemical Studies of Dugald River Waste Rock

AGC-Woodward Clyde (1991)

AustralAsian Resource Consultants (2008)

APPENDIX A : Acid forming characteristicsof drill core samples from previous geochemical studies of Dugald River waste rock

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AGC-WWC 1991	-	229	700	701	1.0	Hanging wall slate	430	7.4	0.36	11	52	4.7	-41	-	-	NAF
AGC-WWC 1991	-	174	168	169	1.0	Hanging wall slate	1260	6.5	1.74	53	75	1.4	-22	-	-	NAF
AGC-WWC 1991	-	230	662	663	1.0	Hanging wall slate	370	7.9	1.25	38	15	0.4	23	-	-	PAF
AGC-WWC 1991	-	230	675	676	1.0	Hanging wall slate	890	7.35	2.88	88	23	0.3	65	-	-	PAF
AGC-WWC 1991	-	186	672	673	1.0	Hanging wall slate	1106	7.71	5.24	160	89	0.6	71	-	-	PAF
AGC-WWC 1991	-	231	491	492	1.0	Hanging wall slate	500	7.48	6.79	208	8	0.0	200	-	-	PAF
AGC-WWC 1991	-	174	171	172	1.0	Lode ore	640	7.3	15.3	468	225	0.5	244	-	-	PAF
AGC-WWC 1991	-	186	684	685	1.0	Lode ore	520	6.9	14.5	444	109	0.2	335	-	-	PAF
AGC-WWC 1991	-	229	720	721	1.0	Lode ore	607	8.1	12.2	373	22	0.1	352	-	-	PAF
AGC-WWC 1991	-	231	500	501	1.0	Lode ore	421	7.2	16.3	499	12	0.0	486	-	-	PAF
AGC-WWC 1991	-	230	684	685	1.0	Lode ore	910	6.4	20.1	615	22	0.0	593	-	-	PAF
AGC-WWC 1991	-	186	696	697	1.0	Footwall slate	310	8.1	1.08	33	159	4.8	-126	-	-	NAF
AGC-WWC 1991	-	230	703	704	1.0	Footwall slate	410	8	0.53	16	122	7.5	-106	-	-	NAF
AGC-WWC 1991	-	229	747	748	1.0	Footwall slate	472	8.14	3.91	120	206	1.7	-86	-	-	NAF
AGC-WWC 1991	-	174	180	181	1.0	Footwall slate	1230	7.1	1.58	48	112	2.3	-63	-	-	NAF
AGC-WWC 1991	-	231	508	509	1.0	Footwall slate	609	8	3.67	112	152	1.4	-40	-	-	NAF
AGC-WWC 1991	-	231	540	541	1.0	Footwall slate	300	9.1	0.7	21	109	5.1	-87	-	-	NAF
AGC-WWC 1991	-	217	1029	1030	1.0	Footwall slate	256	8.98	2.21	68	12	0.2	56	-	-	PAF
AGC-WWC 1991	-	202	792	793	1.0	Footwall slate	521	8.09	7.44	228	65	0.3	162	-	-	PAF
AGC-WWC 1991	-	186	824	825	1.0	Footwall limestone	305	8.3	0.97	30	221	7.4	-191	-	-	NAF
AGC-WWC 1991	-	174	185	186	1.0	Footwall limestone	820	7.65	2.12	65	215	3.3	-151	-	-	NAF
AGC-WWC 1991	-	217	1040	1041	1.0	Footwall limestone	210	9.1	0.84	26	130	5.0	-104	-	-	NAF
AGC-WWC 1991	-	230	760	761	1.0	Footwall limestone	330	8.3	0.92	28	10	0.3	18	-	-	PAF

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	34180	DR319	121	121.5	0.5	Calc-silicate	319	9.0	0.01	0	688	2248	-688	0	11.5	NAF
AARC 2008	34189	DR322	132	132.5	0.5	Calc-silicate	173	9.5	0.01	0	381	1245	-381	0	11.3	NAF
AARC 2008	34181	DR319	121.5	122	0.5	Calc-silicate	135	9.6	0.01	0	367	-	-367	0	11.4	NAF
AARC 2008	34195	DR321	177.5	178	0.5	Calc-silicate	156	9.4	0.02	1	347	567	-346	0	11.1	NAF
AARC 2008	34188	DR322	129	129.5	0.5	Calc-silicate	206	9.3	0.04	1	332	271	-331	0	11.2	NAF
AARC 2008	34187	DR322	126	126.5	0.5	Calc-silicate	168	9.6	0.01	0	325	1062	-325	0	9.3	NAF
AARC 2008	34199	DR318	227	227.45	0.45	Calc-silicate	241	9.2	0.04	1	282	230	-281	0	11.3	NAF
AARC 2008	34046	DR342	107	107.5	0.5	Calc-silicate	122	9.5	0.02	1	240	392	-239	0	11.1	NAF
AARC 2008	34183	DR319	124.5	125	0.5	Calc-silicate	133	9.6	0.01	0	226	739	-226	0	11.5	NAF
AARC 2008	34174	DR320	112	112.5	0.5	Calc-silicate	154	9.5	0.11	3	218	65	-215	0	11.1	NAF
AARC 2008	34200	DR318	227.45	228	0.55	Calc-silicate	203	9.2	0.02	1	174	284	-173	0	11.0	NAF
AARC 2008	34182	DR319	124	124.5	0.5	Calc-silicate	153	9.5	0.01	0	169	552	-169	0	11.1	NAF
AARC 2008	34175	DR320	112.5	113	0.5	Calc-silicate	126	9.7	0.04	1	161	132	-160	0	11.4	NAF
AARC 2008	34026	DR342	106	106.5	0.5	Calc-silicate	123	9.4	0.01	0	160	523	-160	0	11.3	NAF
AARC 2008	34192	DR321	163	163.5	0.5	Calc-silicate	162	9.3	0.01	0	145	474	-145	0	9.2	NAF
AARC 2008	34198	DR318	225	225.5	0.5	Calc-silicate	200	9.4	0.01	0	133	435	-133	0	11.1	NAF
AARC 2008	34196	DR318	219	219.5	0.5	Calc-silicate	175	9.4	0.03	1	124	135	-123	0	10.9	NAF
AARC 2008	34193	DR321	166	166.5	0.5	Calc-silicate	134	9.5	0.01	0	112	366	-112	0	9.0	NAF
AARC 2008	34027	DR342	106.5	107	0.5	Calc-silicate	140	9.3	0.03	1	109	119	-108	0	11.4	NAF
AARC 2008	34197	DR318	222	222.5	0.5	Calc-silicate	141	9.5	0.01	0	91	-	-91	0	11.0	NAF
AARC 2008	34194	DR321	177	177.5	0.5	Calc-silicate	193	9.5	0.01	0	47	-	-47	0	10.2	NAF
AARC 2008	34009	DR346	140	140.5	0.5	Calc-silicate	121	9.3	0.02	1	31	50	-30	0	10.4	NAF
AARC 2008	34008	DR346	127.5	128	0.5	Calc-silicate	97	9.4	0.02	1	9	15	-9	0	7.0	NAF
AARC 2008	34029	DR342	151.5	152	0.5	Mafic feldspar porphyry	154	9.4	0.01	0	401	1310	-401	0	10.4	NAF
AARC 2008	34028	DR342	151	151.5	0.5	Mafic feldspar porphyry	132	9.8	0.01	0	45	-	-45	0	9.2	NAF
AARC 2008	34010	DR346	162.5	163	0.5	Mafic feldspar porphyry	107	9.5	0.01	0	21	-	-21	0	9.4	NAF
AARC 2008	34179	DR320	216.5	217	0.5	White mica schist	197	9.2	0.2	6	252	41	-246	0	11.2	NAF
AARC 2008	34177	DR320	212.5	213	0.5	White mica schist	163	9.5	0.01	0	222	725	-222	0	11.4	NAF
AARC 2008	34178	DR320	216	216.5	0.5	White mica schist	256	9.4	0.01	0	153	500	-153	0	11.4	NAF
AARC 2008	34176	DR320	212	212.5	0.5	White mica schist	189	9.3	0.02	1	138	225	-137	0	11.4	NAF
AARC 2008	34202	DR316	266	266.5	0.5	White mica schist	179	9.5	0.02	1	46	76	-46	0	9.2	NAF
AARC 2008	34205	DR316	272	272.5	0.5	White mica schist	151	9.7	0.02	1	34	56	-34	0	7.7	NAF
AARC 2008	34203	DR316	268	268.5	0.5	White mica schist	128	9.7	0.04	1	33	27	-32	0	7.2	NAF
AARC 2008	34204	DR316	270	270.5	0.5	White mica schist	137	9.7	0.01	0	32	105	-32	0	6.8	NAF
AARC 2008	34030	DR342	260	260.5	0.5	White mica schist	86	9.5	0.06	2	33	18	-31	0	9.3	NAF
AARC 2008	34201	DR316	264	264.5	0.5	White mica schist	132	9.6	0.02	1	31	50	-30	0	7.9	NAF
AARC 2008	34031	DR342	260.5	261	0.5	White mica schist	75	9.6	0.02	1	9	15	-9	0	7.8	NAF
AARC 2008	34047	DR342	273	273.5	0.5	White mica schist	68	9.7	0.03	1	10	10	-9	0	7.2	NAF
AARC 2008	34032	DR342	272.5	273	0.5	White mica schist	89	9.6	0.24	7	10	1.4	-3	1	4.4	UC (PAF)

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	34035	DR342	363.5	364	0.5	Hanging wall slate	206	8.9	2.28	70	276	4.0	-206	0	8.0	NAF
AARC 2008	34033	DR342	362.5	363	0.5	Hanging wall slate	352	8.6	4.14	127	312	2.5	-185	0	8.1	NAF
AARC 2008	34034	DR342	363	363.5	0.5	Hanging wall slate	330	8.7	3.81	117	293	2.5	-176	0	7.8	NAF
AARC 2008	34191	DR322	162	162.5	0.5	Hanging wall slate	170	9.6	0.09	3	142	52	-139	0	11.1	NAF
AARC 2008	34037	DR342	364.5	365	0.5	Hanging wall slate	352	8.6	5.38	165	273	1.7	-108	0	8.0	NAF
AARC 2008	34039	DR342	365.5	366	0.5	Hanging wall slate	211	9.0	1.89	58	158	2.7	-100	0	8.1	NAF
AARC 2008	34165	DR315	102.5	103	0.5	Hanging wall slate	431	8.4	3.3	101	141	1.4	-40	0	8.3	NAF
AARC 2008	34038	DR342	365	365.5	0.5	Hanging wall slate	279	8.8	2.01	62	95	1.5	-33	0	7.9	NAF
AARC 2008	34052	DR341	111.5	112	0.5	Hanging wall slate	127	9.2	0.29	9	26	2.9	-17	0	7.9	NAF
AARC 2008	34051	DR341	111	111.5	0.5	Hanging wall slate	120	9.2	0.52	16	31	1.9	-15	0	8.4	NAF
AARC 2008	34014	DR346	409.5	410	0.5	Hanging wall slate	178	9.1	0.65	20	32	1.6	-12	0	8.6	NAF
AARC 2008	34190	DR322	157	157.5	0.5	Hanging wall slate	174	9.7	0.07	2	11	5	-9	0	7.5	NAF
AARC 2008	34049	DR341	99	99.5	0.5	Hanging wall slate	111	9.4	0.77	24	29	1.2	-5	0	9.0	NAF
AARC 2008	34036	DR342	364	364.5	0.5	Hanging wall slate	398	8.6	4.35	133	136	1.0	-3	0	7.9	NAF
AARC 2008	34015	DR346	410	410.5	0.5	Hanging wall slate	205	9.1	1.13	35	32	0.9	3	0	8.5	UC (NAF)
AARC 2008	34159	DR315	84.5	85	0.5	Hanging wall slate	591	8.6	4.11	126	67	0.5	59	0	7.6	UC (PAF)
AARC 2008	34066	DR340	126.5	127	0.5	Hanging wall slate	114	9.2	0.56	17	12	0.7	5	10	3.0	PAF
AARC 2008	34018	DR346	414.5	415	0.5	Hanging wall slate	172	9.2	0.68	21	14	0.7	7	8	2.8	PAF
AARC 2008	34017	DR346	414	414.5	0.5	Hanging wall slate	162	9.3	0.87	27	14	0.5	13	12	2.7	PAF
AARC 2008	34064	DR340	123	123.5	0.5	Hanging wall slate	139	9.4	0.72	22	8	0.3	14	16	2.8	PAF
AARC 2008	34050	DR341	99.5	100	0.5	Hanging wall slate	122	9.5	0.89	27	10	0.4	17	19	2.6	PAF
AARC 2008	34053	DR341	123	123.5	0.5	Hanging wall slate	89	8.8	0.91	28	5	0.2	23	25	2.6	PAF
AARC 2008	34162	DR315	101	101.5	0.5	Hanging wall slate	143	9.4	1.25	38	15	0.4	23	26	3.2	PAF
AARC 2008	34067	DR340	127	127.5	0.5	Hanging wall slate	185	8.2	1.31	40	8	0.2	32	35	2.6	PAF
AARC 2008	34054	DR341	123.5	124	0.5	Hanging wall slate	96	8.7	1.29	39	6	0.1	34	37	2.6	PAF
AARC 2008	34065	DR340	124.7	125.2	0.5	Hanging wall slate	106	9.0	1.3	40	5	0.1	34	33	2.6	PAF
AARC 2008	34158	DR315	84	84.5	0.5	Hanging wall slate	188	9.1	2.27	69	32	0.5	37	38	2.8	PAF
AARC 2008	34161	DR315	90.5	91	0.5	Hanging wall slate	399	8.6	3.24	99	38	0.4	61	55	2.6	PAF
AARC 2008	34160	DR315	90	90.5	0.5	Hanging wall slate	421	8.4	2.64	81	14	0.2	67	54	2.5	PAF
AARC 2008	34069	DR340	130.5	131	0.5	Hanging wall slate	660	8.0	2.57	79	6	0.1	72	68	2.4	PAF
AARC 2008	34011	DR346	402.5	403	0.5	Hanging wall slate	195	8.5	2.76	84	8	0.1	76	73	2.4	PAF
AARC 2008	34164	DR315	102	102.5	0.5	Hanging wall slate	316	8.3	3.69	113	26	0.2	87	80	2.7	PAF
AARC 2008	34016	DR346	410.5	411	0.5	Hanging wall slate	253	8.7	5.64	173	79	0.5	94	56	2.5	PAF
AARC 2008	34068	DR340	130	130.5	0.5	Hanging wall slate	515	8.1	3.55	109	10	0.1	99	90	2.2	PAF
AARC 2008	34040	DR342	376	377.5	1.5	Hanging wall slate	690	8.0	7.64	234	45	0.2	188	138	2.2	PAF
AARC 2008	34012	DR346	403	403.5	0.5	Hanging wall slate	239	7.6	7.18	220	6	0.0	214	144	2.2	PAF
AARC 2008	34013	DR346	403.5	404	0.5	Hanging wall slate	428	8.0	12.3	376	11	0.0	365	204	2.0	PAF
AARC 2008	34163	DR315	101.5	102	0.5	Hanging wall slate	581	8.2	14.4	441	20	0.0	421	198	2.3	PAF

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	34184	DR319	399	400	1.0	Lode waste	276	9.0	6.87	210	397	2	-187	0	7.6	NAF
AARC 2008	34042	DR342	418.5	419.5	1.0	Lode waste	120	9.5	2.18	67	208	3.1	-141	0	7.9	NAF
AARC 2008	34019	DR346	434.5	435	0.5	Lode waste	260	7.9	1.24	38	7	0.2	31	31	2.7	PAF
AARC 2008	34020	DR346	435.5	436	0.5	Lode waste	139	9.1	1.63	50	10	0.2	40	32	2.6	PAF
AARC 2008	34166	DR315	270.5	271.5	1.0	Lode waste	412	8.1	4.66	143	18	0.1	125	115	2.3	PAF
AARC 2008	34070	DR340	141.5	142.5	1.0	Lode waste	172	8.6	6.75	207	9	0.0	197	133	2.2	PAF
AARC 2008	34173	DR332	414.5	415.4	0.9	Lode waste	270	9.0	8.82	270	11	0.0	259	183	2.2	PAF
AARC 2008	34071	DR340	142.5	143.5	1.0	Lode waste	238	6.7	13.7	419	5	0.0	414	186	2.0	PAF
AARC 2008	34059	DR341	146.5	147.5	1.0	Lode waste	255	8.3	15.4	471	7	0.0	465	215	2.1	PAF
AARC 2008	34058	DR341	137	138	1.0	Lode waste	186	8.5	16.6	508	8	0.0	500	200	2.1	PAF
AARC 2008	34072	DR340	159	159.5	0.5	Footwall slate	334	8.9	0.92	28	148	5.3	-120	0	7.9	NAF
AARC 2008	34075	DR340	160.5	161	0.5	Footwall slate	309	8.8	1.11	34	141	4.2	-107	0	8.2	NAF
AARC 2008	34074	DR340	160	160.5	0.5	Footwall slate	558	8.5	0.98	30	115	3.8	-85	0	8.2	NAF
AARC 2008	34077	DR340	161.5	162	0.5	Footwall slate	138	9.3	1.03	32	113	3.6	-81	0	8.1	NAF
AARC 2008	34061	DR341	157.5	158	0.5	Footwall slate	87	9.4	0.45	14	93	6.8	-79	0	8.2	NAF
AARC 2008	34076	DR340	161	161.5	0.5	Footwall slate	160	9.1	1.01	31	107	3.5	-76	0	8.2	NAF
AARC 2008	34168	DR315	273.2	273.7	0.5	Footwall slate	233	9.2	1.18	36	111	3.1	-75	0	8.5	NAF
AARC 2008	34073	DR340	159.5	160	0.5	Footwall slate	289	8.9	0.67	21	92	4.5	-72	0	8.0	NAF
AARC 2008	34062	DR341	162	162.5	0.5	Footwall slate	103	9.4	0.89	27	89	3.3	-62	0	8.2	NAF
AARC 2008	34167	DR315	272.7	273.2	0.5	Footwall slate	146	9.3	1.2	37	98	2.7	-61	0	8.6	NAF
AARC 2008	34063	DR341	162.5	163	0.5	Footwall slate	97	9.5	0.72	22	76	3.4	-53	0	8.4	NAF
AARC 2008	34060	DR341	157	157.5	0.5	Footwall slate	124	9.4	1.49	46	48	1.0	-2	0	8.1	NAF
AARC 2008	34048	DR342	424	425	1.0	Footwall slate	222	8.9	14.6	447	244	0.5	203	0	8.3	UC (PAF)
AARC 2008	34022	DR346	432.9	433.3	0.4	Footwall slate	134	8.8	1.27	39	12	0.3	27	25	2.3	PAF
AARC 2008	34021	DR346	432.5	432.9	0.4	Footwall slate	220	8.7	1.55	47	11	0.2	37	34	2.6	PAF
AARC 2008	34041	DR342	423	424	1.0	Footwall slate	208	8.6	13.8	422	32	0.1	390	133	2.1	PAF
AARC 2008	34186	DR319	446	446.5	0.5	Footwall limestone	262	9.3	1.27	39	552	14	-513	0	8.7	NAF
AARC 2008	34078	DR340	185	185.5	0.5	Footwall limestone	144	9.4	0.94	29	272	9.5	-243	0	9.0	NAF
AARC 2008	34055	DR341	177	177.5	0.5	Footwall limestone	110	9.4	0.36	11	251	23	-240	0	9.7	NAF
AARC 2008	34057	DR341	183	183.5	0.5	Footwall limestone	115	9.5	0.77	24	244	10	-220	0	9.0	NAF
AARC 2008	34079	DR340	185.5	186	0.5	Footwall limestone	138	9.4	1.21	37	253	6.8	-216	0	8.6	NAF
AARC 2008	34080	DR340	186	186.5	0.5	Footwall limestone	159	9.3	1.34	41	249	6.1	-208	0	9.8	NAF
AARC 2008	34172	DR315	292.5	293	0.5	Footwall limestone	226	9.2	1.76	54	250	4.6	-196	0	8.6	NAF
AARC 2008	34185	DR319	441	441.5	0.5	Footwall limestone	158	9.6	1.07	33	225	7	-192	0	9.6	NAF
AARC 2008	34056	DR341	177.5	178	0.5	Footwall limestone	125	9.4	1.92	59	241	4.1	-182	0	8.9	NAF
AARC 2008	34043	DR342	458	458.5	0.5	Footwall limestone	106	9.7	1.01	31	178	5.8	-147	0	8.7	NAF
AARC 2008	34025	DR346	496	496.5	0.5	Footwall limestone	143	9.4	1.25	38	180	5	-142	0	8.3	NAF
AARC 2008	34045	DR342	471	471.5	0.5	Footwall limestone	109	9.7	1.15	35	166	4.7	-131	0	8.3	NAF

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	37335	DR342	460.1	460.4	0.3	Footwall limestone	168	9.6	0.76	23	142	6.1	-119	0	9.0	NAF
AARC 2008	34171	DR315	292	292.5	0.5	Footwall limestone	186	9.4	1.66	51	153	3.0	-102	0	8.7	NAF
AARC 2008	34170	DR315	281.5	282	0.5	Footwall limestone	234	9.3	1.09	33	116	3.5	-83	0	8.4	NAF
AARC 2008	34024	DR346	492	492.5	0.5	Footwall limestone	126	9.5	0.46	14	89	6	-75	0	8.6	NAF
AARC 2008	34023	DR346	490.5	491	0.5	Footwall limestone	144	9.4	0.63	19	89	5	-70	0	8.9	NAF
AARC 2008	34169	DR315	281	281.5	0.5	Footwall limestone	182	9.4	1.35	41	93	2.3	-52	0	8.6	NAF

Appendix B

Multi-Element Data and Geochemical Abundance Indices for Drill Core Samples from Previous Geochemical Studies of Dugald River Waste Rock

AGC-Woodward Clyde (1991)

AustralAsian Resource Consultants (2008)

APPENDIX B-1: Multi-element data for drill core samples from previous geochemical studies of Dugald River waste rock

Study	Sample ID	Hole No.	From (m)	To (m)	Lithology	ARD Class	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (%)	Sb (mg/kg)	V (mg/kg)	Zn (mg/kg)
AGC-WWC 1991	-	229	700	701	Hanging wall slate	NAF	46	-	-	1	10	-	10	0.05	-	-	120	0.4%	5	-	470
AGC-WWC 1991	-	174	168	169	Hanging wall slate	NAF	80	-	-	1	5	-	250	0.1	-	-	250	1.7%	5	-	670
AGC-WWC 1991	-	230	662	663	Hanging wall slate	PAF	18	-	-	1	30	-	1650	0.05	-	-	25	1.3%	5	-	220
AGC-WWC 1991	-	230	675	676	Hanging wall slate	PAF	85	-	-	1	10	-	90	0.1	-	-	310	2.9%	5	-	1250
AGC-WWC 1991	-	186	672	673	Hanging wall slate	PAF	75	-	-	2	45	-	250	0.1	-	-	230	5.2%	5	-	640
AGC-WWC 1991	-	231	491	492	Hanging wall slate	PAF	19	-	-	1	25	-	250	0.05	-	-	45	6.8%	5	-	95
AGC-WWC 1991	-	174	171	172	Lode ore	PAF	65	-	-	240	30	-	470	4.4	-	-	1.52%	15.3%	25	-	11.9%
AGC-WWC 1991	-	186	684	685	Lode ore	PAF	450	-	-	330	15	-	195	5.3	-	-	6.84%	14.5%	140	-	13.8%
AGC-WWC 1991	-	229	720	721	Lode ore	PAF	65	-	-	125	5	-	145	1.45	-	-	1.78%	12.2%	5	-	8.8%
AGC-WWC 1991	-	231	500	501	Lode ore	PAF	520	-	-	210	30	-	70	2	-	-	5200	16.3%	5	-	8.4%
AGC-WWC 1991	-	230	684	685	Lode ore	PAF	210	-	-	290	20	-	85	2	-	-	3.24%	20.1%	5	-	14.6%
AGC-WWC 1991	-	186	696	697	Footwall slate	NAF	36	-	-	8	5	-	25	0.1	-	-	220	1.1%	5	-	3950
AGC-WWC 1991	-	230	703	704	Footwall slate	NAF	100	-	-	1	5	-	25	0.05	-	-	45	0.5%	5	-	490
AGC-WWC 1991	-	231	540	541	Footwall slate	NAF	24	-	-	1	5	-	25	0.05	-	-	30	0.7%	5	-	510
AGC-WWC 1991	-	229	747	748	Footwall slate	NAF	230	-	-	12	10	-	60	0.15	-	-	110	3.9%	5	-	1600
AGC-WWC 1991	-	174	180	181	Footwall slate	NAF	18	-	-	1	5	-	115	0.1	-	-	60	1.6%	5	-	730
AGC-WWC 1991	-	231	508	509	Footwall slate	NAF	155	-	-	44	15	-	30	0.55	-	-	175	3.7%	5	-	2.6%
AGC-WWC 1991	-	217	1029	1030	Footwall slate	PAF	60	-	-	6	5	-	65	0.15	-	-	420	2.2%	5	-	3800
AGC-WWC 1991	-	202	792	793	Footwall slate	PAF	210	-	-	14	25	-	45	1.5	-	-	1150	7.4%	5	-	2.8%
AGC-WWC 1991	-	186	824	825	Footwall limestone	NAF	38	-	-	1	5	-	40	0.05	-	-	110	1.0%	5	-	330
AGC-WWC 1991	-	174	185	186	Footwall limestone	NAF	105	-	-	1	20	-	95	0.05	-	-	45	2.1%	5	-	350
AGC-WWC 1991	-	217	1040	1041	Footwall limestone	NAF	85	-	-	1	10	-	50	0.05	-	-	80	0.8%	5	-	250
AGC-WWC 1991	-	230	760	761	Footwall limestone	PAF	12	-	-	1	10	-	40	0.05	-	-	85	0.9%	5	-	400

* Note: Samples in the AGC-Woodward Clyde (1991) study were also assayed for bismuth but the concentrations in all samples were at or below the analytical detection limit of 5 mg/kg.
As the detection limit was particularly high in comparison to typical soil values, the bismuth assay results were not considered in the current review.

APPENDIX B-1 : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Lithology	ARD Class	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (%)	Sb (mg/kg)	V (mg/kg)	Zn (mg/kg)
AARC 2008	34009	DR346	140	140.5	Calc-silicate	NAF	5	60	2	1	15	37	5	0.1	596	28	5	0.02%	-	43	16
AARC 2008	34027	DR342	106.5	107	Calc-silicate	NAF	5	130	1	1	9	28	5	0.1	740	24	5	0.03%	-	42	5
AARC 2008	34174	DR320	112	112.5	Calc-silicate	NAF	5	40	1	1	2	8	9	0.1	694	12	18	0.1%	-	15	162
AARC 2008	34180	DR319	121	121.5	Calc-silicate	NAF	5	<10	1	1	2	10	7	0.1	1900	5	5	0.01%	-	6	5
AARC 2008	34182	DR319	124	124.5	Calc-silicate	NAF	9	180	1	1	2	7	5	0.1	594	4	5	0.01%	-	12	5
AARC 2008	34188	DR322	129	129.5	Calc-silicate	NAF	5	30	1	1	14	27	5	0.1	1560	19	5	0.04%	-	35	108
AARC 2008	34192	DR321	163	163.5	Calc-silicate	NAF	5	300	2	1	13	36	5	0.1	1710	22	5	0.01%	-	37	15
AARC 2008	34194	DR321	177	177.5	Calc-silicate	NAF	5	360	2	1	20	62	5	0.1	1230	37	5	0.01%	-	86	28
AARC 2008	34196	DR318	219	219.5	Calc-silicate	NAF	5	90	1	1	12	28	6	0.1	1220	25	5	0.03%	-	46	17
AARC 2008	34198	DR318	225	225.5	Calc-silicate	NAF	5	80	2	1	10	24	5	0.1	918	20	5	0.01%	-	41	6
AARC 2008	34200	DR318	227.45	228	Calc-silicate	NAF	5	40	2	1	16	42	6	0.1	1140	28	5	0.02%	-	55	8
AARC 2008	34029	DR342	151.5	152	Mafic feldspar porphyry	NAF	5	270	1	1	25	9	36	0.1	1200	28	5	0.01%	-	104	5
AARC 2008	34031	DR342	260.5	261	White mica schist	NAF	5	110	1	1	38	94	23	0.1	229	18	5	0.02%	-	82	5
AARC 2008	34047	DR342	273	273.5	White mica schist	NAF	5	110	1	1	6	53	16	0.1	215	18	5	0.03%	-	31	5
AARC 2008	34176	DR320	212	212.5	White mica schist	NAF	5	90	1	1	16	31	106	0.1	679	29	5	0.02%	-	46	18
AARC 2008	34178	DR320	216	216.5	White mica schist	NAF	5	120	1	1	15	31	23	0.1	1070	29	5	0.01%	-	59	13
AARC 2008	34202	DR316	266	266.5	White mica schist	NAF	5	100	3	1	17	28	64	0.1	553	30	5	0.02%	-	37	11
AARC 2008	34204	DR316	270	270.5	White mica schist	NAF	5	140	1	1	17	30	5	0.1	510	30	5	0.01%	-	43	19
AARC 2008	34033	DR342	362.5	363	Hanging wall slate	NAF	5	60	2	1	62	28	399	0.1	1270	24	7	4.1%	-	49	14
AARC 2008	34035	DR342	363.5	364	Hanging wall slate	NAF	5	60	2	1	19	38	689	0.1	1160	14	5	2.3%	-	57	116
AARC 2008	34037	DR342	364.5	365	Hanging wall slate	NAF	5	60	1	1	53	39	1040	0.1	1290	27	7	5.4%	-	71	175
AARC 2008	34039	DR342	365.5	366	Hanging wall slate	NAF	5	20	2	1	19	35	358	0.1	834	16	10	1.9%	-	54	84
AARC 2008	34049	DR341	99	99.5	Hanging wall slate	NAF	9	80	1	1	4	65	60	0.1	562	10	5	0.8%	-	43	14
AARC 2008	34051	DR341	111	111.5	Hanging wall slate	NAF	8	20	1	1	6	23	10	0.1	187	19	5	0.5%	-	5	11
AARC 2008	34190	DR322	157	157.5	Hanging wall slate	NAF	5	70	1	1	10	49	20	0.1	588	18	5	0.07%	-	62	28
AARC 2008	34011	DR346	402.5	403	Hanging wall slate	PAF	44	20	1	5	5	4	57	0.8	320	22	27	2.8%	-	5	4870
AARC 2008	34013	DR346	403.5	404	Hanging wall slate	PAF	188	20	2	2	42	8	225	0.4	741	78	68	12.3%	-	13	2780
AARC 2008	34017	DR346	414	414.5	Hanging wall slate	PAF	5	80	2	1	14	32	260	0.1	603	17	20	0.9%	-	55	43
AARC 2008	34053	DR341	123	123.5	Hanging wall slate	PAF	36	30	1	1	5	27	26	0.1	89	10	6	0.9%	-	8	42
AARC 2008	34065	DR340	124.7	125.2	Hanging wall slate	PAF	41	40	1	1	13	34	13	0.1	330	25	9	1.3%	-	75	46
AARC 2008	34067	DR340	127	127.5	Hanging wall slate	PAF	174	30	1	1	6	13	5	0.1	160	19	5	1.3%	-	11	10
AARC 2008	34069	DR340	130.5	131	Hanging wall slate	PAF	1190	60	1	1	20	4	31	0.1	107	41	18	2.6%	-	10	14
AARC 2008	34158	DR315	84	84.5	Hanging wall slate	PAF	69	20	1	9	29	33	632	0.4	518	45	22	2.3%	-	79	5360
AARC 2008	34160	DR315	90	90.5	Hanging wall slate	PAF	250	20	1	7	21	58	1770	0.5	316	53	6	2.6%	-	107	4350
AARC 2008	34162	DR315	101	101.5	Hanging wall slate	PAF	519	30	1	15	10	39	403	1.3	372	13	22	1.3%	-	104	1.1%
AARC 2008	34164	DR315	102	102.5	Hanging wall slate	PAF	108	20	1	32	10	32	514	2.3	498	27	23	3.7%	-	100	27100
AARC 2008	34015	DR346	410	410.5	Hanging wall slate	UC	6	60	1	1	41	41	652	0.1	328	61	23	1.1%	-	71	125

APPENDIX B-1 : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Lithology	ARD Class	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (%)	Sb (mg/kg)	V (mg/kg)	Zn (mg/kg)
AARC 2008	34184	DR319	399	400	Lode (mineralised waste)	NAF	21	340	1	66	6	7	87	4.6	10300	18	128	6.9%	-	13	4.4%
AARC 2008	34059	DR341	146.5	147.5	Lode (mineralised waste)	PAF	246	80	1	38	25	44	209	2.2	219	32	197	15.4%	-	34	7.7%
AARC 2008	34071	DR340	142.5	143.5	Lode (mineralised waste)	PAF	304	20	1	52	29	3	95	1	1470	20	649	13.7%	-	8	4.4%
AARC 2008	34166	DR315	270.5	271.5	Lode (mineralised waste)	PAF	12	130	1	12	5	18	323	0.4	932	26	169	4.7%	-	69	6660
AARC 2008	34061	DR341	157.5	158	Footwall slate	NAF	29	50	1	1	2	66	8	0.1	3270	8	48	0.5%	-	31	203
AARC 2008	34063	DR341	162.5	163	Footwall slate	NAF	12	70	1	1	4	65	12	0.1	1970	11	21	0.7%	-	36	68
AARC 2008	34073	DR340	159.5	160	Footwall slate	NAF	36	50	1	1	3	7	7	0.1	2020	10	27	0.7%	-	7	333
AARC 2008	34075	DR340	160.5	161	Footwall slate	NAF	116	40	2	5	8	24	15	0.1	2540	22	38	1.1%	-	30	2830
AARC 2008	34077	DR340	161.5	162	Footwall slate	NAF	67	320	1	1	8	26	19	0.1	2390	19	185	1.0%	-	30	345
AARC 2008	34168	DR315	273.2	273.7	Footwall slate	NAF	23	200	1	1	6	31	50	0.1	1710	14	61	1.2%	-	43	218
AARC 2008	34170	DR315	281.5	282	Footwall slate	NAF	5	180	1	1	6	35	28	0.1	2480	19	18	1.1%	-	45	156
AARC 2008	34172	DR315	292.5	293	Footwall slate	NAF	22	60	1	1	10	7	25	0.1	944	16	73	1.8%	-	11	387
AARC 2008	34019	DR346	434.5	435	Footwall slate	PAF	26	120	3	1	6	8	158	0.1	394	14	48	1.2%	-	17	74
AARC 2008	34021	DR346	432.5	432.9	Footwall slate	PAF	5	70	1	1	4	2	36	0.1	147	13	33	1.6%	-	5	19
AARC 2008	34041	DR342	423	424	Footwall slate	PAF	1070	70	1	1	69	60	673	0.4	153	24	168	13.8%	-	39	197
AARC 2008	34023	DR346	490.5	491	Footwall limestone	NAF	9	150	2	1	4	39	127	0.1	1280	12	18	0.6%	-	63	65
AARC 2008	34025	DR346	496	496.5	Footwall limestone	NAF	183	100	1	1	6	28	335	0.1	2540	21	14	1.3%	-	43	47
AARC 2008	34043	DR342	458	458.5	Footwall limestone	NAF	14	90	2	1	10	34	110	0.1	3610	21	27	1.0%	-	37	42
AARC 2008	34045	DR342	471	471.5	Footwall limestone	NAF	5	70	1	1	8	28	191	0.1	2440	22	61	1.2%	-	27	29
AARC 2008	34055	DR341	177	177.5	Footwall limestone	NAF	7	30	1	1	3	13	7	0.1	915	5	43	0.4%	-	6	60
AARC 2008	34057	DR341	183	183.5	Footwall limestone	NAF	9	20	1	3	4	12	19	0.1	1130	8	67	0.8%	-	6	1250
AARC 2008	34079	DR340	185.5	186	Footwall limestone	NAF	16	70	1	1	5	6	14	0.1	787	11	44	1.2%	-	10	129
AARC 2008	34186	DR319	446	446.5	Footwall limestone	NAF	9	70	1	3	4	6	17	0.2	1330	10	77	1.3%	-	10	1800

* underlined values indicate concentration less than the analytical detection limit

APPENDIX B-2 Geochemical abundance indices for drill core samples from previous geochemical studies of Dugald River waste rock

Element		Calc-silicate											Mafic feldspar porphyry							Hanging wall slate																					
		DR346 (140-140.5m)	DR342 (106.5-107m)	DR320 (112-112.5m)	DR319 (121-121.5m)	DR319 (124-124.5m)	DR322 (129-129.5m)	DR321 (163-163.5m)	DR321 (177-177.5m)	DR318 (219-219.5m)	DR318 (225-225.5m)	DR318 (227.45-228m)	DR342 (151.5-152m)	DR342 (260.5-261m)	DR342 (273-273.5m)	DR320 (212-212.5m)	DR320 (216-216.5m)	DR316 (266-266.5m)	DR316 (270-270.5m)	DR342 (362.5-363m)	DR342 (363.5-364m)	DR342 (364.5-365m)	DR342 (365.5-366m)	DR341 (99-99.5m)	DR341 (111-111.5m)	DR322 (157-157.5m)	229 (700-701m)	174 (168-169m)	DR346 (410-410.5m)	230 (662-663m)	230 (675-676m)	186 (672-673m)	231 (491-492m)	DR346 (402.5-403m)	DR346 (403.5-404m)	DR346 (414-414.5m)	DR341 (123-123.5m)	DR340 (124.7-125.2m)	DR340 (127-127.5m)	DR340 (130.5-131m)	DR315 (84-84.5m)	DR315 (90-90.5m)	DR315 (101-101.5m)	DR315 (102-102.5m)
		NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	UC	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF
As	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	1	3	3	1	2	4	0	2	2	4	6	2	4	5	3
Ba	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0
Be	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0
Cd	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1	0	0	0	0	0	4	3	4	5
Co	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	1	1	0	1	1	0	1	0	0	0	0	0	1	0	0	0
Cr	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0
Cu	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	3	4	2	0	0	0	0	2	3	5	1	2	2	0	2	2	0	0	0	0	3	5	3	3
Hg	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	2	2	3	4
Mn	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0
Ni	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0
Pb	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0
S	(%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	5	4	2	2	0	1	4	3	3	4	5	6	4	6	3	3	3	3	4	4	4	3	5
Sb	(mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-
V	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0
Zn	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3	2	0	5	4	0	0	0	0	5	5	6	6

APPENDIX B-2: *Continued*

Element		Lode Waste				Footwall slate																		Footwall limestone												Median Soil Content	
		DR319 (399-400m)	DR341 (146.5-147.5m)	DR340 (142.5-143.5m)	DR315 (270.5-271.5m)	DR341 (157.5-158m)	DR341 (162.5-163m)	DR340 (159.5-160m)	DR340 (160.5-161m)	DR340 (161.5-162m)	DR315 (273.2-273.7m)	DR315 (281.5-282m)	DR315 (292.5-293m)	186 (696-697m)	230 (703-704m)	231 (540-541m)	229 (747-748m)	174 (180-181m)	231 (508-509m)	DR346 (434.5-435m)	DR346 (432.5-432.9m)	DR342 (423-424m)	217 (1029-1030m)	202 (792-793m)	DR346 (490.5-491m)	DR346 (496-496.5m)	DR342 (458-458.5m)	DR342 (471-471.5m)	DR341 (177-177.5m)	DR341 (183-183.5m)	DR340 (185.5-186m)	DR319 (446-446.5m)	186 (824-825m)	174 (185-186m)	217 (1040-1041m)	230 (760-761m)		
		NAF	PAF	PAF	PAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	PAF	PAF	PAF	PAF	PAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	PAF	
As	(mg/kg)	1	4	5	0	1	0	2	3	2	1	0	1	2	3	1	4	1	4	1	0	6	2	4	0	4	0	0	0	0	0	0	2	3	3	0	6 mg/kg
Ba	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	500 mg/kg
Be	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	6 mg/kg
Cd	(mg/kg)	6	6	6	4	0	0	0	3	0	0	0	0	3	0	0	4	0	6	0	0	0	3	4	0	0	0	0	0	2	0	2	0	0	0	0	0.4 mg/kg
Co	(mg/kg)	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8 mg/kg
Cr	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	70 mg/kg
Cu	(mg/kg)	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3	0	0	1	2	1	2	0	0	0	0	0	1	0	0	30 mg/kg
Hg	(mg/kg)	5	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0.06 mg/kg
Mn	(mg/kg)	2	0	0	0	1	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	1	0	0	0	0	0	-	-	-	-	1000 mg/kg
Ni	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	50 mg/kg
Pb	(mg/kg)	1	1	3	1	0	0	0	0	1	0	0	0	2	0	0	1	0	1	0	0	1	3	4	0	0	0	0	0	0	0	0	1	0	0	0	35 mg/kg
S	(%)	6	6	6	5	2	2	2	3	3	3	3	4	3	2	2	5	3	5	3	3	6	4	6	2	3	3	3	1	2	3	3	3	4	3	3	0.07 %
Sb	(mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	-	-	-	0	0	-	-	-	-	-	-	-	-	0	0	0	0	5 mg/kg
V	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	90 mg/kg
Zn	(mg/kg)	6	6	6	6	0	0	1	4	1	0	0	1	4	1	1	3	2	6	0	0	0	4	6	0	0	0	0	0	3	0	3	1	1	0	1	90 mg/kg

Appendix C

Results of Column Leach Tests Involving Dugald River Waste Rock

AustralAsian Resource Consultants (2008)

APPENDIX C-1: Results of column leach tests involving Dugald River waste rock - Acid forming characteristics of column leach samples

Parameter	Unit	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
		HW Slate	Footwall Limestone	PAF Mixture	Footwall Slate	HW Calc-silicate	Calc-silicate & Porphyry	Mica Schist
Existing pH		8.6	9.3	8.8	9.0	9.4	9.4	9.6
EC	µS/cm	343	206	350	278	131	171	110
Total S	(%S)	2.39	0.56	9.47	0.96	0.03	0.02	0.05
MPA	kg H2SO4/t	73	17	290	29	1	1	2
ANC	kg H2SO4/t	71	222	35.6	112	180	197	80.3
NAPP	kg H2SO4/t	2	-205	254	-83	-179	-196	-79
NAG	kg H2SO4/t	0	0	161	0	0	0	0
NAGpH		8.5	10.7	1.9	8.4	11.5	11.8	11.7
ARD Class		UC	NAF	PAF	NAF	NAF	NAF	NAF

APPENDIX C-2: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Slate (Column 1)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	7.37	7.73	7.55	7.91	6.55	7.46	7.25	6.31	6.79	6.52	7.05	5.36	6.88	6.7	6.02	5.56	4.64	4.92
EC	401	379	229	218	203	275	244	170	297	227	259	98	191	119	196	171	209	375
Alk	17	21	25	22	24	19	22	15	4	6	9	4	6	1	<1	2	<1	<1
Acy	<1	<1	2	2	2	4	4	6	4	2	2	4	2	6	20	14	37	26
SO4	145	132	86	66	78	76	93	89	102	83	102	38	65	44	70	68	108	100
Si	0.42		0.7		0.5		0.73		0.41		0.47		0.23		0.12		0.35	
Cl	3		3		<1		3		<1		<1		<1		<1		<1	
Ca	40		30		29		35		31		32		19		15		19	
Mg	9		5		5		5		6		5		5		7		10	
Na	15		6		4		3		3		3		1		1		<1	
K	4		3		2		2		2		2		1		1		2	
Al	0.08		0.02		<0.01		0.02		0.1		<0.01		<0.01		0.05		0.19	
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Ba	0.005		0.004		0.006		0.006		0.006		0.005		0.004		0.003		0.004	
Cd	<0.0001		<0.0001		0.0003		0.0002		0.0009		0.0002		0.0007		0.0006		0.001	
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Co	0.004		0.001		0.004		0.003		0.005		0.003		0.01		0.013		0.031	
Cu	0.013		<0.001		<0.001		0.001		<0.001		<0.001		0.005		0.013		0.021	
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.002	
Mn	0.284		0.102		0.122		0.066		0.124		0.074		0.209		0.248		0.513	
Mo	0.001		0.004		0.004		0.003		0.001		0.001		<0.001		<0.001		<0.001	
Ni	0.021		0.003		0.012		0.008		0.013		0.007		0.021		0.031		0.069	
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sr	0.083		0.052		0.044		0.041		0.036		0.035		0.017		0.015		0.015	
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sn	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
U	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.002	
Zn	0.028		0.013		0.095		0.057		0.083		0.053		0.174		0.255		0.503	
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05	
Fe	<0.05		<0.05		0.62		0.46		1.04		0.15		1.85		5.5		10.4	
Hg	0.0007		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
SiO2	0.9		1.5		1.1		1.6		0.9		1		0.5		0.2		0.8	
F	<0.1		0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	

APPENDIX C-3: Results of column leach tests involving Dugald River waste rock - Leachate composition for FW Limestone (Column 2)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.89	8.79	8.54	8.33	7.5	7.76	8.03	6.23	7.56	6.55	7.35	7.91						
EC	177	173	170	140	180	149	162	122	149	144	137	72						
Alk	21	128	22	24	23	31	21	23	20	17	13	11						
Acy	<1	<1	<1	<1	<1	6	6	<1	2	2	2	4						
SO4	47	52	56	36	68	38	53	44	34	41	42	18						
Si	0.22		0.36		0.21		0.23		0.14		0.13							
Cl	2		6		<1		2		8		<1							
Ca	11		18		23		18		16		16							
Mg	1		3		4		4		2		3							
Na	16		10		9		5		2		2							
K	2		3		3		2		2		2							
Al	0.11		0.03		0.03		0.02		0.02		0.02							
Sb	0.001		0.001		0.001		<0.001		<0.001		<0.001							
As	0.001		0.001		<0.001		<0.001		0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.025		0.012		0.014		0.01		0.013		0.007							
Cd	<0.0001		<0.0001		0.0002		<0.0001		0.0001		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	0.002		<0.001		0.001		0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.042		0.02		0.037		0.015		0.021		0.013							
Mo	<0.001		0.003		0.002		0.002		0.001		0.001							
Ni	0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.072		0.091		0.089		0.062		0.045		0.044							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Zn	<0.005		0.012		0.019		0.007		0.09		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		0.07		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	0.5		0.8		0.4		0.5		0.3		0.3							
F	0.2		0.2		0.2		0.1		<0.1		0.1							

APPENDIX C-4: Results of column leach tests involving Dugald River waste rock - Leachate composition for PAF Rock Mixture (Column 3)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	7.23	7.48	7.12	7.59	6.41	6.64	5.59	4.99	6.03	5.67	5.24	5.19	4.62	5.17	5.49	4.78	4.52	4.45
EC	241	160	124	173	216	269	247	255	237	230	238	272	453	231	266	233	233	297
Alk	20	20	20	22	4	4	4	4	28	3	1	3	<1	<1	<1	2	<1	<1
Acy	<1	<1	2	2	15	20	26	33	18	22	18	15	64	24	47	35	51	63
SO4	82	50	42	57	105	106	100	139	76	98	85	115	170	96	128	98	103	129
Si	0.1		0.08		0.07		0.09		0.08		0.1		0.11		0.12		0.07	
Cl	<1		<1		<1		3		<1		<1		1		2		<1	
Ca	23		16		25		21		19		18		18		18		12	
Mg	3		2		8		8		8		8		19		12		8	
Na	10		3		4		3		1		1		1		1		2	
K	4		2		2		2		<1		<1		<1		<1		<1	
Al	0.04		0.02		0.09		0.14		0.08		0.16		0.47		0.36		0.37	
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Ba	0.018		0.011		0.023		0.01		0.01		0.008		0.006		0.006		0.004	
Cd	0.0002		0.0003		0.0021		0.0031		0.0037		0.0045		0.009		0.0089		0.0084	
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Co	0.003		0.003		0.014		0.016		0.014		0.012		0.036		0.02		0.02	
Cu	0.001		<0.001		0.004		0.003		0.002		0.006		0.019		0.026		0.031	
Pb	<0.001		0.003		0.014		0.019		0.008		0.016		0.018		0.028		0.031	
Mn	0.829		0.406		1.99		2.23		2.24		2.02		6.27		3.24		2.81	
Mo	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Ni	0.01		0.01		0.052		0.056		0.051		0.05		0.14		0.075		0.074	
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sr	0.07		0.032		0.041		0.032		0.022		0.024		0.026		0.023		0.015	
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sn	0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
U	<0.001		<0.001		0.003		0.005		0.002		0.004		0.008		0.007		0.008	
Zn	0.102		0.339		2.03		3.02		3.35		3.94		9.41		7.21		6.79	
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05	
Fe	<0.05		0.46		4.18		9.89		6.76		7.68		18.1		12.4		15.4	
Hg	0.0004		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
SiO2	0.2		0.2		0.1		0.2		0.2		0.2		0.2		0.2		0.1	
F	0.2		0.2		0.3		0.2		<0.1		0.1		0.4		0.2		0.2	

APPENDIX C-5: Results of column leach tests involving Dugald River waste rock - Leachate composition for FW Slate (Column 4)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.42	8.1	7.8	8.11	6.86	8.11	7.82	7.08	7.27	7.82	6.67	6.78						
EC	176	161	113	126	137	172	137	133	178	132	136	136						
Alk	12	15	23	82	14	21	22	16	16	9	13	10						
Acy	<1	<1	2	<1	2	2	4	12	12	2	2	2						
SO4	53	50	32	33	52	54	46	54	51	43	42	44						
Si	0.16		0.08		<0.05		0.07		0.11		0.07							
Cl	<1		4		<1		1		<1		<1							
Ca	18		15		19		19		19		18							
Mg	3		2		4		3		4		3							
Na	5		2		2		2		1		1							
K	3		2		2		2		1		1							
Al	0.06		0.03		0.03		0.02		0.04		0.02							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.012		0.004		0.006		0.004		0.006		0.004							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		0.0002		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	<0.001		<0.001		0.002		<0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.216		0.184		0.308		0.232		0.354		0.149							
Mo	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ni	0.002		<0.001		0.002		0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.025		0.015		0.018		0.014		0.013		0.012							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Zn	<0.005		<0.005		0.017		0.007		0.043		0.007							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		0.17		<0.05		<0.05		0.05							
Hg	0.0004		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	0.4		0.2		<0.1		0.1		0.2		0.1							
F	0.2		0.1		0.1		0.1		<0.1		<0.1							

APPENDIX C-6: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Calc-Silicate (Column 5)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	9.07	9.07	9.16	9.25	8.51	8.57	9.28	7.23	8.45	8.16	8.81	9.00						
EC	83	87	75	61	61	88	64	55	63	57	57	50						
Alk	36	214	38	116	25	66	24	27	27	22	31	22						
Acy	<1	<1	<1	<1	<1	4	<1	<1	<1	<1	<1	2						
SO4	8	9	5	3	6	7	8	5	10	6	5	4						
Si	0.74		0.68		0.39		0.43		0.44		0.33							
Cl	2		4		<1		2		3		<1							
Ca	7		7		7		6		5		8							
Mg	<1		<1		<1		<1		2		<1							
Na	9		6		4		5		13		3							
K	1		1		<1		1		1		<1							
Al	0.17		0.08		0.07		0.05		0.12		0.05							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	<0.001		<0.001		0.002		<0.001		<0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.004		0.004		0.004		0.005		0.007		0.004							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		0.0002		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	<0.001		<0.001		0.002		<0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.012		0.005		0.018		0.007		0.008		0.007							
Mo	0.024		0.017		0.009		0.012		0.006		0.007							
Ni	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.013		0.01		0.01		0.01		0.007		0.007							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	0.002		0.003		0.002		0.003		0.002		0.001							
Zn	<0.005		<0.005		<0.005		<0.005		0.062		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	1.6		1.5		0.8		0.9		1		0.7							
F	0.2		0.1		<0.1		<0.1		<0.1		<0.1							

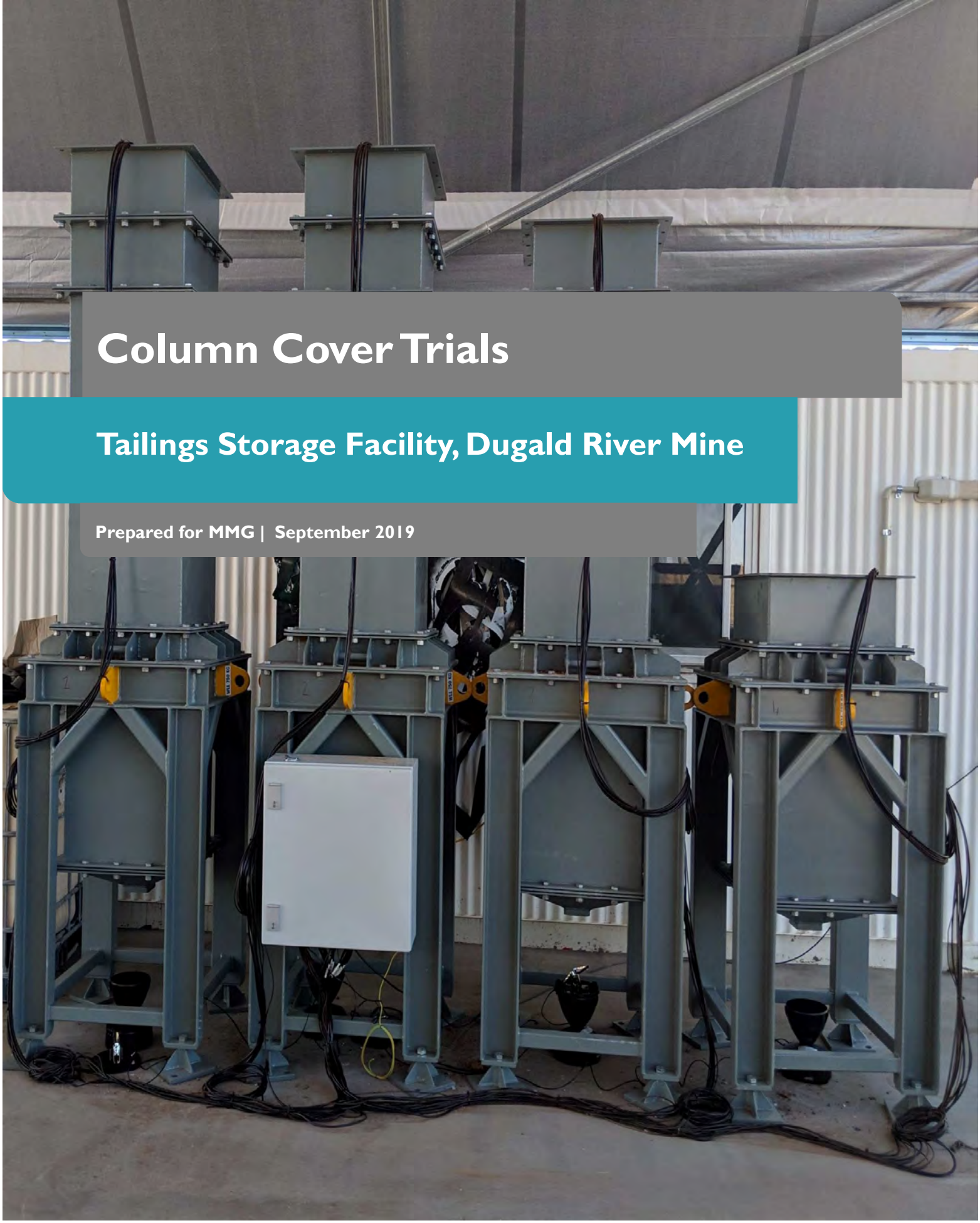
APPENDIX C-7: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Calc-Silicate & Mafic Feldspar Porphyry (Column 6)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.97	9.08	9.19	9.22	8.76	8.09	9.22	6.57	8.51	7.47	8.94	8.73						
EC	100	106	76	73	69	90	70	65	67	61	53	43						
Alk	32	120	24	85	22	62	21	26	24	19	18	13						
Acy	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	2						
SO4	10	10	8	6	12	8	10	10	6	8	4	4						
Si	0.57		0.52		0.26		0.37		0.34		0.24							
Cl	5		8		1		4		<1		<1							
Ca	8		7		8		7		7		7							
Mg	<1		<1		<1		<1		<1		<1							
Na	9		7		7		5		4		3							
K	1		1		1		1		1		<1							
Al	0.09		0.05		0.05		0.04		0.07		0.04							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.006		0.004		0.007		0.006		0.006		0.004							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
Cr	<0.001		<0.001		0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	<0.001		<0.001		0.002		0.002		0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.012		0.01		0.023		0.01		0.011		0.008							
Mo	0.006		0.006		0.005		0.005		0.002		0.002							
Ni	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.019		0.015		0.018		0.015		0.01		0.008							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	0.002		<0.001		<0.001		<0.001		<0.001		<0.001							
U	0.001		0.003		0.002		0.003		0.001		0.001							
Zn	<0.005		<0.005		0.006		<0.005		0.203		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	1.2		1.1		0.5		0.8		0.7		0.5							
F	0.2		<0.1		<0.1		<0.1		<0.1		<0.1							

APPENDIX C-8: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Mica Schist (Column 7)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.96	9.12	9.27	9.25	8.53	6.42	9.06	6.43	8.64	7.26	8.32	8.97						
EC	78	80	53	45	43	65	49	59	56	58	60	45						
Alk	24	47	36	35	23	44	17	27	23	16	19	15						
Acy	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	2						
SO4	9	10	5	1	3	3	4	5	3	4	3	3						
Si	0.56		0.49		0.15		0.33		0.41		0.19							
Cl	1		4		<1		2		<1		<1							
Ca	7		6		7		6		7		6							
Mg	<1		<1		<1		<1		<1		<1							
Na	6		4		3		3		2		2							
K	<1		<1		<1		<1		<1		<1							
Al	0.13		0.08		0.07		0.07		0.12		0.06							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	0.002		0.001		0.002		0.002		0.002		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.002		0.001		0.001		0.001		0.002		0.001							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	0.001		<0.001		0.002		0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.011		0.009		0.017		0.009		0.009		0.007							
Mo	0.008		0.005		0.004		0.004		0.002		0.002							
Ni	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.011		0.007		0.007		0.006		0.004		0.004							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	0.002		0.001		0.001		<0.001		<0.001		<0.001							
Zn	<0.005		<0.005		0.015		<0.005		0.013		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	1.2		1		0.3		0.7		0.9		0.4							
F	0.1		<0.1		<0.1		<0.1		<0.1		<0.1							

Appendix I: Column Cover Trials



Column Cover Trials

Tailings Storage Facility, Dugald River Mine

Prepared for MMG | September 2019

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Column Cover Trials

Tailings Storage Facility

Dugald River Mine

Prepared for MMG | 12 September 2019

Project number:	17007
Document title:	Column Cover Trials | Tailings Storage Facility | Dugald River Mine
Revision:	V2-1
Date:	12 September 2019
Client:	MMG
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Document history and status

Revision	Date	Description	By	Review	Approved
V0-1	14 June 2019	Draft	N Jamson	T Rohde	T Rohde
V0-3	26 June 2019	Draft	N Jamson	T Rohde	T Rohde
V1-1	11 September 2019	Draft	N Jamson	C Rieck	T Rohde
V2-1	12 September 2019	Final	N Jamson	C Rieck	T Rohde

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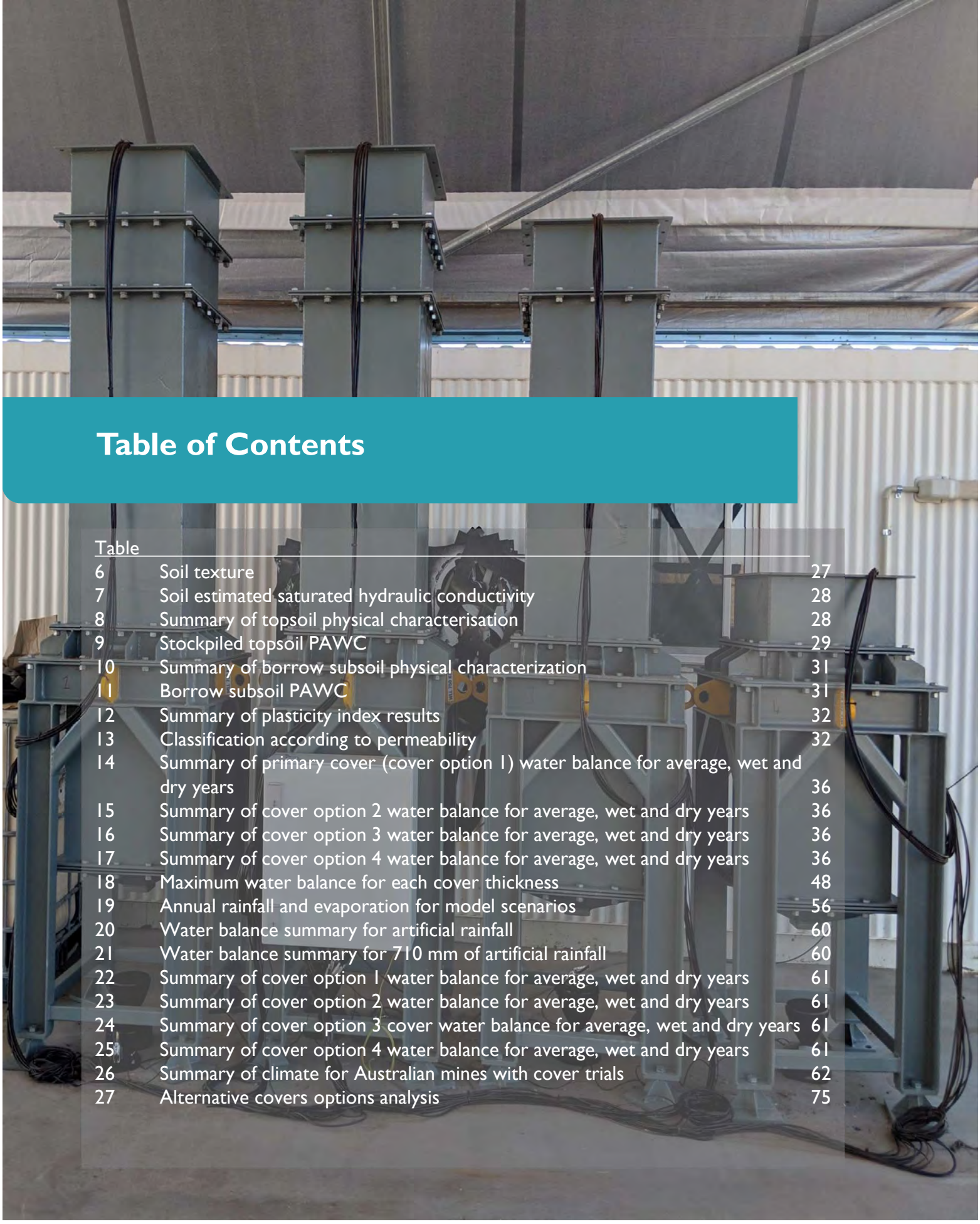

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Important note about your report

The sole purpose of this report and the associated services performed by SGM environmental Pty Limited (SGME) is to develop cover configurations and thicknesses (the covers) that are appropriate for the climate at Dugald River Mine and establish column trials (the trials) to test the performance of the covers in accordance with the scope of services set out in the contract between SGME and MMG. That scope of services, as described in this report, was developed with the Client.

In preparing this report, SGME has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by MMG and/or from other sources. Except as otherwise stated in the report, SGME has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

SGME derived the data in this report from information sourced from MMG, designated laboratories and/or information that has been made available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the potential covers and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.

SGME has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by SGME for use of any part of this report in any other context.

Reporting of the physical and chemical characteristics of soil, rock and other cover materials are based on a desktop assessment of data that has been measured by MMG and other third parties.

This report has been prepared on behalf of, and for the exclusive use of, MMG, and is subject to, and issued in accordance with, the provisions of the contract between SGME and MMG.

SGME accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

Executive summary

This study has shown through cover column trials (the trials) and a semi-calibrated model that the tailings storage facility (TSF) cover will likely require a 1 m thick infiltration storage layer (ISL) to reduce the potential for seepage into the potentially contaminating tailings. A reduction of rainfall infiltration will limit the potential for environmental harm through acid rock drainage (ARD) and limit water management requirements.

An environmental risk assessment was undertaken in conjunction with preliminary, uncalibrated modelling in SVFlux. The purpose of this was to determine the most suitable store and release cover options for the TSF (which would then progress to column trials). The preliminary model showed that cover option 2 was the preferred option. The availability of NAF waste rock for use in the TSF cover is unknown at this stage. Borrow subsoil was identified as a potential alternative material for use in the ISL and RPL. This material was therefore trialled in place of NAF waste rock in the trials.

The trials were commissioned in December 2018 and were subjected to varying amounts of artificial rainfall (510-910 millimetres (mm)) over a six-month period to develop a maximum water balance. The trials have not shown any signs of significant capillary rise. Following the trials, a semi-calibrated model was developed in SVFlux using maximum water balance from the trials. That is, soil water characteristic curves (SWCCs), saturated hydraulic conductivities and potential evaporation rates. The semi-calibrated model showed a good correlation to the observed results and it was accepted that the semi-calibrated model could be used to predict the long-term performance of the covers within a seepage error range of 4-7%.

Finally, the trials performance was simulated for a wet, average and dry year to predict the likely long-term performance of the four different covers had they been built on the TSF. The model was also run to simulate 710 mm of artificial rainfall applied to the trials (ie the artificial rainfall applied to cover option 3). The long-term prediction showed that a cover containing a 1 m thick ISL provides the best balance between rainfall infiltration storage and seepage. Seepage was predicted to be under 10% of annual rainfall in the long-term. The 710 mm of artificial rainfall model showed that the covers with a 0.5 m ISL are likely to experience high rates of seepage (>10% of annual rainfall) when subjected to short duration, high intensity rainfall (eg monsoonal conditions). This can be attributed to a lower infiltration storage capacity and as well as lower evaporation. A thicker ISL will also aid in the establishment of native vegetation and potentially further decrease seepage through transpiration. Cover option 1 and 2 are therefore the preferred cover options at this stage. Cover option 1 consists of:

- a 0.4 m CB layer of gap-graded NAF waste rock above the tailings at a density of 1.43 t/m^3; and
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.31 t/m^3; and
- a 1 m ISL of borrow subsoil above the RPL at a density of 1.64 t/m^3; and
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3.

Cover option 2 consists of:

- a 0.3 m CB layer of gap-graded NAF waste rock above the tailings at a density of 1.38 t/m^3;
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.27 t/m^3;
- a 0.3 m CB layer of gap-graded NAF waste rock above the RPL at a density of 1.38 t/m^3;
- a 1 m ISL of borrow subsoil above the CB layer at a density of 1.64 t/m^3; and
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3.

The necessity of an RPL cannot be confirmed or rejected with confidence at this stage. Additional trials are required and are discussed in Section 7.1. Cover options 1-4 will also need to be re-trialled with NAF waste rock in place of borrow subsoil (in the RPL and ISL), as either of these materials may be used in the final TSF cover (depending on NAF waste rock availability) (see recommendations, Section 7.1).

A comparison to Australian examples of mine site covers suggests that the preferred covers would perform comparably to those in the literature and below the maximum desirable seepage rate. Option 3 and 4 would likely perform above the maximum desirable seepage rate during short duration, high intensity rainfall events. This review also suggests that a 1 m thick ISL is likely required and that the optimum cover thickness for the Mine is likely between 1.2-2.3 m (depending on whether an RPL and/or CBs are included).

Three recommendations are made from this study:

1. The *Conceptual Closure Plan* (MMG 2015) has the following material balance available:
    - 79,751 m^3 of soil (MMG 2015);
    - 25,445 m^3 of soil, rock and vegetation mulch; and
    - 3.5 Mt or 1,750,000 m^3 of NAF waste rock assuming a density of 2 t/m^3.

    A detailed study is required to identify the potential sources and total volumes of potential cover material.
2. As the ISL and RPL in the chosen cover may contain borrow subsoil or NAF waste rock (depending on NAF waste rock availability), it is recommended that cover options 1-4 are trialled with NAF waste rock substituted for borrow subsoil. These covers will then be subjected to an artificial rainfall program. These covers would therefore include:
    - Cover option 5:
        - a 0.4 m CB layer of NAF waste rock;
        - a 0.5 m RPL of NAF waste rock above the CB;
        - a 1 m ISL of NAF waste rock above the RPL; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 6:
        - a 0.3 m CB layer of NAF waste rock;
        - a 0.5 m RPL of NAF waste rock above the CB;
        - a 0.3 m CB layer of NAF waste rock above the RPL;
        - a 1 m ISL of NAF waste rock above the CB layer; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 7:
        - a 0.3 m CB layer of NAF waste rock;
        - a 0.5 m RPL of NAF waste rock above the CB;
        - a 0.3 m CB layer of NAF waste rock above the RPL;
        - a 0.5 m ISL of NAF waste rock above the CB layer; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 8:
        - a 0.5 m ISL of NAF waste rock; and
        - a 0.2 m topsoil layer above the ISL.
3. The necessity of an RPL cannot be confirmed or rejected for the covers in this report. Additional trials (following the trials in recommendation 2) are therefore recommended to eliminate this uncertainty. This will involve decommissioning two column trials and constructing the following covers. These trials will then be subjected to an artificial rainfall program.
    - Cover option 9:
        - a 0.5 m RPL of borrow subsoil;
        - a 1 m ISL of borrow subsoil above the RPL; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 10:
        - a 1 m ISL of borrow subsoil; and
        - a 0.2 m topsoil layer above the ISL.

    These configurations could then be repeated for NAF waste rock in place of borrow subsoil if required.
4. Following the two sets of recommended trials, the covers of interest (based on the column trial results) should be moved to an uncovered position so that they are exposed to naturally occurring rainfall and evaporation. Vegetation should also be established on the trials. This will allow for a more thorough evaluation of the potential for capillary rise and the subsequent requirement for a CB. Periodic sampling of the trials could also be carried out. This will also allow the water balance to be further refined, including the prediction of long-term performance.
5. Large field trials should then be established and monitored prior to building the preferred cover on the TSF. The final decision on cover thickness should be based on (field) monitoring data for infiltration and seepage.

1.0 Introduction

1.1 Purpose

This report describes the development, implementation and findings from tailings cover column trials (the trials) conducted at Minerals and Metals Group (MMG) Dugald River Mine (the Mine). The trials were conducted to meet the requirements of the Mines Environmental Authority (EA) EPML 00731213 Schedule 1 – Land and Rehabilitation Conditions 115 to 117, as follows:

> (115) Within six (6) months of the commencement of tailings disposal in the tailings storage facility, the holder of this environmental authority must commence trials to establish suitable capping systems for infrastructure on the licensed place including but not limited to the tailings storage facility and all waste rock dumps.
>
> (116) By 1 October 2017 and once every two years thereafter the holder of the environmental authority must submit a report to the administering authority detailing the success and findings from the capping system trials.
>
> (117) By 2 October 2019 the holder of the environmental authority must submit to the administering authority a report nominating the most appropriate capping system for the tailings storage facility based on the results from trials required in condition 118.

1.2 Location and tenements

The Mine is located approximately (~) 85 kilometres (km) north-east of Mt Isa and 65 km north-west of Cloncurry in north-western Queensland (Figure 1). The Mine is located within the Mount Isa Mineral Province which is characterised by mineral exploration, mining and pastoral activities. The Mine is located on Roseby Station pastoral leases (the station), owned by Macmillan Holdings. The station is used for cattle grazing on unimproved pastures.

The Mine tenure includes 40 mining leases (MLs), one mining lease application (MLA) and one mineral development licence (MDL) granted under the *Mineral Resources Act 1989* and subsequent *Mines and Energy Legislation Amendment Act 2011* (Figure 1).

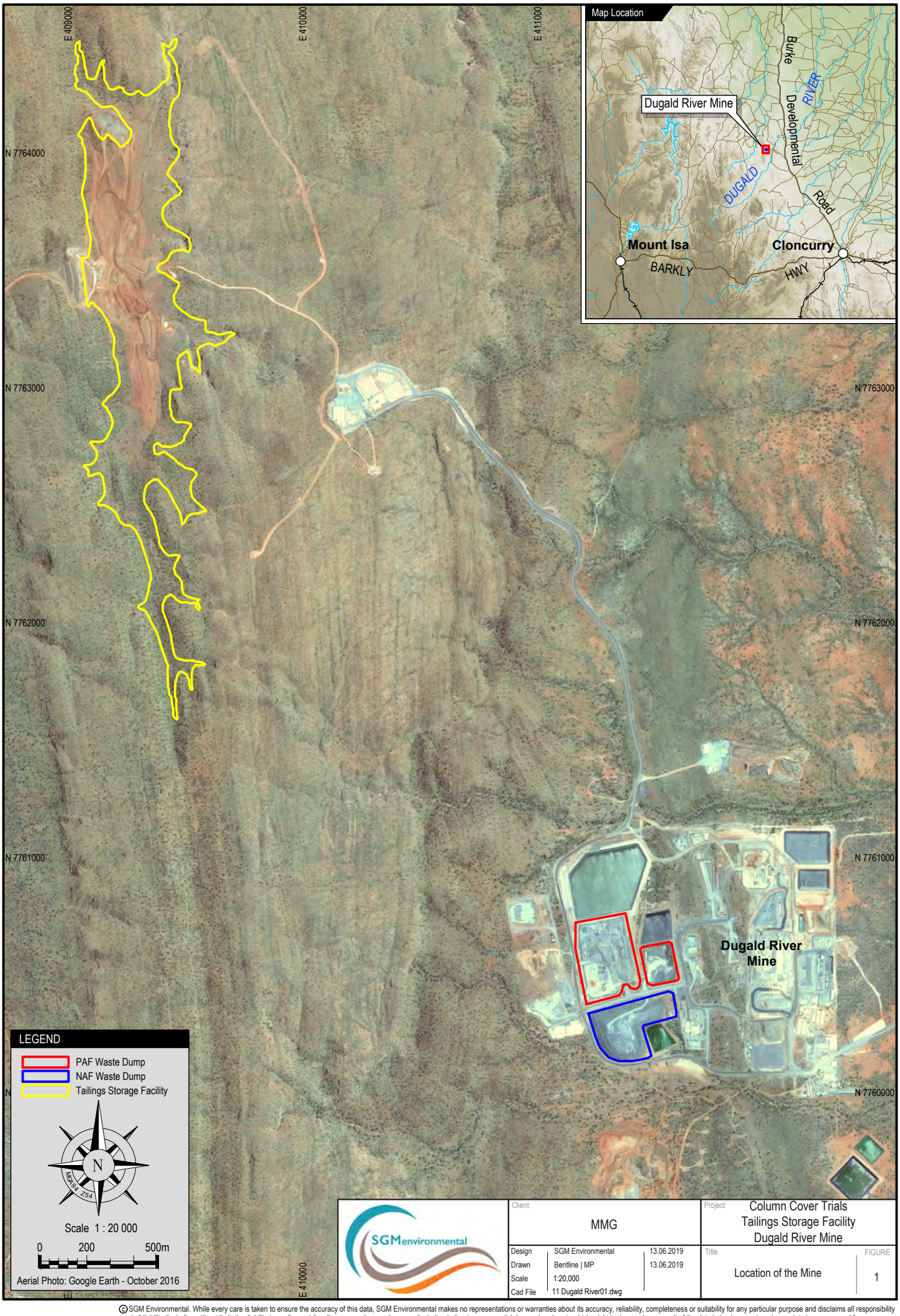
The tailings storage facility (TSF) is located on ML90211 (Figure 1).

1.3 Operational overview

The Mine is an underground zinc (Zn) and lead (Pb) mine. Ore is mined underground using conventional long hole open stoping and down hole benching methods. The Mine is accessed by twin declines. Ore is trucked to the surface to the run of mine (ROM) pad and concentrated through a flotation separation plant. Metal concentrate is stockpiled in a concentrate storage shed prior to placement in sealed containers for transport offsite by truck. Process waste (tailings) is transferred to the TSF for final disposal, or combined with cement to paste fill underground voids. Non-ore grade waste rock is generally used as backfill underground. Where waste rock cannot be directly placed underground, it is classified based on sulfide concentration as 'non-acid forming' (NAF) or 'potential acid forming' (PAF) waste, segregated and transferred to the surface for temporary storage in separate waste rock dumps.

The site also includes accommodation infrastructure, sewage treatment plants, access roads and water containment infrastructure.

The Mine's TSF is a valley fill TSF with 2 discharge locations to the north and south. The target tailings solids content is 55% prior to discharge. The tailings beach grades down towards the centre of the TSF. Tailings supernatant pools occur in the centre of the TSF and are intermittently pumped back to the processing plant for reuse as process water.



Client	MMG	Project	Column Cover Trials Tailings Storage Facility Dugald River Mine
Design	SGM Environmental	13.06.2019	
Drawn	Bentline | MP	13.06.2019	
Scale	1:20,000		
Cad File	11 Dugald River01.dwg		
		Title	Location of the Mine
		FIGURE	1

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At rehabilitation, very little reprofiling of the TSF surface will be required other than the embankment which will be converted to a rock lined spillway. The spillway will move excess water (rainfall runoff and cover seepage) off the top surface of the rehabilitated landform, preventing ponding.

The tailings at the Mine have the potential to (refer to Section 3.1 for more detail):

- leach metal and are PAF ie they produce ARD;
- generate acidic conditions and oxidise soon after discharge into the TSF; and
- develop a hard pan on the surface soon after deposition resulting in tailings below ~0.5 metres below ground level (m bgl) remaining fresh and unoxidised indefinitely after deposition.

Therefore, the PAF tailings, like PAF waste rock, require careful rehabilitation to minimise the risk of environmental harm to the receiving environment from ARD.

The *Conceptual Closure Plan* (MMG 2015) nominates the following objectives:

- return most of the disturbed land to a condition like the pre-existing condition of low intensity grazing, native habitat or to an agreed beneficial use:
    - TSF changes from Land Suitability Class 4-5 to Class 5 ie unsuitable land with extreme limitations that preclude its use for further agricultural use but the land is suited to native habitat;
    - landscape functionality will be like identified reference sites; and
    - levels of metals, sulfate, pH and electrical conductivity (EC) in surface soils will be like that of surface soils on reference sites.
- make disturbed areas stable to ensure that the proposed subsequent land use is not compromised by surface instability or erosion; and
- ensure that constructed landforms are geochemically stable to the extent that they do not impact on surface water or groundwater quality.

1.4 Climate

The mean annual maximum temperature at Cloncurry is 31.2 degrees Celsius (°C), with November to January being the hottest months (>35°C). The mean annual minimum temperature is 18.5°C with June to August being the coolest months (<12°C).

The average annual rainfall for the region is 513 millimetres (mm). Regionally there is a distinct wet season (between November and April), with very little rain falling in the remaining months of the year. Historical rainfall data from the weather station at Cloncurry Airport (Station number: 029141) shows that January and February exhibit the highest mean monthly rainfall, with both months averaging above 100 mm (149.1mm and 116.9 mm respectively). These months also experience the rainiest days, with more than 7 rain days per month.

The driest months of the year are July and August with mean rainfall under 5 mm (4 mm and 4.15 mm respectively). These months average less than one day of rain.

The evaporation rate is primarily temperature-driven with the highest mean monthly evaporation (328.6 mm) occurring in December, and the lowest (159.0 mm) in June. Evaporation exceeds rainfall in all months by a factor of three.

1.5 Report structure

This report is presented as five topics to address EA condition 116:

- Section 2.0 presents a risk assessment and the cover objectives and desirable attributes which will guide cover design.

- Section 3.0 presents a review of the physical and chemical properties of topsoil, borrow subsoil, waste rock and tailings to determine the range of suitable cover materials available to rehabilitate the TSF.
- Section 4.0 presents a summary of the preliminary modelling and the covers which will progress to column trials.
- Section 5.0 presents the method and set-up and the results of the trials that have been established at the Mine to test four potential cover options.
- Section 6.0 presents the semi-calibrated model and provides a preliminary prediction of long-term performance.
- Section 7.0 presents conclusions and recommendations.

2.0 Cover System Selection and Objectives

2.1 GARD guide cover assessment

Applying the GARD Guide cover criteria to the Mines' climate suggests a **store and release cover** is the most suitable cover system for the Mine's TSF (Figure 2). No alternate cover systems have been assessed for application at the Mine. The subsequent materials review, cover modelling and column trials aim to determine the most effective store and release cover configuration to meet the cover system objectives.

A store and release cover is a cover system constructed to reduce net infiltration by storing moisture during higher precipitation periods and releasing moisture via evapotranspiration in dryer periods. The store and release cover may be combined with other engineered controls, for example a reduced permeability layer (RPL) and/or a capillary break layer/s (CB) to further reduce the potential for environmental harm from the TSF after closure.

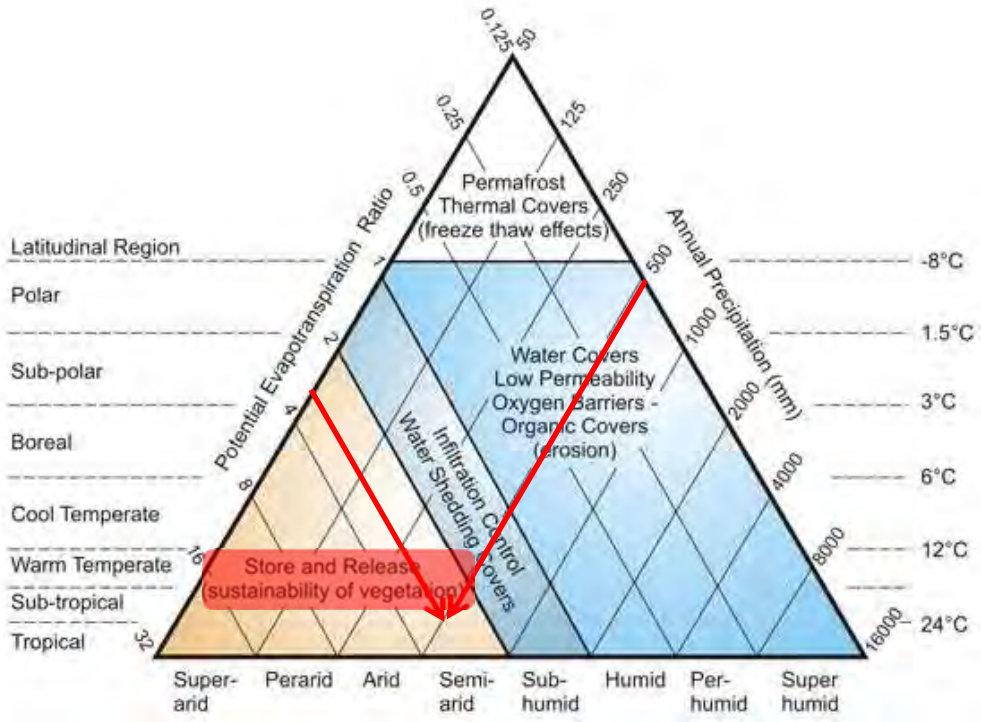


Figure 2 Covers and climate types (from GARD Guide 2009)

2.2 Environmental risk assessment

In order to define the basis of design for the store and release cover system and to guide the establishment of objectives for the cover system, an environmental risk assessment was conducted. The risk assessment assessed potential impacts on the receiving environment associated with the long-term storage of tailings in the TSF.

The environmental risk assessment was conducted using a risk assessment approach that is consistent with *AS/NZS ISO 31000:2009, Risk management - Principles and guidelines* (the risk standard), and the Mine risk evaluator developed by MMG (MMG document number 16254157). The risk matrix which identifies likelihood descriptions and consequence ratings is presented in Appendix C.

2.2.1 Results

Table 1 presents the environmental risk assessment grouped as per the key review areas.

These risks will be addressed through the cover which will incorporate characteristics described in the cover priorities and cover purpose and desirable attributes in Section 2.3. This information is all considered in the cover options analysis shown in Appendix D.

Table 1 Environmental risk assessment

Review topic	Hazard source	Risk name	Cause	Pathway	Receptor	Impact	Consequence	Likelihood	Risk level	Rationale
Geochemical	TSF	ARD	Sulfide oxidation with or without associated neutralisation reactions.	Infiltration, seepage, runoff	Surface water, groundwater, dependent ecosystems	Poor seepage water quality. Poor water quality in surface water and groundwater. Surface salts from evaporation of near surface infiltration.	5	E	Very high	Kinetic testing indicates tailings are acid forming and metal leaching. Tailings have little ANC.
		Exposure of PAF tailings	Catastrophic failure. Gully erosion. Differential settlement and cracking of TSF.	Infiltration, seepage, runoff, wind	Surface water, groundwater, dependent ecosystems	Increased solute load to environment.	5	E	Very high	As above.
		Poor quality seepage	Heavy rainfall events. Lack of water mixing. Poor water management. Constituents of concern in tailings.	Infiltration, seepage	Surface water, groundwater, dependent ecosystems	Poor seepage water quality. Release of heavy metals and salts from TSF by leaching. Poor water quality in surface water and groundwater.	5	E	Very high	As above.

Review topic	Hazard source	Risk name	Cause	Pathway	Receptor	Impact	Consequence	Likelihood	Risk level	Rationale
						Surface salts from evaporation of near surface infiltration.				
Erosivity		Wind erosion	Drying of TSF. Storm event (high winds).	Wind	Surface water, vegetation, grazing land, dependent ecosystems	Poor visual amenity. Spread of potentially contaminating tailings material on and off the ML. Smothering of vegetation.	3	D	Medium	Winds within the area can be variable and are influenced by the location of high-pressure cells and storm fronts that may move over the Mine. Windiest months occurring from October through to March.
		Water erosion	Run on. Access to land by cattle.	Runoff, infiltration, seepage	Surface water, groundwater, dependent ecosystems	Excessive downstream sedimentation. Increased seepage of poor quality water. Unsafe and unsustainable landform.	5	E	Very high	Hard-panning of surface layer as oxidation takes place.

Review topic	Hazard source	Risk name	Cause	Pathway	Receptor	Impact	Consequence	Likelihood	Risk level	Rationale
Surface water		Water logging	Head of water within TSF causing a groundwater mound, with seepage at the toe. Poor infiltration. Storm event.	Capillary rise	Vegetation	Death of vegetation. Capillary rise of salts. Instability of TSF embankment.	5	D	High	Monthly rainfall rarely exceeds evaporation.
Groundwater		Reduced water quality	Seeping of constituents from TSF into groundwater.	Infiltration, seepage	Groundwater, dependent ecosystems	Prevention of beneficial groundwater use.	3	B	Low	TSF is designed to contain all tailings and water. No seepage is anticipated and therefore there is no impact on the groundwater and pre-existing groundwater elevation.
Vegetation		Inability to establish and sustain native vegetation	Insufficient seed supply for rehabilitation. Insufficient and inappropriate	-	-	Poor visual amenity. Unstable landform with increased erosion rates.	3	E	High	Kinetic testing indicates tailings are acid forming and metal leaching. Unlikely to be

Review topic	Hazard source	Risk name	Cause	Pathway	Receptor	Impact	Consequence	Likelihood	Risk level	Rationale
			growth medium with shortfalls in plant available water. Lack of evidence of ability to grow appropriate species in available substrate. Climatic uncertainty (extreme variability).			Increased seepage of poor water quality.				favourable for plant growth.

2.3 Cover system objectives

Based on the outcomes of the environmental risk assessment the cover system objectives are as follows:

- limit rainfall infiltration into the tailings to prevent seepage, and mobilisation of oxidation products from the PAF tailings that may form ARD impacting on surface water and/or groundwater; and
- provide an environment favourable to the growth of vegetation and minimise the risk of erosion.

The TSF cover will have the following desirable attributes:

- The cover should be simple and easy to construct.
- The cover should mimic the surrounding undisturbed soil profile ie the cover should include an ISL capable of providing PAWC and nutrients to sustain vegetation growth.
- The geochemistry of the cover should closely replicate those of surrounding undisturbed soil. That is, the pH of the ISL should be near-neutral and non-saline and will likely have low fertility.
- The cover should limit the potential for seepage into the tailings. For semi-arid Australian environments, seepage should be less than 10% of cumulative rainfall or 8.64×10^{-4} m/day.
- If required, the cover should limit the potential for seepage by inclusion of an RPL.
- If required, the cover should limit the potential for capillary rise by inclusion of a CB if required.

These objectives and desirable attributes are aligned to the Mine's *Conceptual Closure Plan* (MMG 2015) objectives of:

- return the majority of disturbed land to a condition similar to the pre-existing condition of low intensity grazing, native habitat or to an agreed beneficial use;
- on rehabilitation of the Project, make disturbed areas stable to ensure that the proposed subsequent land use is not compromised by surface instability and erosion; and
- ensure that constructed landforms are geochemically stable to the extent that they do not impact on surface water or groundwater quality.

3.0 Material Review

The purpose of this chapter is to review soil, waste rock, and tailings:

- geochemistry;
- physical attributes; and
- research undertaken to date towards potential cover designs.

Any potential constraints and opportunities that may give rise to potential risks, and would influence the cover design, are also discussed.

3.1 Tailings

3.1.1 Geochemistry

EGi (2009) completed a geochemical analysis of a sample of tailings to determine total sulfur (S), net acid generation (NAG) and potential sulfate loads in a kinetic column test. The geochemical analysis found that the tailings sample had a total S of 7.9 % and was strongly acid generating with a NAG capacity of 86 kilograms of sulfuric acid per tonne of tailings (kg H_2SO_4/t). Under column leach testing, the tailings acidified to around pH 3.5 within the first few months of leaching. Over the course of the 52-week column test, the concentration of sulfate in leachate ranged from 1,640-5,720 milligrams per litre (mg/L) and averaged 3,080 mg/L.

Static geochemical testing of three tailings samples were undertaken as part of the MMG (2018) sampling program (Appendix A). The tailings had a total S content of 7.25-7.94% with a NAG capacity of 132-149 kg H_2SO_4/t. Net acid production potential (NAPP) values ranged from 219-232 kg H_2SO_4/t. These results are consistent with the EGi (2009) findings. Water-soluble metals are those that are easily leachable in rainfall and surface runoff. Water-soluble levels of aluminium (Al), Pb, manganese (Mn) and Zn were elevated.

Therefore, the tailings at the Mine will be PAF and are expected to produce acidic seepage with high concentrations of metals and suflates.

3.1.2 Unified soil classification system

ATC Williams (2008 and 2015) and MMG (2018) collected a sample of tailings from the Mine which was submitted to a laboratory for particle size distribution analysis. The MMG (2018) sample consists largely of silt with smaller amounts of fine sand and clay (Figure 3).

Other available physical characterisation results for tailings are reported in (MMG 2018, ATC 2008 and ATC Williams 2015) Table 2. The MMG (2018) results are presented in Appendix B.

Table 2 Tailings physical characterisation results

Test	ATC (2008)	ATC Williams (2015)	MMG (2018)
Specific gravity	2.96	2.97	3.04
Atterberg limits			
Liquid limit	21	19	29
Plasticity Index	6	0	8
Unified soil classification	Low plasticity clay	Low plasticity silt	Low plasticity clay

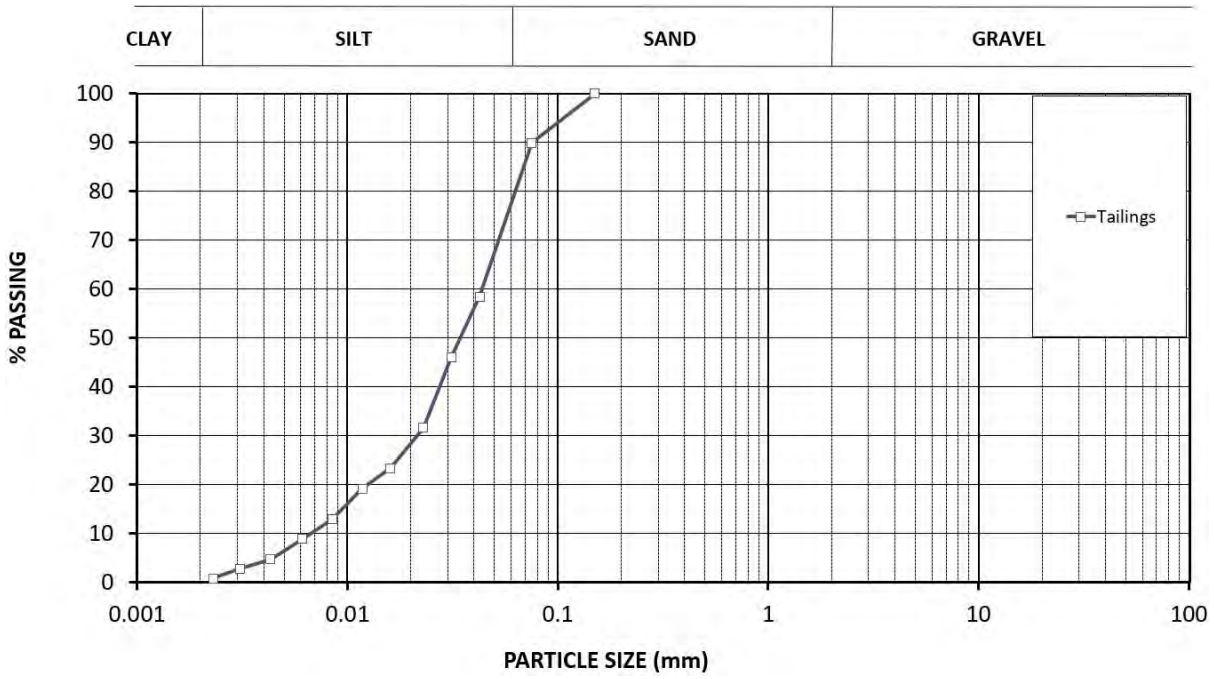


Figure 3 Tailings PSD (MMG 2018)

3.1.3 Compaction

MMG (2018) collected a bulk tailings sample for standard compaction tests. This was used to determine the standard maximum dry density (SMDD) and standard optimum moisture content (SOMC) which came in at 1.68 tonnes per cubic metre (t/m^3) and 20% respectively.

3.1.4 Permeability

Saturated hydraulic conductivity was measured by ATC Williams (2015) as part of a rowe cell consolidation test. The saturated hydraulic conductivity of the tailings ranges between 3×10^{-8} meters per second (m/s) to 2×10^{-7} m/s. Assuming that each metre of cover applies about 35 kilopascals (kPa) of pressure (Williams & King 2016) then the corresponding void ratio (e) is equal to 0.85 or 6×10^{-8} m/s.

Saturated hydraulic conductivity was measured using the constant head method by MMG (2018). The tailings sample is classified as having an extremely low permeability (at 95% SMDD) (Greeves et al. 1995) (Table 3) (4.1×10^{-8} m/s).

Table 3 Classification according to permeability

Degree of permeability	Range of coefficient of permeability *k* (m/s)
Very high	$>3.3 \times 10^{-5}$
High	3.3×10^{-5} to 1.7×10^{-5}
Moderate	1.7×10^{-5} to 5.6×10^{-6}
Low	5.6×10^{-6} to 2.8×10^{-6}
Very low	2.8×10^{-6} to 1.4×10^{-7}
Extremely low	**$< 1.4 \times 10^{-7}$**

3.2 Cover materials

The available materials at the Mine to construct a store and release cover are topsoil, borrow subsoil and NAF waste rock.

3.2.1 Geochemistry

3.2.1.1 Soil

The characteristics of soil in the vicinity of the operation have been determined by reviewing soil studies conducted during the Mine's environmental approvals process (AARC 2010) and analysis of stockpiled topsoil conducted in 2018 (MMG) during the trials.

3.2.1.2 Pre-disturbance soil

a Fertility

Soil fertility was assessed by AARC (2010) as part of the land suitability assessment for the environmental approval for the Mine (the land suitability assessment). The land suitability assessment described six types of soil broadly categorised as non-texture contrast soil. That is, the soil horizons do not have large textural changes (Table 4). The low fertility classification is derived from a laboratory assessment of the soil types for nitrate, total and available phosphorous (P), available potassium (K), organic carbon, chloride and exchangeable cations (AARC 2010). All soil types display circum-neutral pH (AARC 2010) and do not require pH correction before vegetation can be established.

Table 4 Soil type, description, fertility and salinity

Soil type	Australian Soil Classification	Description	Fertility	Salinity
Red plain	Rudosol	Sandy loam to sandy clay loam at least 75 cm deep usually overlying rock at shallow depth	Generally low	Non-saline
Knapdale	Tenosol	Skeletal sandy clay loam overlying rock at shallow depth	Generally low	Non-saline
Dale	Tenosol	Sandy loam at least 75 cm deep usually overlying rock at shallow depth	Generally low	Non-saline
Miners	Rudosol	Sandy clay loam overlying rock at shallow depth	Generally low	Non-saline
Prospectors	Tenosol	Clay loam overlying rock at shallow depth	Generally low	Non-saline
Pocket	Tenosol	Sand and/or clay loam overlying rock at shallow depth	Generally low	Non-saline

Based on the assessment of soil fertility (AARC 2010), it can be assumed that stockpiled soil that may be used in the cover will be non-saline and will have generally low to moderately low fertility. It is not expected to limit vegetation establishment.

b Metal concentrations

As part of the AARC (2010) land suitability assessment, metal concentrations were measured to determine baseline soil conditions. The Mine lies in a mineralised zone and metals such as Pb, silver (Ag), Cu, Zn, iron (Fe), boron (B) and Mn may be elevated in the soil. Metal concentrations were assessed for each soil type against the *Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland* (DERM 1998). The AARC (2010) analysis found that concentrations of Cu, Fe, Mn, Zn and B were all below environmental and health investigation limits described in Appendix 9.1 of DERM (1998). The concentration of Pb exceeded both the environmental and health investigation limits described in Appendix 9.1 of DERM (1998) in the Miners soil unit. Therefore, an elevated Pb concentration in the cover may not be a result of contamination.

c Erosivity

All soil types were assessed for exchangeable sodium percentage (ESP) and exchangeable calcium (Ca). AARC (2010) found that all soil types had ESP values less than 6% and are Ca dominated. Therefore, the soils are not dispersive.

3.2.1.3 Stockpiled topsoil

Three samples of stockpiled topsoil were collected by the Mine as part of this study (MMG 2018). The full chemistry results are shown in Appendix A.

a Fertility

Stockpiled topsoil fertility results are presented in Table 5:

- Exchangeable magnesium (Mg) and K are both considered adequate while Ca is very high. ESP is very low indicating that the topsoil is not sodic. Cation exchange capacity (CEC) is either slightly below or just above sufficiency levels indicating a limited capacity to store nutrients.
- Topsoil is moderately alkaline (pH 8.2-8.3) which is consistent with the Pocket soil type identified in Section 3.2.1.2a. The elevated exchangeable Ca indicates that the source of the alkalinity is from calcium carbonates. This pH range is not expected to restrict plant growth.
- Topsoil EC is moderate with most of this salinity coming from soluble carbonates and suflate salts (not chloride). It is important to note that sulfate salinity is generally better tolerated than chloride salinity. EC is unlikely to restrict plant growth.
- Total nitrogen (N) levels are very low while soluble nitrite and nitrate are below sufficiency levels in two out of the three samples. Nitrogen deficiency may be a restriction to plant growth.
- P (Colwell) is above sufficiency levels for all samples indicating that P is unlikely to be a restriction to plant growth.

The stockpiled topsoil has similar chemical properties to pre-disturbance soils and is therefore expected to match surface soil pH, EC, sulfate and soluble metals of reference sites. It is expected that the stockpiled topsoil will exhibit low to moderately low soil fertility but not to the point that it is expected that vegetation will not establish in the topsoil.

Table 5 Stockpiled topsoil and borrow subsoil fertility assessment

			Sample					
Constituent	**Unit**	**Sufficiency**	**Topsoil 1**	**Topsoil 2**	**Topsoil 3**	**Borrow subsoil 1**	**Borrow subsoil 2**	**Borrow subsoil 3**
pH	pH unit	6.0-7.5	**8.2**	**8.2**	**8.3**	**8.4**	**8.5**	**8.6**
EC	deci-Siemens per meter (dS/m)	<1.9	1.2	1.5	1.1	**2.4**	1	1.1
Soluble chloride	Milligrams per kilogram (mg/kg)	<800	<10	<10	<10	20	<10	<10
Soluble sulfate	mg/kg	-	20	20	20	140	10	20
CEC	milliequivalent/100 grams (meq/100 g)	12-25	**8.7**	**8.1**	**9.2**	**11.1**	**10.5**	12.6
Exchangeable Ca	%	60-75	**85.1**	**84.0**	**84.8**	**80.2**	**81.0**	**82.5**
Exchangeable Mg	%	10-20	11.5	11.1	10.9	16.2	13.3	14.3
Exchangeable K	%	3-8	3.4	3.7	3.3	3.6	5.7	3.2
Exchangeable aluminium (Al)	%	<1	<1	<1	<1	<1	<1	<1
ESP	%	<6	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrite and nitrate	mg/kg	>15	**7.8**	22.3	**1.8**	79.5	**11.1**	**14.7**
Total N	mg/kg	>1,500	**470**	**380**	**350**	**750**	**570**	**880**
Bicarbonate extractable P (Colwell)	mg/kg	>10	14	17	15	**<5**	**8**	**6**

Notes: 1. Bold = did not meet or exceed sufficiency target

b Erosivity

The stockpiled topsoil has a very low ESP indicating that it is not sodic. Structural stability of soil is heavily influenced by a combination of EC of the soil solution and ESP. If a soil is sodic, it is vulnerable to dispersion. Dispersed soils have reduced infiltration and hydraulic conductivity leading to an increased potential for erosion and build-up of salts in the root zone. Dispersion declines as the EC of the soil solution increases. The Electrochemical Stability Index (ESI) expresses this relationship (EQN1):

$$ESI = EC_{1:5}/ESP \quad [EQN1]$$

Australian soils with an ESI <0.05 have the potential to disperse. The median ESI of the stockpiled topsoil was 500, indicating a high structural stability. The topsoil has a low to moderate fine sand and silt content. These particles are most susceptible to liquefication.

The Emerson aggregate test showed that all samples fall into either Class 4 or Class 8. Class 4 indicates the topsoil will readily slake but with a low risk of dispersion. Class 8 indicates that the topsoil will not readily slake with a negligible risk of dispersion. Therefore, the topsoil is non-dispersive and has low potential to erode.

3.2.1.4 Borrow subsoil

a Fertility

Three samples of borrow subsoil were collected by the Mine as part of this study (MMG 2018). Results are presented in Table 5 and Appendix A:

- Exchangeable Mg and K are both considered adequate while Ca is very high. ESP is very low indicating that the borrow subsoil is not sodic. CEC is either slightly below or just above sufficiency levels indicating a limited capacity to store nutrients.
- The borrow subsoil is moderately to strongly alkaline (pH 8.4-8.6) which is consistent with the topsoil described in Section 3.2.1.3a. The elevated exchangeable Ca indicates that the source of alkalinity is from calcium carbonates. This pH range is not expected to restrict plant growth.
- EC is moderate to high with most of this salinity coming from soluble carbonates and suflate salts (and not chloride). It is important to note that sulfate salinity is generally better tolerated than chloride salinity. EC is unlikely to restrict plant growth.
- Total N levels are very low while soluble nitrite and nitrate are below sufficiency levels in two out of the three samples. Nitrogen deficiency may be a restriction to plant growth.
- P (Colwell) is below sufficiency levels for all samples indicating that P may be a restriction to plant growth.

It is expected that the borrow subsoil will exhibit low soil nutrition but not to the point that it is expected that vegetation will not establish in the borrow subsoil.

b Erosivity

The borrow subsoil samples have a very low ESP indicating that they are not sodic. The borrow subsoil also had a median ESI of 510, indicating a high structural stability. The borrow subsoil samples have a low to moderate fine sand and silt content. The Emerson aggregate test showed that all samples fall into Class 4. Class 4 indicates the borrow subsoil; will readily slake but with a low risk of dispersion. Therefore, the borrow subsoil is non-dispersive and has a low potential to erode.

3.2.1.5 Waste rock

Waste rock was first geochemically analysed by AGC Woodward-Clyde (1991) followed by AARC (2008) (the early geochemical analysis) with further analysis completed by EGi (2010). The early geochemical analysis found that:

- the initial pH of most samples was circum-neutral, suggesting that drainage from freshly mined waste rock will likely be neutral to alkaline;
- most samples were enriched to some extent with sulfur (S), but most samples also had high to very high acid neutralising capacity (ANC) and were classified as NAF;
- S contents were distributed as follows:
    - 30% low (<0.01 to 0.3 %S);
    - 20% low to moderate (0.3 to 1.0 %S); and
    - 50% high to very high (> 1%S).
- ANCs were distributed as follows:
    - 14% low (<10 kilograms of sulfuric acid per tonne of waste rock (kg H_2SO_4/t));
    - 28% low-moderate (10 to 50 kg H_2SO_4/t); and
    - 58% high to very high (>50 kg H_2SO_4/t).

The early geochemical analysis also found that ~70-75% of waste rock would be PAF with PAF waste rock coming from the lode, hanging wall and foot wall.

PAF waste rock

Geochemistry was further assessed by EGi (2010) who also reported that the majority of PAF waste rock will be associated with the lode. Waste rock from within the lode will have:

- a high to very high capacity for acid generation (high sulfur content (9.47 %S);
- a low to moderate ANC (36 kg H_2SO_4/t); and
- a high net acid producing potential (NAPP) (254 kg H_2SO_4/t) if stockpiled in WRDs.

It is also likely that some waste rock from the adjoining hanging wall and foot wall will also be PAF. The acidification of PAF waste rock is likely to lead to leaching of Fe, Zn, Mn and Al, all of which are enriched (EGi 2010). However, other environmentally important metals such as mercury (Hg), arsenic (As), chromium (Cr), Pb, antimony (Sb), tin (Sn) and selenium (Se) are expected to remain below the analytical detection limit (EGi 2010).

NAF waste rock

NAF waste rock at the Mine is most likely associated with calc-silicate, mafic feldspar porphyry, white mica schist lithologies and footwall limestone lithology. Further, the calc-silicate and footwall limestone are likely to have a high to very high ANC ranging from 80-222 kg/t H_2SO_4 (EGi 2010). NAF waste rock leachate is:

- expected to be neutral to moderately alkaline (pH 7.6-8.4);
- have moderate alkalinity (21-54 milligrams per litre (mg/L));
- low to moderate sulfate (4-46 mg/L); and
- low Ca concentrations (7-17 mg/L).

NAF waste rock is not expected to release metals; however, Zn, Hg, Mn and Ca concentrations may approach the analytical detection limit (0.0001 mg/L) (EGi 2010).

Therefore, NAF waste rock is considered an asset at the Mine and is suited for use for rehabilitation and civil construction activities. Excess NAF waste rock should only be returned underground as stope fill if not used in rehabilitation or construction projects.

3.2.2 Physical characterisation

The physical characteristics of soil, borrow subsoil, and tailings will determine the potential performance of the cover. Ore is not included in this section since it is PAF and is mined for sale and therefore not available for rehabilitation earthworks. Residual ore remaining on the PAF WRD will be used as stope fill.

The following sections describe the physical characteristics of potential cover materials and tailings that will be used in the preliminary and semi-calibrated SVFlux models (SoilVision 2018) to determine how a range of potential covers may behave after construction on the TSF.

3.2.2.1 Pre-disturbance soil

a Particle size distribution

Soil texture was assessed in the field by AARC (2010) using hand texturing (Table 6). The hand texture classification can be converted to a particle size distribution using reference soils in the SoilVision (2009) program (Figure 4).

Table 6 Soil texture

Soil type	Hand texture result
Red plain	Sandy loam to sandy clay
Knapdale	Sandy clay loam
Dale	Sandy loam
Miners	Sandy clay loam
Prospectors	Clay loam
Pocket	Sand and/or clay loam

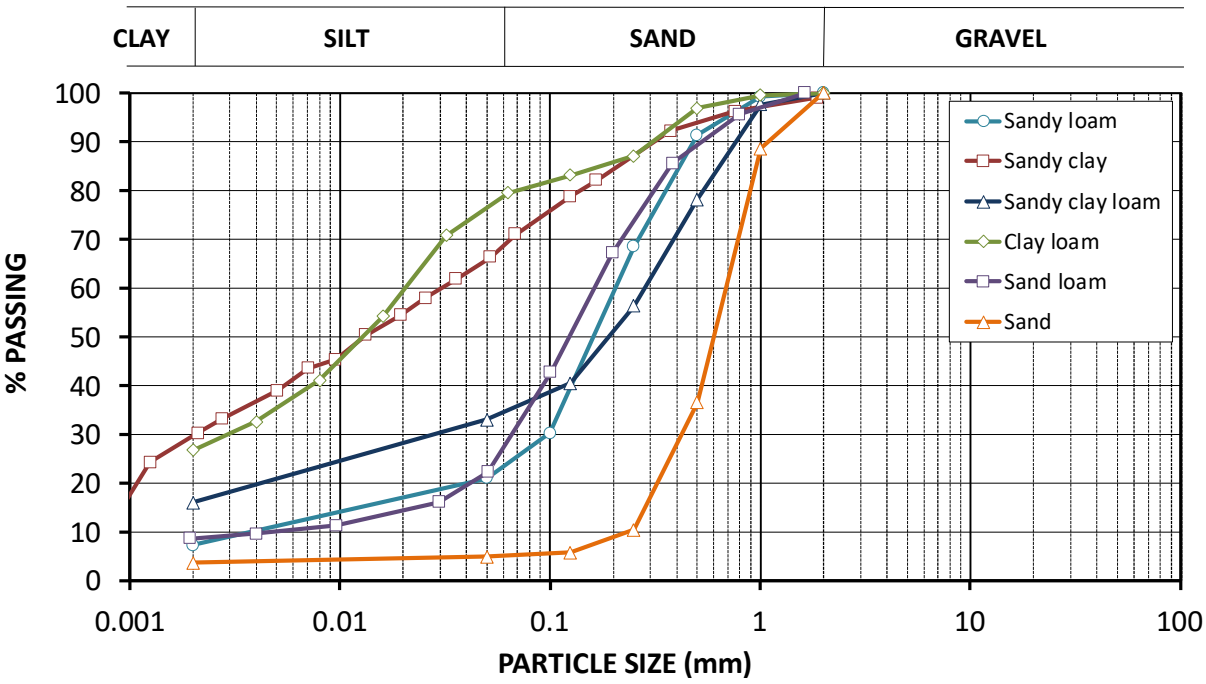


Figure 4 Soil particle size distribution from hand textures using SoilVision

Figure 4 indicates that the soil textures described by AARC (2010) are likely bound by sand and clay loam at the lower and upper limits respectively.

b Permeability

Soil permeability can be estimated from hand texture, structure, ESP and EC using the scheme described in Charman & Murphy (2010) (Table 7).

Table 7 Soil estimated saturated hydraulic conductivity

Soil type	Hand texture result	Structure	ESP	Median EC	Low saturated hydraulic conductivity	High saturated hydraulic conductivity
		Units	**%**	**dS/m**	**metres per second (m/s)**	**m/s**
Red plain	Sandy loam to sandy clay	Single grain/weak	<5%	<0.7	1.67×10^{-5}	1.94×10^{-4}
Knapdale	Sandy clay loam	Single grain/weak	<5%	<0.7	1.67×10^{-5}	1.94×10^{-4}
Dale	Sandy loam	Single grain/weak	<5%	<0.7	1.67×10^{-5}	1.94×10^{-4}
Miners	Sandy clay loam	Single grain/weak	<5%	~0.8	1.39×10^{-6}	5.56×10^{-6}
Prospectors	Clay loam	Single grain/weak	<5%	<0.7	2.78×10^{-8}	6.94×10^{-7}
Pocket	Sand and/or clay loam	Single grain/weak	<5%	<0.7	3.33×10^{-5}	8.33×10^{-5}

The average saturated hydraulic conductivity of soil at the mine is 6.88×10^{-5} m/s.

3.2.2.2 Stockpiled topsoil

Physical characterisation data was collected on the stockpiled topsoil as part of the MMG (2018) sampling program (Appendix B).

a Unified soil classification system

Two basic parameters can be determined from the particle size distribution curves (Figure 5). These are the effective size, D_{10}, which is the particle size in mm through which 10% of the particle size passes, the uniformity coefficient, C_u; and the coefficient of curvature, C_z. C_u and C_z are defined by the following relationships (Das 2000 & Das 2002).

[EQN2]

[EQN3]

The parameters shown in Table 8 may be used to classify the stockpiled topsoil in terms of its grading. The higher the value of the C_u, the larger the range of particle sizes in the material. A well-graded material is regarded as one that has a C_u greater than about 4 if it is primarily a gravel matrix, and 6 if it is sand; and a C_z between 1 and 3, for both sand and gravel (Das 2000 & Das 2002).

Table 8 Summary of topsoil physical characterisation

Sample identification	D_{10}(mm)	D_{30}(mm)	D_{60}(mm)	C_u	C_z
Topsoil 1	0.015	0.08	1.2	80	0.36
Topsoil 2	0.001	0.02	0.15	150	2.7
Topsoil 3	0.001	0.03	0.5	500	1.8

Topsoil in its current state is well-graded except for Topsoil 1 which is poorly graded due to a low clay content. Well-graded materials have a lower propensity for segregation of coarse and fine particles. This can potentially lead to macropore flow and unacceptable rates of seepage from the cover.

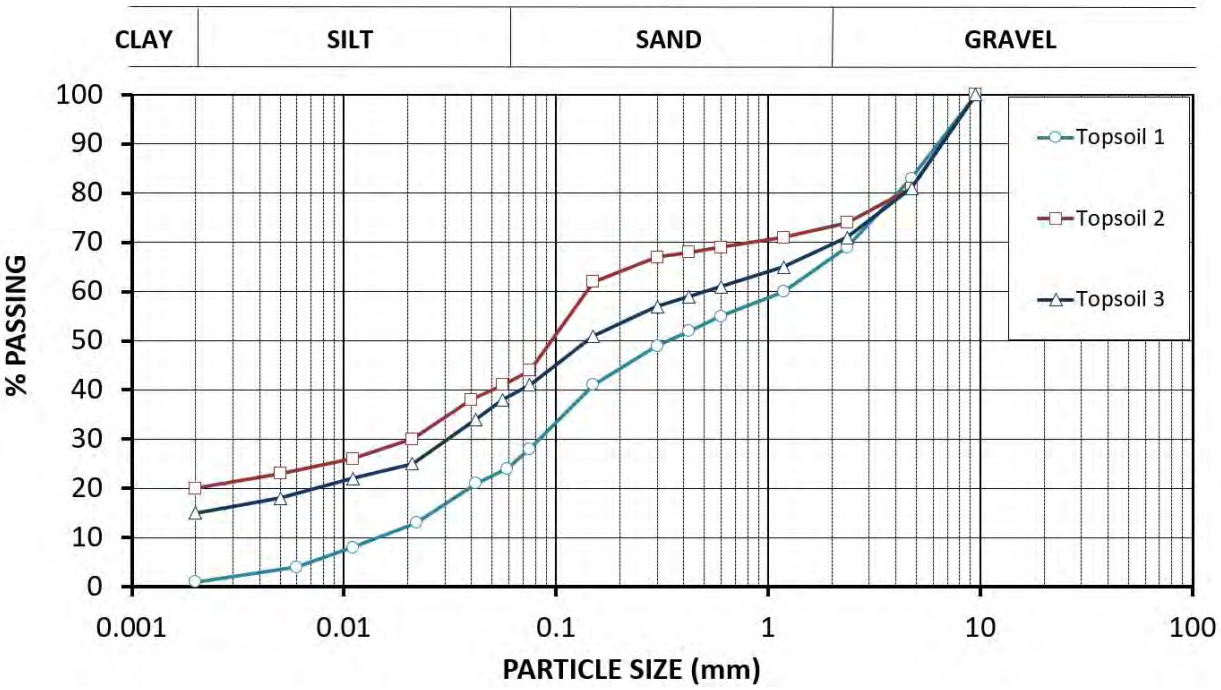


Figure 5 Particle size distributions of stockpiled topsoil (MMG 2018)

b Plant available water capacity

The potential plant available water capacity (PAWC) has been derived from the difference between the volumetric water content (VWC) of the water-entry value and the air-entry value. These values were obtained from the SWCCs measured in the trials (Section 6.1.3.2a).

Table 9 Stockpiled topsoil PAWC

Sample identification	PAWC (1 metre of stockpiled topsoil)	PAWC classification
Topsoil 1	25 mm	Very low (<50mm)
Topsoil 2	28 mm	Very low (<50mm)
Topsoil 3	27 mm	Very low (<50 mm)

In general, the stockpiled topsoil has a low PAWC. The ISL will therefore need to be sufficiently thick to account for this.

3.2.2.3 Borrow subsoil

Physical characterisation data was collected on borrow subsoil as part of the MMG (2018) sampling program (Appendix B).

a Unified soil classification system

The PSD for the borrow subsoil is shown in Figure 6. C_u and C_z values for the borrow subsoil samples are shown in Table 10.

Table 10 Summary of borrow subsoil physical characterisation

Sample identification	D_{10}(mm)	D_{30}(mm)	D_{60}(mm)	C_u	C_z
Borrow subsoil 1	0.001	0.042	0.35	350	5
Borrow subsoil 2	0.001	0.027	0.28	280	2.6
Borrow subsoil 3	0.001	0.027	0.2	200	3.6

Two borrow subsoil samples are slightly poorly graded (Borrow subsoil 1 and Borrow subsoil 3) and one is well-graded (Borrow subsoil 2). The borrow subsoil is still expected to compact to a dense state. Optimum compaction; however, will be achieved when the particle size distribution is closest to ideal (represented by a straight line through the target particle sizes). The poor grading of the material may also lead to some macropore flow and potentially higher rates of seepage.

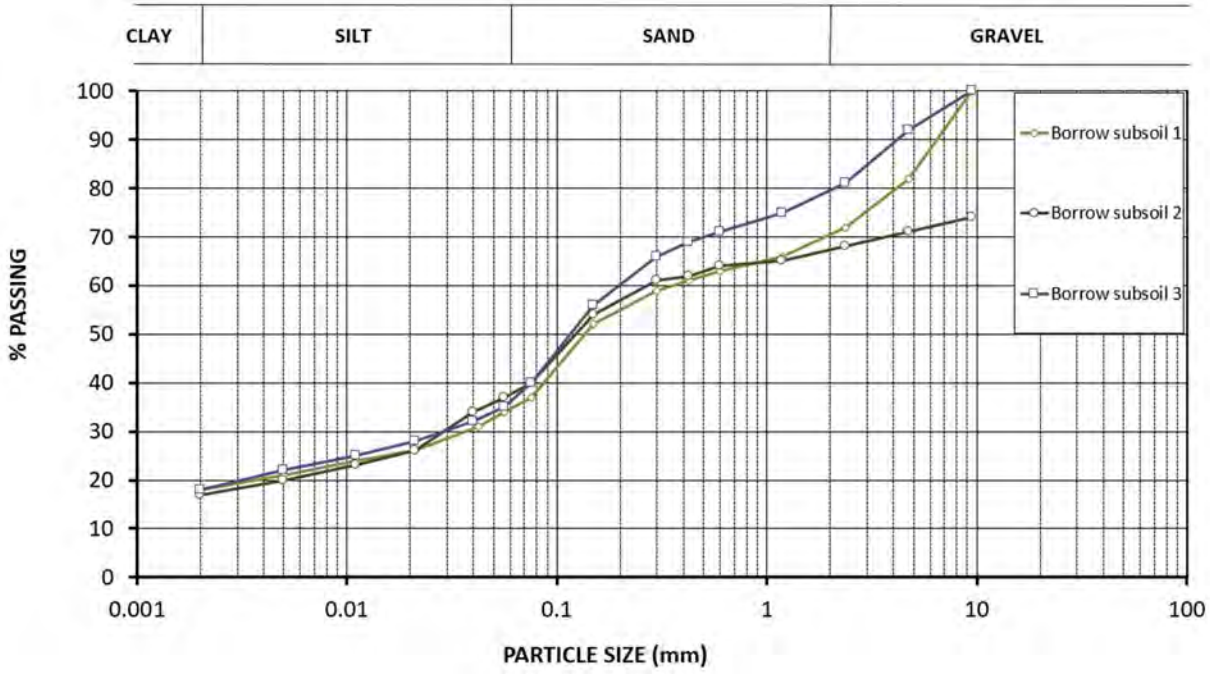


Figure 6 Particle size distributions of borrow subsoil

b Plant available water capacity

The potential PAWC has been derived from the difference between the VWC of the water-entry value and the air-entry value. These values were obtained from the SWCCs measured in the trials (Section 6.1.3.2a).

Table 11 Borrow subsoil PAWC

Sample identification	PAWC (1 metre of borrow subsoil)	PAWC classification
Borrow subsoil 1	25 mm	Very low (<50mm)
Borrow subsoil 2	26 mm	Very low (<50mm)
Borrow subsoil 3	31 mm	Very low (<50 mm)

In general, the potential cover ISLs have a low PAWC. The ISL will therefore need to be sufficiently thick to account for this.

c Shrink/swell properties

The potential for the borrow subsoil to shrink and/or swell is determined from the Atterberg limit test and the particle size distribution. The most useful of the Atterberg limits is the plastic limit which is summarised in Table 12. Table 12 shows that the sample is classified as slightly plastic. Materials with a high plasticity index tend to be clay, those with a medium plasticity index tend to be silt, and those with a plasticity index of 0-3 (non-plastic) tend to have little or no silt or clay (Fredlund & Rahardjo 1993).

Table 12 Summary of plasticity index results

Sample identification	(0-3) non-plastic	(3-15) slightly plastic	(15-30) medium plastic	>30 highly plastic
Borrow subsoil	-	9	-	-

The shrink/swell potential of the spoil can be assessed using the plasticity index. The critical value for the plasticity index varies between guidelines but generally a plasticity index of >25% indicates a high potential for shrink/swell behaviour. The borrow subsoil is below the critical value indicating that there is low potential for shrink/swell behaviour. Secondary flow paths are unlikely to form as a result of the material drying out and cracking.

d Compaction

Standard compaction tests were completed on the borrow subsoil to determine the standard maximum dry density (SMDD) and standard optimum moisture content (SOMC) which came in at 2.03 t/m^3 and 9.5% respectively.

e Permeability

Saturated hydraulic conductivity was measured using the constant head method. The borrow subsoil is classified as having an extremely low permeability (at 95% SMDD) (based on Greeves et al. 1995) (7.4 x 10^{-10} m/s) (Table 13). Borrow subsoil would therefore likely be suitable for use in an RPL.

Table 13 Classification according to permeability

Degree of permeability	Range of coefficient of permeability *k* (m/s)
Very high	>3.3 x 10^{-5}
High	3.3 x 10^{-5} to 1.7 x 10^{-5}
Moderate	1.7 x 10^{-5} to 5.6 x 10^{-6}
Low	5.6 x 10^{-6} to 2.8 x 10^{-6}
Very low	2.8 x 10^{-6} to 1.4 x 10^{-7}
Extremely low	**< 1.4 x 10^{-7}**

4.0 Cover Trial Development

4.1 Current closure plan cover

The current conceptual Mine Closure Plan describes the primary (referred to as cover option 1), unproven, 1.9 m cover design for the rehabilitation of the TSF. This cover system's layers are presented and described in Figure 7.

Cross section	Thickness (m)	Material properties	Material source	Placement and compaction
	0.2	Soil (soil and/or soil, rock and vegetation mulch)	Soil stockpiles 105,196 m^3	End dumping No compaction 50% of TSF area only
	1.0	ISL (NAF waste rock)	NAF WRD 1,750,000 m^3	End dumping followed by smoothing No compaction
	0.5	RPL (NAF waste rock)	NAF WRD 1,750,000 m^3	End dumping Grading Compaction to ~95% of maximum dry density
	0.4	CB (NAF waste rock)	NAF WRD 1,750,000 m^3	Described in Appendix D

Figure 7 Cover cross section

4.2 Preliminary cover model

The purpose of this section is to summarise the preliminary modelling that was completed to determine the most suitable store and release cover options for the TSF. These would then progress to cover trials. The following was used to undertake a cover options analysis (Appendix D):

- cover priorities and purpose;
- cover desirable attributes;
- the environmental risk assessment;
- cover materials available; and
- current available technology.

The top three ranked covers (cover option 1, 2 and 3) were then used in the preliminary modelling. Cover option 4 was also modelled to assess how thick the ISL should be and to investigate whether a RPL or CB is required. It is important to note that the model is uncalibrated and requires monitoring data for infiltration and seepage from field trials before the final decision on cover thickness can be made. The methodology and rationale behind the covers examined in the preliminary modelling is shown in Appendix D.

Cover option 1 is the cover specified in the EIS and is the primary design for rehabilitation of the TSF and includes:

- a 0.4 m CB layer of gap-graded NAF waste rock;
- a 0.5 m RPL of NAF waste rock above the CB layer;
- a 1 m ISL of NAF waste rock above the RPL; and
- a 0.2 m topsoil layer above the ISL.

Cover option 2 is the cover that discussions with DES have indicated is DES' preferred cover:

- a 0.6 m CB layer comprised of 0.3 m of gap-grade gravel overlain by 0.3 m of clean filter sand;
- a 0.5 m RPL of NAF waste rock above the CB layer;
- a 1 m ISL of NAF waste rock above the RPL; and
- a 0.2 m topsoil layer above the ISL.

Cover option 3 is the cover that discussions with DES have indicated is DES' preferred cover with an ISL half the thickness of cover option 2. The aim of this was to explore the effect of a thinner ISL and includes:

- a 0.6 m CB layer comprised of 0.3 m of gap-grade gravel overlain by 0.3 m of clean filter sand;
- a 0.5 m RPL of NAF waste rock above the CB layer;
- a 0.5 m ISL of NAF waste rock above the RPL; and
- a 0.2 m topsoil layer above the ISL.

Cover option 4 aims to explore the effects of no CB or RPL and includes:

- a 0.5 m ISL of NAF waste rock; and
- a 0.2 m topsoil layer above the ISL.

The model was initially run for a 128-year period using patched climate data from SILO (Scientific Information for Landowners) for Cloncurry Airport (the primary model run). The model was then run for a dry, average and wet year based on the 128-year patched SILO climate data.

4.2.1 Results

The model has been used to develop a water balance for cover option 1 and alternative cover options for the average, dry and wet year model scenarios, presented in Table 14 to Table 17.

Table 14 Summary of primary cover (cover option 1) water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	307	460	1,156
Stored infiltration (%)	5	3	27
Seepage (%)	0.9	1	6
Actual evaporation (%)	94.1	96	67

Table 15 Summary of cover option 2 water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	307	460	1,156
Stored infiltration (%)	4.7	3	32.1
Seepage (%)	0.01	1	0.1
Actual evaporation (%)	95.3	96	67.8

Table 16 Summary of cover option 3 water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	307	460	1,156
Stored infiltration (%)	4.2	15.1	10.1
Seepage (%)	2.8	16	33.2
Actual evaporation (%)	93	68.9	56.7

Table 17 Summary of cover option 4 water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	307	460	1,156
Stored infiltration (%)	1.2	11.6	8.2
Seepage (%)	3	20.6	36
Actual evaporation (%)	95.2	67.8	55.8

The results (Table 14 to Table 17) show that during dry periods, the Primary Cover and alternative cover options are all expected to limit seepage to less than the rate of natural groundwater recharge (Cook et al. 2004). However, the average year results indicate that seepage through alternative cover option 3 and 4 will exceed the rate of natural groundwater recharge. Further, the rate of seepage will continue to increase during wet periods to a maximum of 36% of rainfall. Therefore, it is likely that alternative cover options 3 and 4 will periodically have unacceptably high seepage rates. The expected high seepage rate is unlikely to result in successful rehabilitation of the TSF due to a very-high water management demand. Finally, it is also considered unlikely that alternative cover option 3 or 4 will retain enough PAWC to allow sustained vegetation growth on the TSF cover. A reduced PAWC for a cover less then 0.5 m is supported by PAWC analysis of soil (Section 3.2.2.2b and Section 3.2.2.3b).

As would be reasonably expected, the wet year model scenario does result in an increase in potential seepage for cover option 1 and 2. However, for both covers the seepage rate is in line with other Australian cover examples (Section 6.2.3) and is less than the rate of natural groundwater recharge (Cook et al. 2004). Further, the model also suggests that a CB will also help to limit the potential for seepage because the air-filled voids of the CB will act as a physical barrier to infiltration.

4.2.2 Preferred cover option

Based on the preliminary model results, the preferred cover option is alternative cover option 2.

4.3 Final cover options to trial

The availability of NAF waste rock for use in the TSF cover is unknown at this stage. Borrow subsoil was identified as a potential alternative material for use in the ISL and RPL. This material was therefore trialled in place of NAF waste rock in the trials. Cover options 1, 2, 3 and 4 were all progressed to column trials as per Section 4.2 with the NAF waste rock ISL and RPL substituted for a borrow subsoil ISL and RPL.

5.0 Column Cover Trials

The low rainfall environment of the Mine was seen as a limiting factor to achieving a timely response from potential cover trials. Regional experience indicates that several years of data would be required to capture a representative window of how the cover responds to seasonal changes. Space availability on the TSF to construct the trials is also a limiting factor. In order to achieve interim data of cover performance, it was decided that the cover trials would be constructed as large columns. This approach allowed the Mine to decide the frequency and quantity of rainfall, providing greater capacity to develop a maximum water balance for each column trial quickly.

The trials were instrumented with volumetric water content sensors (also capable of measuring electrical conductivity) and matric suction sensors to measure how rainfall infiltration and dissolved ions are stored within the cover (Section 5.1.4). Matric suction and volumetric water content data are used to form soil water characteristic curves for each of the materials in the covers. These curves describe the behaviour of water storage and movement and are a key input required for the model (Section 6.0). Seepage was measured using rain gauge tipping buckets (Section 5.1.2.1). All this data, combined with the back-calculated evaporation rate (EQN4), gives a maximum water balance which will be used to validate the accuracy of the model (Section 5.2.3)

5.1 Method

5.1.1 Sensor calibrations

The trials were instrumented with VWC and matric suction sensors. The following sections describe how the sensors were calibrated prior to installation.

5.1.1.1 Matric suction sensors

a Theory

The matric suction sensors consist of a heating and reference wire surrounded by sintered ceramic (the components). The sintered ceramic is porous and when buried in the trial will wet and dry in response to wetting and drying of the trial. The matric suction sensor infers how wet or dry the sintered ceramic, and hence the cover is, daily by measuring the temperature of the reference wire at one second followed by 30 seconds of heating of the heater wire followed by a final measure of the reference wire at 30 seconds. How hot the reference wire becomes is a function of the cover. That is, how wet or dry the sintered ceramic is. For example, if the sintered ceramic is wet then it will heat more slowly, and hence to a lesser extent, compared to if the sintered ceramic was dry. Matric suction sensors require calibration so that an empirical relationship between change in temperature (ΔT) and matric suction can be developed for each sensor prior to installation in the trials.

b Calibration set-up

The matric suction sensors were calibrated in either soil, borrow subsoil or tailings, correlating to their depth of burial within the trials.

Matric suction sensors were individually calibrated by comparing the measured ΔT of the matric suction sensor to the matric suction of the soil or tailings. The matric suction of the soil or tailings was determined by measuring total suction with a dew-point water potential meter and calculating osmotic suction from EC. Matric suction was then calculated by subtracting osmotic suction from total suction.

The method used for calibration of the matric suction sensors is presented in Appendix E.

The derived calibrations apply to:

- dewatering of sensors, and do not account for hysteresis; and
- constant temperature and humidity conditions, as applied during the calibration process.

c Results

Calibration functions for each trial are presented in Appendix F. Campbell Scientific matric suction sensors are recommended for use for matric suctions ranging from 10-1,000 kilopascals (kPa). These sensors are regularly calibrated for suctions greater than 1,000 kPa (Flint et al. 2002). The calibration functions presented extended up to 1,000,000 kPa, it is however unlikely that matric suctions of this order will ever be achieved in the field. The expected range for environmental conditions at the Mine are likely to extend from 10 kPa to approximately 100,000 kPa, corresponding to wet and dry seasons respectively.

5.1.2 Construction

Four columns, one for each cover option, were built to specifications provided by SGME. A built column is shown in Photograph 1. Columns ranged from 1.1 m to 2.5 m tall depending on the thickness of the cover trialled. Each column has a surface area of 0.25 metres squared (m^2).

Photograph 1 Cover column trial

5.1.2.1 Seepage volume

The columns include a flume on their base so that seepage can be captured. Rain gauge tipping buckets were placed under the flumes to measure the volume of seepage. The rain gauge tipping buckets sit on-top of a collection reservoir which allows seepage water to be collected. Seepage chemistry was not analysed during the trials.

5.1.3 Filling

The trials are made up of layers of soil, waste rock and tailings which are described in the following sections.

A 0.1 m layer of clean gravel was placed on the bottom of each trial to act as a drainage layer (the filter layer). Geofabric was placed on top of the filter layer to prevent tailings from clogging it by migrating into the gravel pore spaces. Geofabric was also placed over drainage tap openings to further assist in stopping potential migration of fines.

It should be noted that the tailings in the bottom of each column are compacted to greater than 100% of MDD (Section 3.1.3) to mimic the potential compaction that may result from continuous compaction during cover construction on the TSF.

5.1.3.1 EIS cover (cover option 1)

Cover option 1 is the cover specified in the EIS and is the primary design for rehabilitation of the TSF and includes:

- a 0.3 m layer of fresh tailings above the filter layer compacted to a bulk density of 2.19 t/m^3. The target density was achieved by compacting eight, 20.5 kilogram (kg) buckets of tailings into 0.08 m^3. No sensors were placed in the tailings.
- a 0.4 m CB layer of gap-graded NAF waste rock above the tailings layer at a density of 1.43 t/m^3. The target density was achieved by compacting seven, 20.4 kg buckets of air-dry NAF waste rock into 0.1 m^3. One sensor pair was placed in the middle of this layer (Figure 8).
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.31 t/m^3. The target density was achieved by compacting 14, 20.65 kg buckets of air-dry NAF waste rock into 0.125 m^3. One sensor pair was placed at the top and bottom of this layer (Figure 8).
- a 1 m ISL of borrow subsoil above the RPL at a density of 1.64 t/m^3. This was achieved by compacting 20, 20.5 kg buckets of air-dry NAF waste rock into 0.25 m^3. One sensor pair was placed at the bottom of this layer (Figure 8).
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3. This was achieved by compacting four, 21.5 kg buckets of topsoil into 0.05 m^3. One sensor pair was placed at the bottom of this layer (Figure 8).

5.1.3.2 DES cover (cover option 2)

Cover option 2 is the cover option preferred by DES and includes:

- a 0.1 m layer of fresh tailings above the filter layer compacted to a bulk density of 2.4 t/m^3. The target density was achieved by compacting three, 20 kg buckets of tailings into 0.025 m^3. No sensors were placed in the tailings.
- a 0.3 m CB layer of gap-graded NAF waste rock above the tailings layer at a density of 1.38 t/m^3. The target density was achieved by compacting five, 20.8 kg buckets of air-dry NAF waste rock into 0.075 m^3. One sensor pair was placed in the middle of this layer (Figure 8).
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.27 t/m^3. The target density was achieved by compacting 14, 20.31 kg buckets of air-dry NAF waste rock into 0.125 m^3. One sensor pair was placed at the top and bottom of this layer (Figure 8).
- a 0.3 m CB layer of gap-graded NAF waste rock above the RPL at a density of 1.38 t/m^3. The target density was achieved by compacting five, 20.8 kg buckets of air-dry NAF waste rock into 0.075 m^3. One sensor pair was placed in the middle of this layer (Figure 8).
- a 1 m ISL of borrow subsoil above the CB layer at a density of 1.64 t/m^3. This was achieved by compacting 20, 20.5 kg buckets of air-dry NAF waste rock into 0.25 m^3. One sensor pair was placed in the middle of this layer (Figure 8).
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3. This was achieved by compacting four, 21.5 kg buckets of topsoil into 0.05 m^3. No sensors were placed in the topsoil.

5.1.3.3 DES cover with a half thickness ISL (cover option 3)

Cover option 3 is the preferred DES cover option with an ISL half the thickness of cover option 2. The aim of this was to explore the effect of a thinner ISL and includes:

- a 0.4 m layer of fresh tailings above the filter layer compacted to a bulk density of 2.03 t/m^3. The target density was achieved by compacting 10, 20.34 kg buckets of tailings into 0.1 m^3. No sensors were placed in the tailings.
- a 0.3 m CB layer of gap-graded NAF waste rock above the tailings layer at a density of 1.35 t/m^3. The target density was achieved by compacting five, 20.26 kg buckets of air-dry NAF waste rock into 0.075 m^3. One sensor pair was placed at the top of this layer (Figure 8).
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.27 t/m^3. The target density was achieved by compacting 14, 20.27 kg buckets of air-dry NAF waste rock into 0.125 m^3. One sensor pair was placed at the top and bottom of this layer (Figure 8).
- a 0.3 m CB layer of gap-graded NAF waste rock above the RPL at a density of 1.38 t/m^3. The target density was achieved by compacting five, 20.49 kg buckets of air-dry NAF waste rock into 0.075 m^3. One sensor pair was placed in the middle of this layer (Figure 8).
- a 0.5 m ISL of borrow subsoil above the CB layer at a density of 1.59 t/m^3. This was achieved by compacting 10, 19.82 kg buckets of air-dry NAF waste rock into 0.125 m^3. One sensor pair was placed at the top of this layer (Figure 8).
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3. This was achieved by compacting four, 21.5 kg buckets of topsoil into 0.05 m^3. No sensors were placed in the topsoil.

5.1.3.4 ISL cover (cover option 4)

Cover option 4 aims to explore the effects of no CB or RPL and includes:

- a 0.3 m layer of fresh tailings above the filter layer compacted to a bulk density of 2.15 t/m^3. The target density was achieved by compacting 10, 20.12 kg buckets of tailings into 0.075 m^3. One sensor pair was placed at the top and bottom of this layer (Figure 8).
- a 0.5 m ISL of borrow subsoil above the tailings layer at a density of 1.62 t/m^3. This was achieved by compacting 10, 20.2 kg buckets of air-dry NAF waste rock into 0.125 m^3. One sensor pair was placed at the top and bottom of this layer (Figure 8).
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3. This was achieved by compacting 4, 21.5 kg buckets of topsoil into 0.05 m^3. One sensor pair was placed in the middle of this layer (Figure 8).

5.1.4 Installation of instruments

The trials included buried sensor pairs in the topsoil, ISL, CB, RPL and tailings layers. The sensor pairs comprise a matric suction sensor and a VWC sensor. The trials have five pairs of VWC and matric suction sensors buried at the depths shown in Figure 8.

Cover option 1		Cover option 2		Cover option 3		Cover option 4	
Sensor number	Burial depth	Sensor number	Burial depth	Sensor number	Burial depth	Sensor number	Burial depth
1-1	0.3 m	1-6	0.7 m	2-1	0.5 m	2-6	0.3 m
1-2	1.2 m	1-7	1.5 m	2-2	1 m	2-7	0.5 m
1-3	1.4 m	1-8	1.7 m	2-3	1.2 m	2-8	0.7 m
1-4	1.7 m	1-9	2 m	2-4	1.5 m	2-9	0.9 m
2-10	2 m	1-10	2.2 m	2-5	1.7 m	1-5	1 m

Notes: 1. Light brown = topsoil, orange = ISL, reddish brown = RPL, green = CB, grey = tailings

Figure 8 Burial depth of sensors

5.1.5 Wetting and drying

The trials were subjected to 12 artificial rainfall events over 6 months. The purpose of the artificial rainfall was to allow the trials to wet up and dry out so that soil water characteristic curves and a maximum water balance could be developed for each cover:

- 30 mm simulated rainfall on day 2;
- 30 mm simulated rainfall on day 15;
- 30 mm simulated rainfall on day 28;
- 30 mm simulated rainfall on day 42;
- 30 mm simulated rainfall on day 56;
- 30 mm simulated rainfall on day 70;
- 30 mm simulated rainfall on day 97;
- 100 mm simulated rainfall on day 112;
- 200 mm simulated rainfall on day 125;
- 200 mm simulated rainfall on day 144 to cover options 1, 2 and 3 only; and
- 200 mm simulated rainfall on day 158 to cover options 1 and 2 only.

This equates to a total of 910 mm of artificial rainfall applied to cover options 1 and 2, 710 mm of artificial rainfall to cover option 3 and 510 mm of artificial rainfall applied to cover option 4. The total artificial rainfall applied to each cover varied due to the varying thicknesses and materials of the different covers and the subsequent requirements to generate appropriate wetting up and drying out data.

During wetting events, artificial rainfall could pond on the surface of the trials (Photograph 2).

Photograph 2 Ponding of water on the trials

5.2 Results and discussion

5.2.1 Stored infiltration

Stored infiltration in the trials can be calculated daily by multiplying the change in VWC by depth. The daily incremental change in stored infiltration (ΔSW) balances the infiltration budget daily as either wetting (+ve Δ SW) or drying (-ve ΔSW). As such, it is proportional to the rate of evaporation. Figure 9 presents the stored infiltration for the trials.

In Figure 9:

- Figure 9a shows the stored infiltration of cover option 1;
- Figure 9b shows the stored infiltration of cover option 2;
- Figure 9c shows the stored infiltration of cover option 3; and
- Figure 9d shows the stored infiltration of cover option 4.

Of the four trials, cover option 2 stores the most total infiltration (~ 48 mm) followed by cover option 1 (~ 39 mm) and cover option 3 (~37 mm), while cover option 4 stores the least infiltration (~ 20 mm).

Note that delays in stored infiltration being detected in the columns (following watering events) are likely due to bypass flow initially occurring in macro-pores. This typically occurs faster than the gradual wetting up and flow in the soil matrix (ie matrix flow). Evaporation of ponded water from the top of the trials may also be contributing to this pattern.

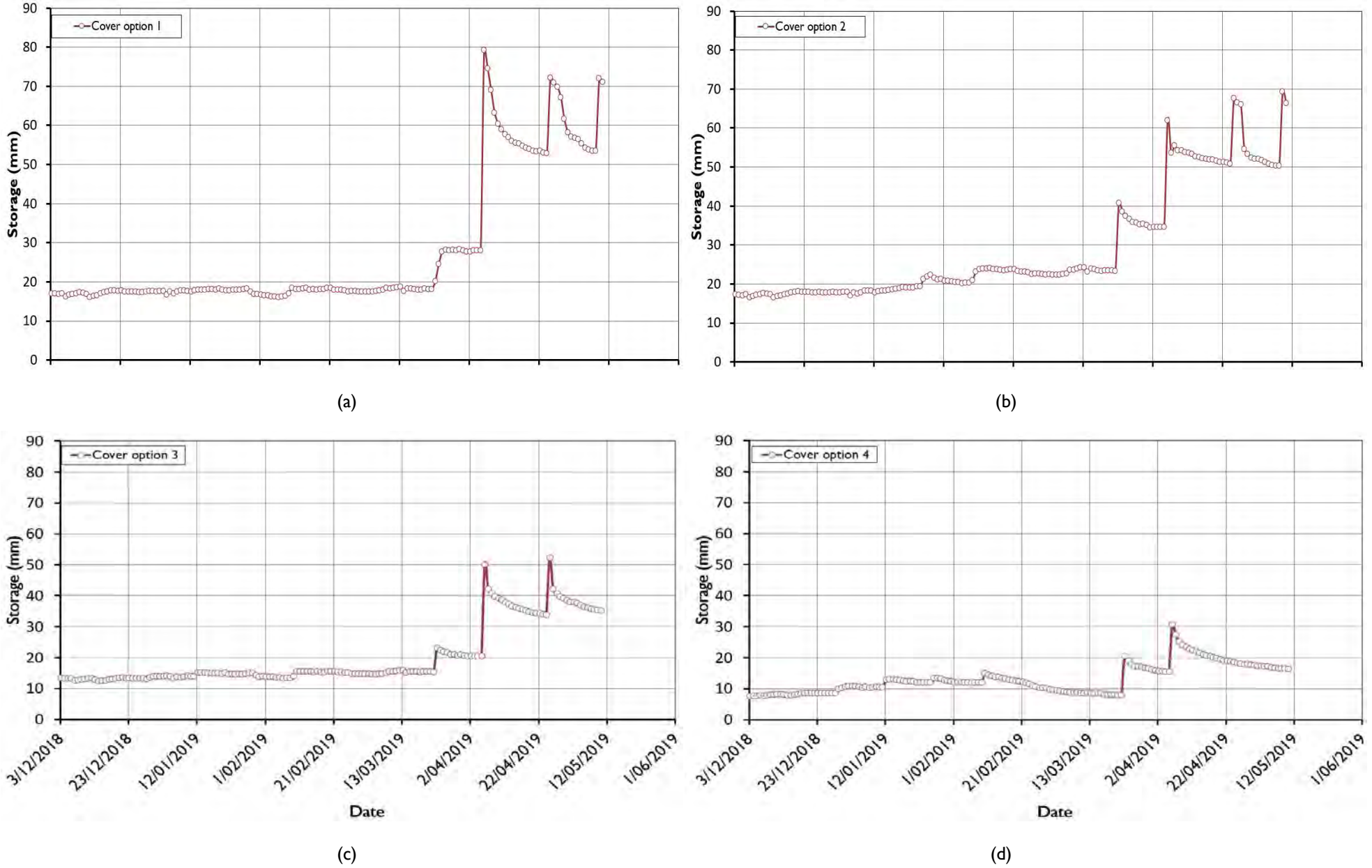


Figure 9 Stored infiltration in the trials

5.2.2 EC

The trials have not shown any signs of significant capillary rise (Figure 10). The rises in EC observed in Figure 10 correlate with increasing VWC (thereby dissolving existing salts in the cover) and are not as a result of capillary rise from the tailings.

The trials will need to be moved outside and monitored for an extended period of time to fully evaluate the potential for capillary rise and the subsequent need for a CB. This will expose the trials to natural rates of rainfall (ie lower than that what was artificially applied) and a higher evaporation rate (therefore a higher potential for capillary rise) (see Section 7.1).

In Figure 10:

- Figure 10a shows the EC of cover option 1;
- Figure 10b shows the EC of cover option 2;
- Figure 10c shows the EC of cover option 3; and
- Figure 10d shows the EC of cover option 4.

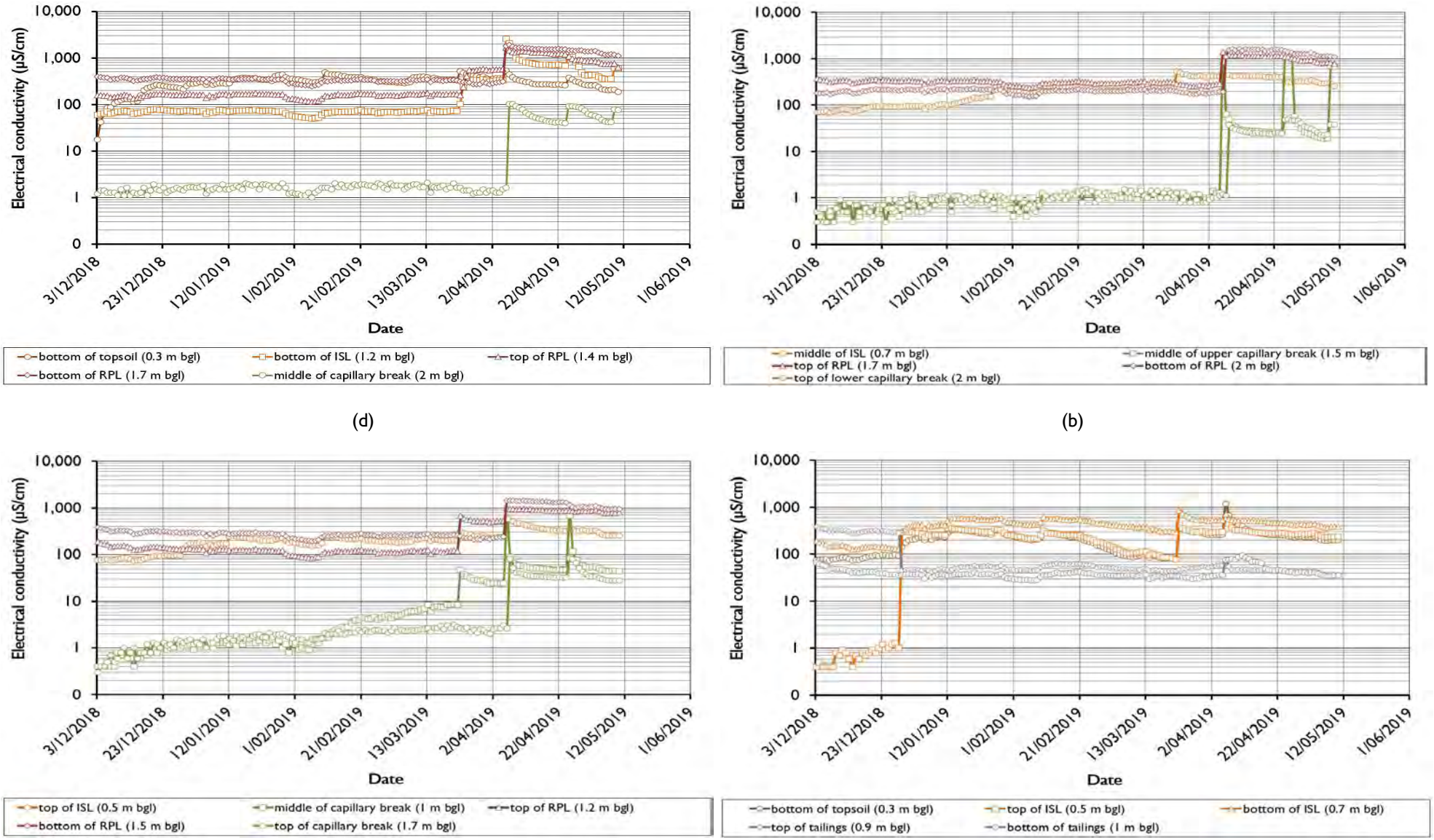


Figure 10 Electrical conductivity of the trials

5.2.3 Water balance

Incorporating stored infiltration, artificial rainfall and seepage allows for the calculation of a water balance for each trial by solving for evaporation using EQN4:

Evaporation = Artificial rainfall – seepage – stored infiltration [EQN4]

Table 18 summarises the maximum water balance for the trials.

Seepage results are only included in Table 18 to complete the maximum water balance for the trials. The seepage results are not comparable between trials as the artificial rainfall applied varied between each cover option. Seepage results are therefore not indicative of potential future cover performance. A scenario whereby all columns experience 710 mm of artificial rainfall (ie the rainfall applied to cover option 3) has been modelled in Section 6.2.1. Future cover performance has also been modelled in Section 6.2.2.

Table 18 Maximum water balance for each cover thickness

Cover thickness	**Flux**		**Flux**
Units		**mm**	**(% of cumulative artificial rainfall)**
Cover option 1	Store infiltration	54.1	5.9
	Seepage	133.7	14.7
	Evaporation	722.3	79.4
Cover option 2	Store infiltration	49	5.4
	Seepage	244.5	26.9
	Evaporation	616.5	67.7
Cover option 3	Store infiltration	21.7	3.1
	Seepage	50.9	7.2
	Evaporation	637.3	89.8
Cover option 4	Store infiltration	9.5	1.9
	Seepage	0.9	0.2
	Evaporation	499.6	98

6.0 Semi-calibrated SVFlux modelling

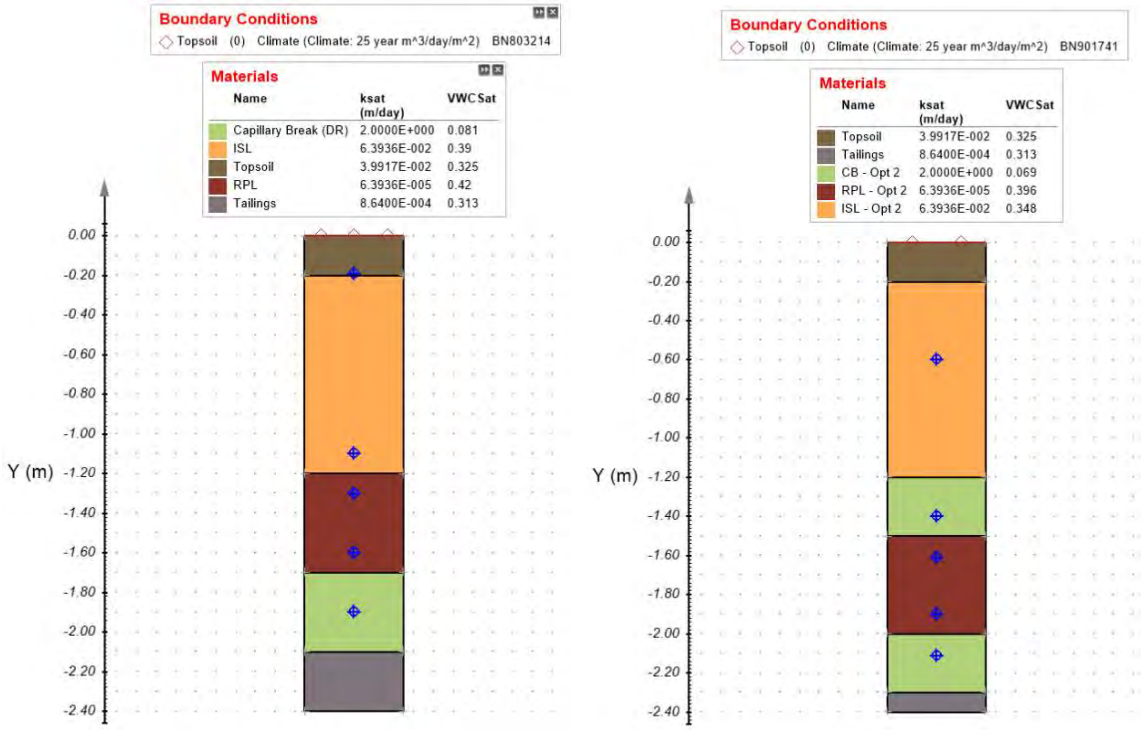
6.1 Method

The model was developed in one dimension and calculates the upward and downward movement of rainfall infiltration and seepage in the trials; it assumes no surface runoff or run on and allows ponding at the surface of the cover (Photograph 2).

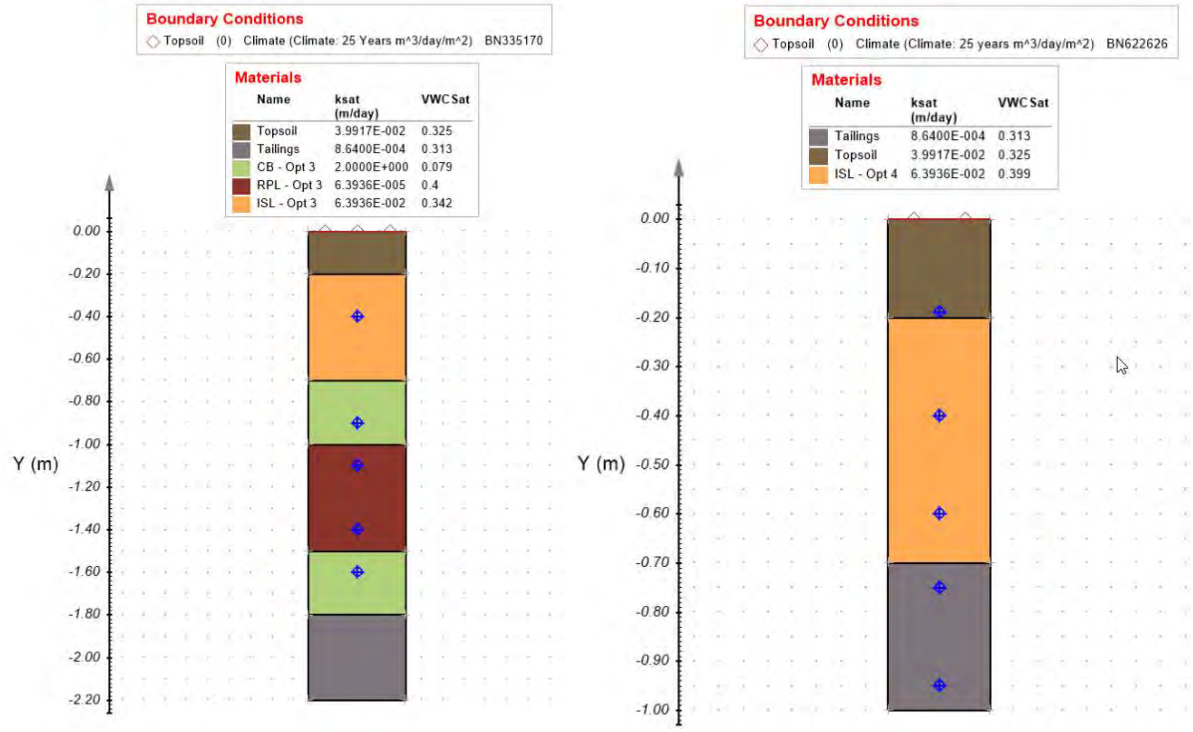
Transpiration from vegetation has been conservatively excluded since data is not available for this parameter ie the model only considers evaporation.

6.1.1 Model dimensions

The models were developed to replicate the trials, that is varying ISL thicknesses, with and without RPLs and/or CBs. Cover option 1-4 are shown in Figure 11a-d respectively.



(a) (b)



(c) (d)

Figure 11 Model dimensions

6.1.2 Mesh geometry

The model automatic mesh generation and automatic mesh refinement algorithms were used to generate the finite element mesh in the model.

6.1.3 Initial conditions

6.1.3.1 Evaporation

Potential evaporation in the model was kept as a constant at 0.0035 m/day. The potential evaporation rate is the average for the four trials.

6.1.3.2 Physical characteristics

a SWCCs

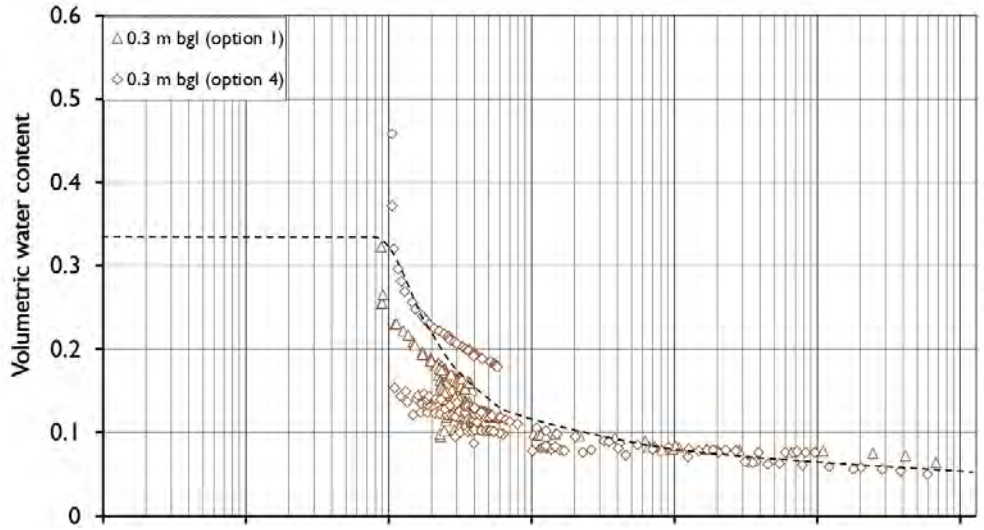
The model requires SWCCs. A SWCC is the relationship between VWC and matric suction for each depth where the sensors are placed in the cover (the in-situ results).

The in-situ SWCCs for the ISL, RPL, topsoil and CB were fitted to the in-situ results using the Fredlund & Xing (1994) method (Figure 13). The SWCC for the underlying tailings was derived from the PSD using pedotransfer functions (Fredlund and Xing 1994). This was due to the in-situ results not generating a complete SWCC (ie the relationship between VWC and matric suction in the tailings was not fully defined).

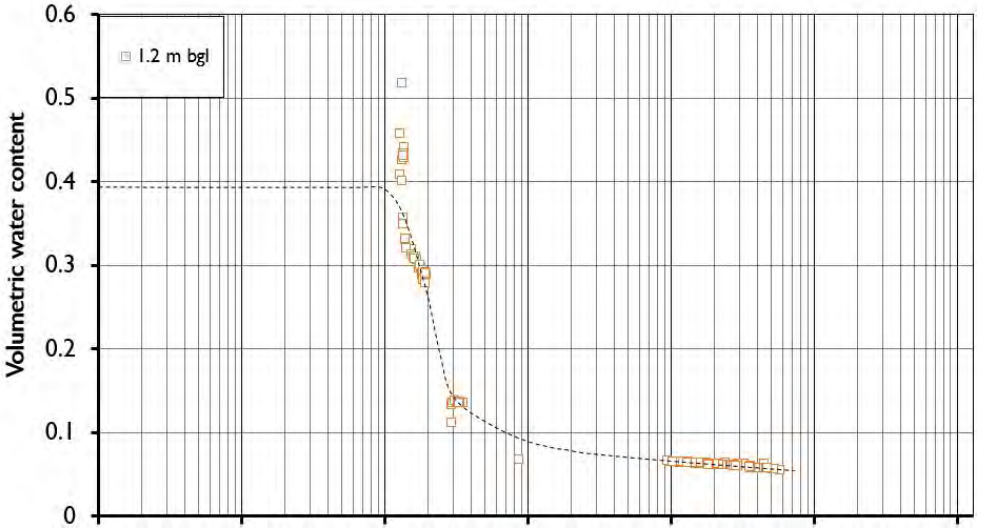
In Figure 13:

- Figure 13a is the topsoil SWCC for all of the trials;
- Figure 13b is the ISL SWCC for cover option 1;

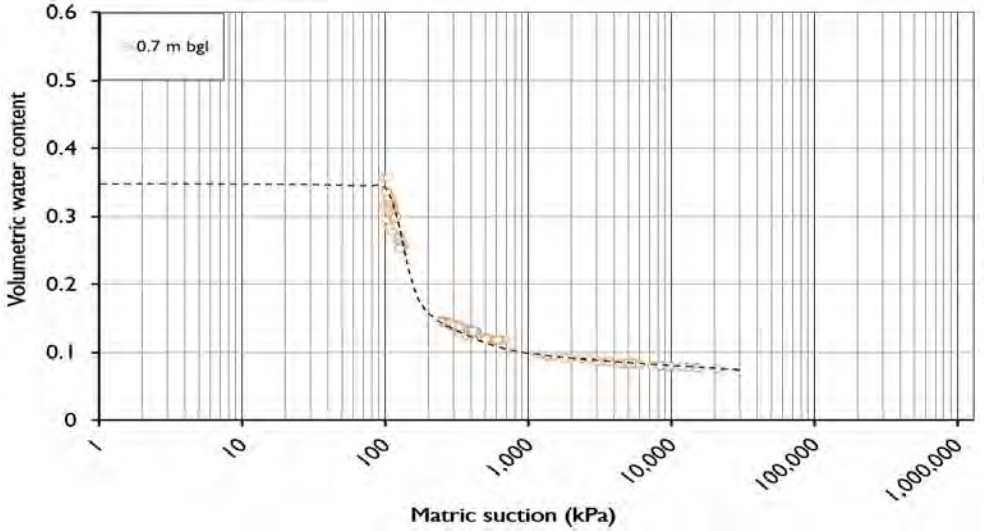
- Figure 13c is the ISL SWCC for cover option 2;
- Figure 13d is the ISL SWCC for cover option 3;
- Figure 13e is the ISL SWCC for cover option 4;
- Figure 13f is the CB SWCC for cover option 1;
- Figure 13g is the CB SWCC for cover option 2;
- Figure 13h is the CB SWCC for cover option 3;
- Figure 13i is the RPL SWCC for cover option 1;
- Figure 13j is the RPL SWCC for cover option 2;
- Figure 13k is the RPL SWCC for cover option 3; and
- Figure 13l is the tailings SWCC for all of the trials;


△ 0.3 m bgl (option 1)
◇ 0.3 m bgl (option 4)
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

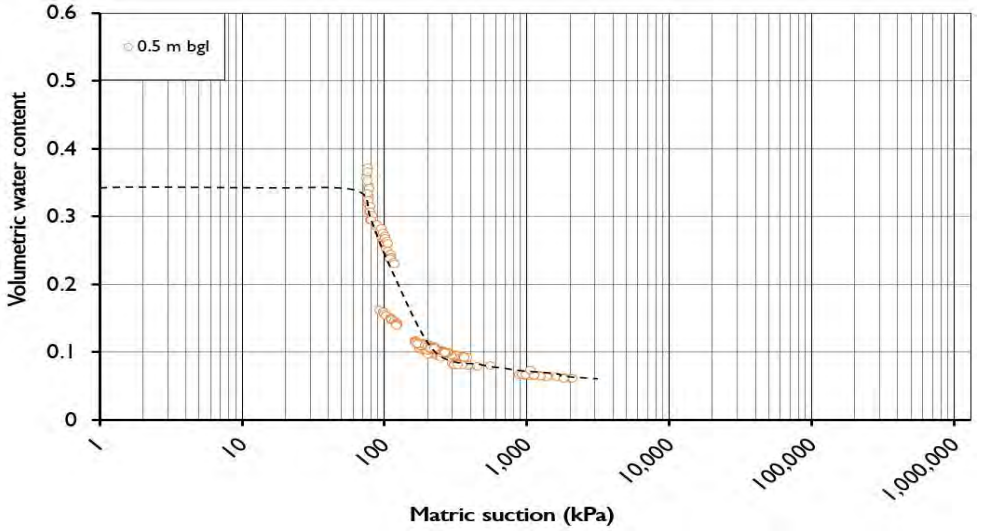
(a)


1.2 m bgl
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

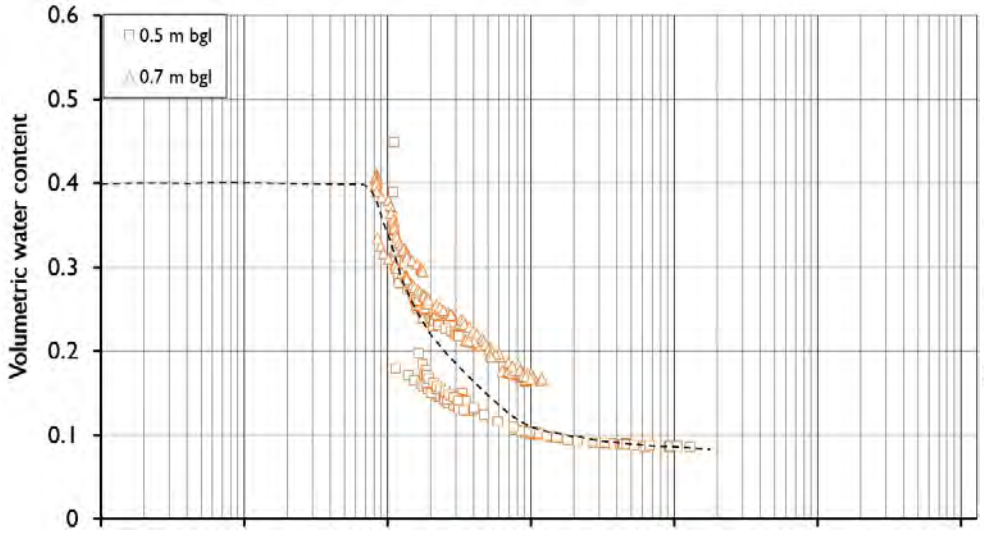
(b)


0.7 m bgl
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
1,000
10,000
100,000
1,000,000
Matric suction (kPa)

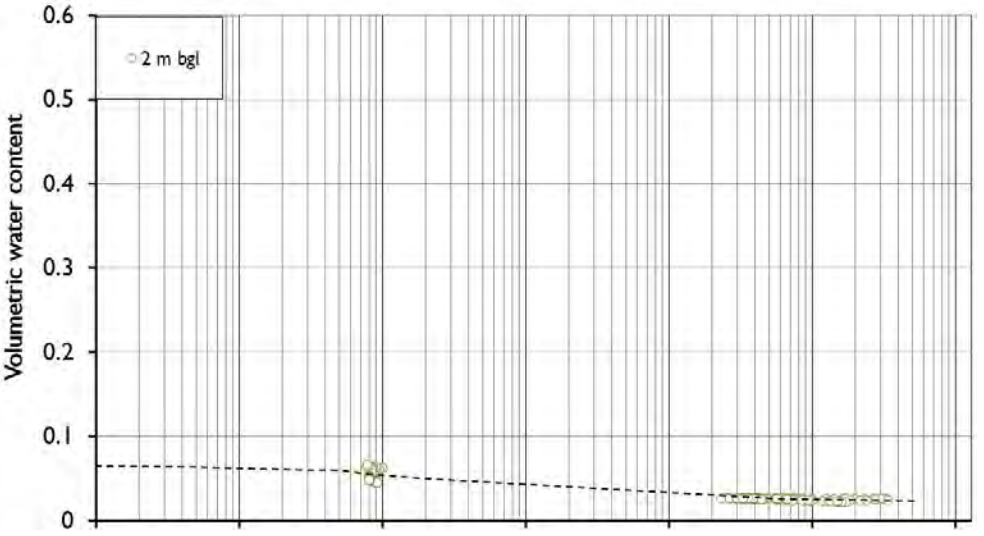
(c)


0.5 m bgl
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
1,000
10,000
100,000
1,000,000
Matric suction (kPa)

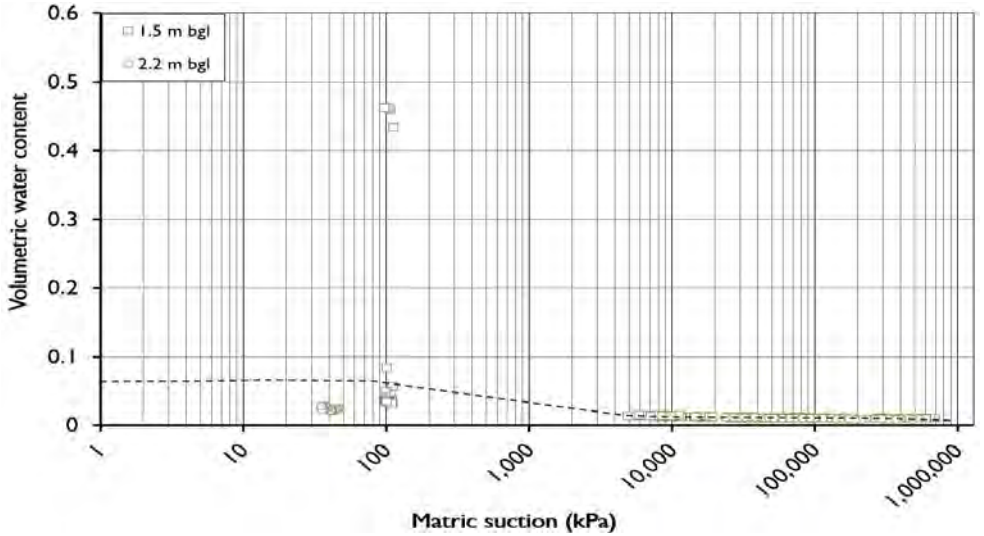
(d)


0.5 m bgl
0.7 m bgl
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

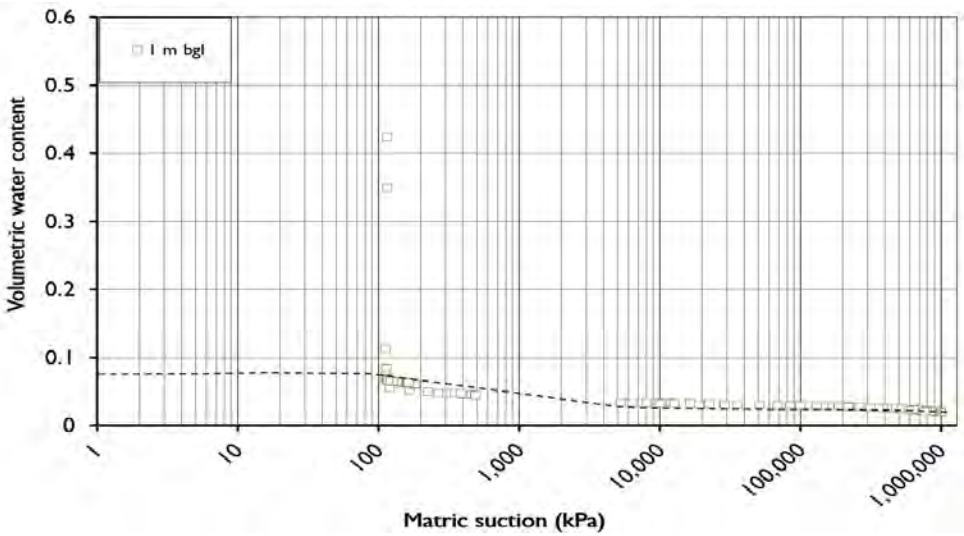
(e)


2 m bgl
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

(f)


1.5 m bgl
2.2 m bgl
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
1,000
10,000
100,000
1,000,000
Matric suction (kPa)

(g)


1 m bgl
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
1,000
10,000
100,000
1,000,000
Matric suction (kPa)

(h)

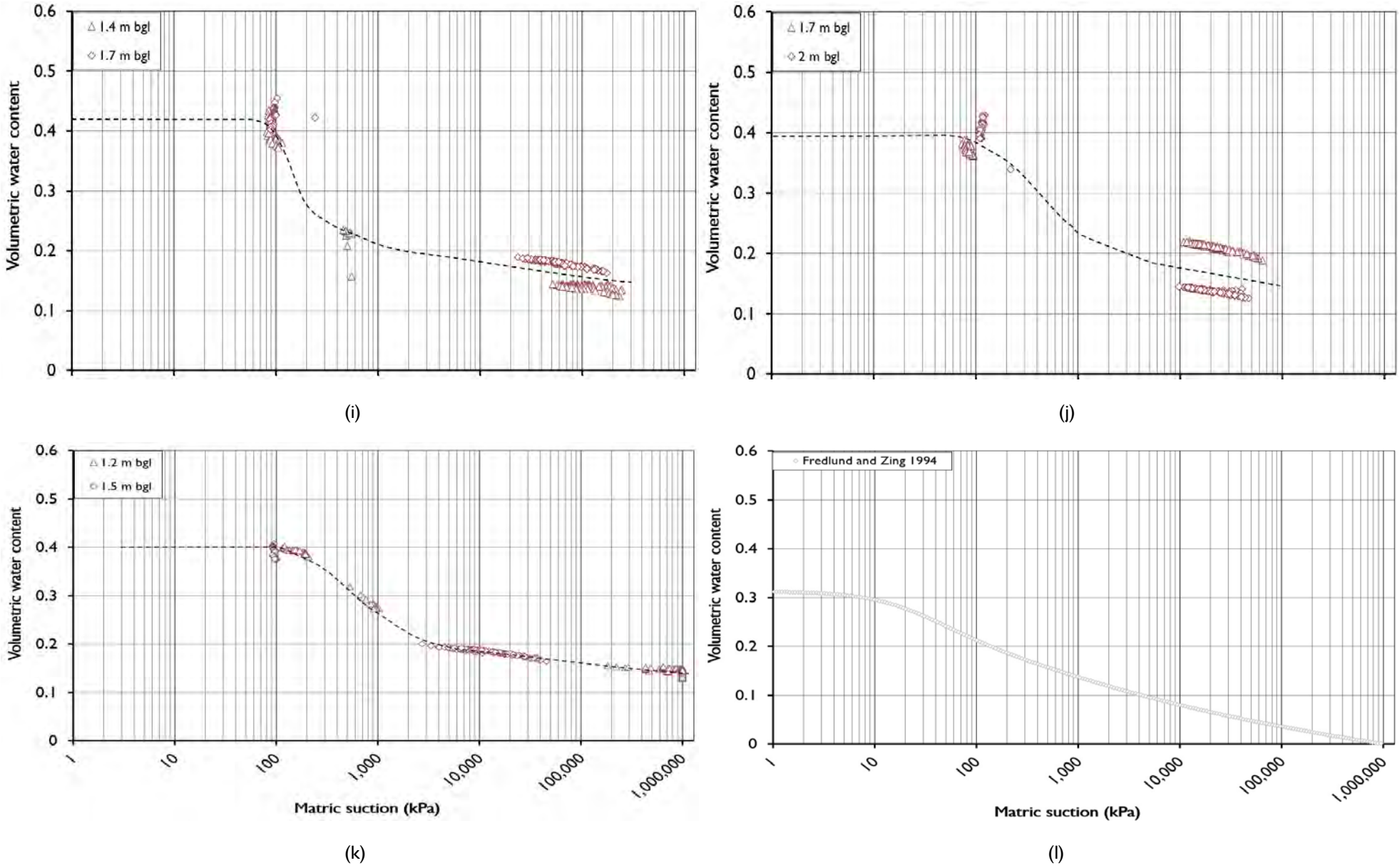


Figure 12 In-situ SWCCs

b Saturated hydraulic conductivity

The saturated hydraulic conductivity of the topsoil, ISL, RPL, CB and tailings were derived from the 2018 sampling program carried out by the Mine:

- topsoil — 0.04 m/day or 4.62 x 10^{-7} m/s;
- ISL — 0.063 m/day or 7.4 x 10^{-7} m/s;
- RPL — 0.000063 m/day or 7.4 x 10^{-10} m/s;
- CB — 2 m/day or 2.31 x 10^{-5}m/s;
- tailings — 0.0001 m/day or 1 x 10^{-8} m/s.

These values assume that the cover is built perfectly to engineering specifications. Differing saturated hydraulic conductivities were therefore also modelled to represent the possible range of values that may be encountered if the covers were to be built on the TSF.

c Unsaturated hydraulic conductivity

The model derives unsaturated hydraulic conductivity curves from the SWCCs and the saturated hydraulic conductivity.

6.1.4 Analysis method

Rainfall data spanning 128 years from 1889 to 2019 was obtained from the Bureau of Meteorology SILO data drill (https://www.longpaddock.qld.gov.au/silo/).

The model was initially run for 25-years. The model was then run for a six month period ie the monitoring period using the artificial rainfall data described in Section 5.1.5.

Finally, the model was run for a dry, average and wet years described in further detail in Section 6.1.4.2.

6.1.4.1 Steady state conditions

The primary model run (25 years) allowed the initial head condition within the model to reach a steady-state.

6.1.4.2 Transient analysis

A series of transient analyses were completed using the steady state conditions as the initial conditions.

Transient analysis was completed for:

- the six months described in Section 5.1.5;
- the average year;
- the wet year; and
- the dry year.

The annual sequence of daily rainfall corresponding to the average, wettest and driest years was selected from the ranked annual rainfalls (from wettest to driest):

- 1896 was chosen for the average year;
- 2009 was chosen for the wet year; and
- 1905 was chosen for the dry year.

The daily mean values for maximum and minimum temperature, maximum and minimum humidity and wind speed were obtained from the SILO data drill and were used for the scenarios.

The annual rainfall for the scenarios are presented in Table 19.

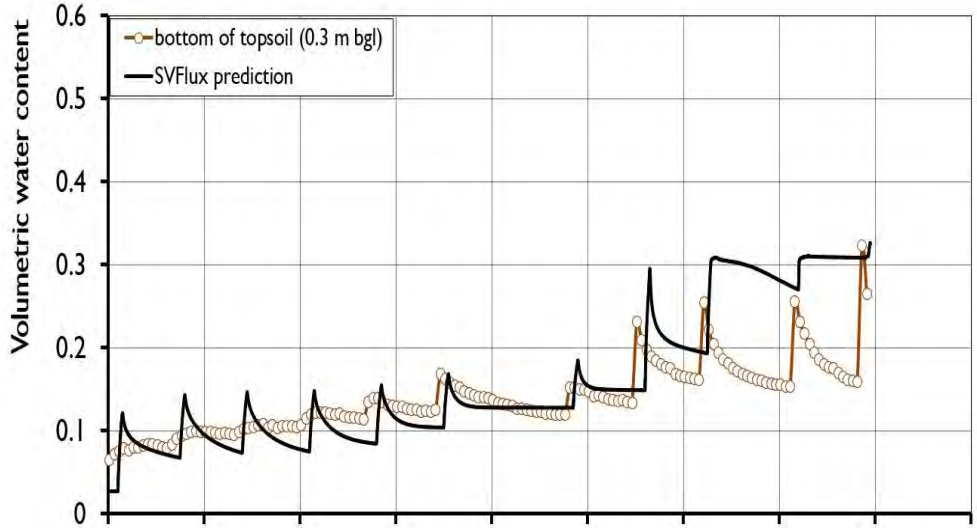
Table 19 Annual rainfall and evaporation for model scenarios

Scenarios	Year	Annual rainfall (mm)
Six month period	-	510-910
Average	1896	471
Wet	2009	1391.1
Dry	1905	117.3

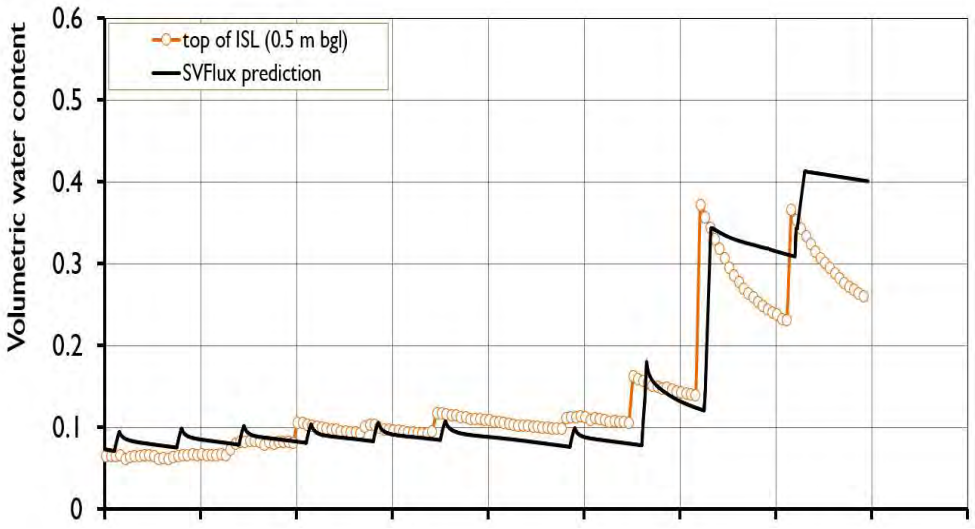
6.2 Results

As an example, Figure 13a shows the results of model topsoil VWC prediction compared to the in-situ results for cover option 1. Figure 13b-f shows the results of the model ISL, RPL and CB VWC predictions compared to the in-situ results for cover option 3 respectively. It is noticeable that the model prediction closely matches the magnitude of response measured in the trials. The exception is the RPLs which slowly wet up in the model. In the trials, the RPL stayed relatively dry before quickly wetting up. This indicates that water may be ponding on the RPL surface in the trials whereas the model allows a relatively uniform flow of rainfall through the layer. By the end of the six months, the RPL is saturated in both the model and the trials.

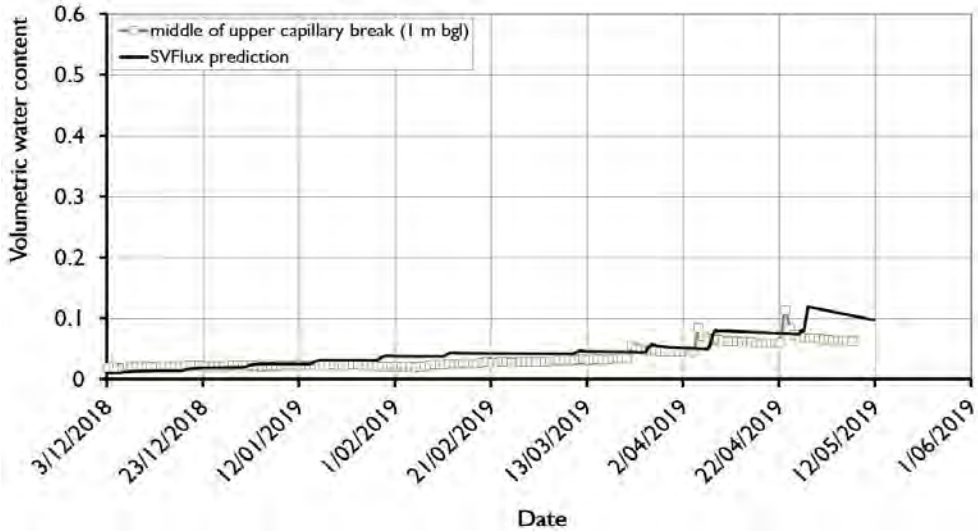
The model has validated the initial conditions described in Section 6.1.3 and provides actual evaporation results using the Modified Wilson Empirical Equation (Wilson et al. 1997) which are presented in Section 6.2.1.


bottom of topsoil (0.3 m bgl)
SVFlux prediction
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

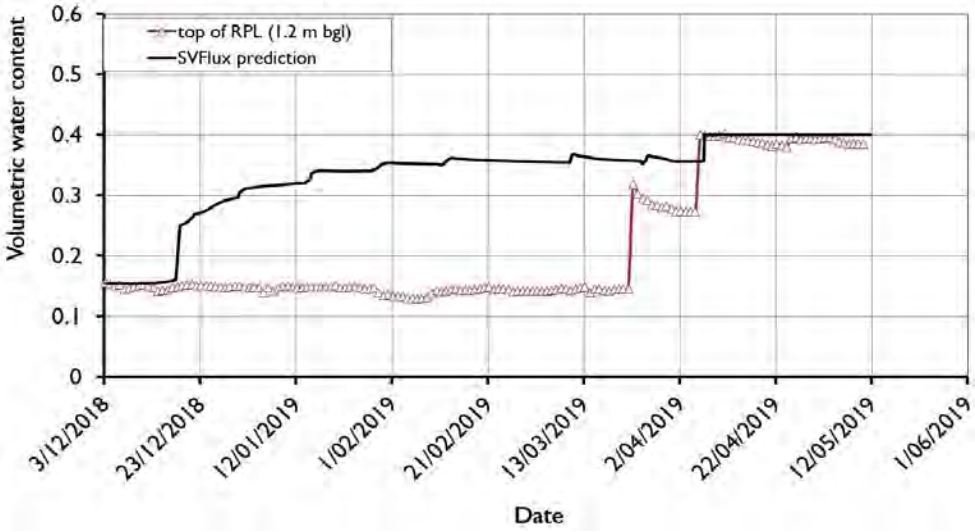
(a)


top of ISL (0.5 m bgl)
SVFlux prediction
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

(b)


middle of upper capillary break (1 m bgl)
SVFlux prediction
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
3/12/2018
23/12/2018
12/01/2019
1/02/2019
21/02/2019
13/03/2019
2/04/2019
22/04/2019
12/05/2019
1/06/2019
Date

(c)


top of RPL (1.2 m bgl)
SVFlux prediction
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
3/12/2018
23/12/2018
12/01/2019
1/02/2019
21/02/2019
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22/04/2019
12/05/2019
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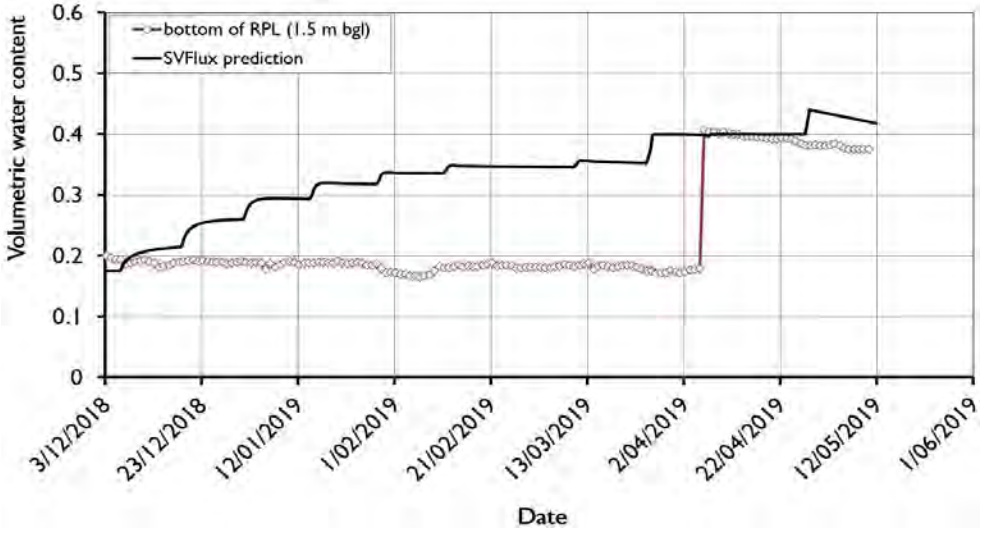
Date

(d)



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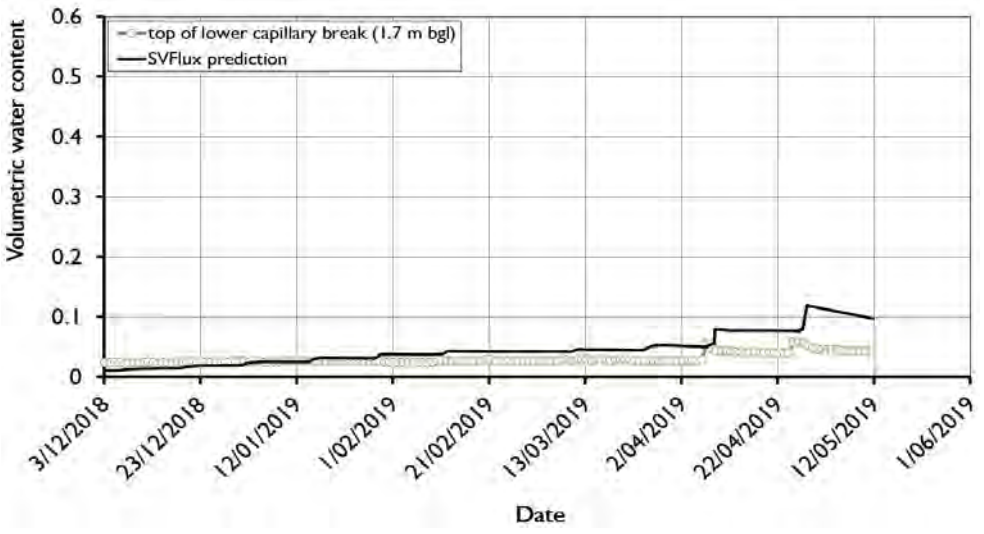

(f)

Figure 13 Model results compared to the trials

6.2.1 Water balance

A comparison of the artificial rainfall water balance from the trials to the model is presented in Table 20. A range is given representing the range of saturated hydraulic conductivity values that may be encountered in the covers if they were to be built on the TSF. The comparison shows that whilst the semi-calibrated model shows a high correlation between the predicted and observed stored infiltration, it is less accurate in its prediction of seepage. Modelled seepage was within 4-7% of that observed in the trials which still represents a reasonable degree of accuracy. The exception is cover option 2 (explained below). A comparison is also given where the trials are subject to an equal amount of artificial rainfall (710 mm, which was originally applied to cover option 3).

The inconsistency of the results is likely to do with the SWCCs. That is, the model accuracy would likely improve if the cover was represented by further segregation of the SWCCs presented in Figure 8. Further, the model cannot account for macro-pore infiltration flow in response to short duration, high intensity rainfall which can result in bypass flow through the trials. This is particularly evident in cover option 2 where seepage in the column differs significantly between the trial and the model. Another possibility is that infiltration may have flowed along the edges of the column, resulting in higher seepage being recorded in the rain gauge tipping bucket.

Table 20 Water balance summary for artificial rainfall

	Cover option 1		Cover option 2		Cover option 3		Cover option 4	
	Column	**Model**	**Column**	**Model**	**Column**	**Model**	**Column**	**Model**
Artificial rainfall (mm)	910	910	910	910	710	710	510	510
Stored infiltration (%)	5.9	4.3-5.1	5.4	5.3-5.9	3.1	2.3-2.6	1.9	1.7-3.9
Seepage (%)	14.7	8	26.9	3.4	7.2	12.9-13	0.2	4.6-4.7
Evaporation (%)	79.4	86.9-87.7	67.7	90.7-91.3	89.8	82-82.6	98	91.5-93.7

Table 21 Water balance summary for 710 mm of artificial rainfall

	Cover option 1	Cover option 2	Cover option 3	Cover option 4
	Model	**Model**	**Model**	**Model**
Artificial rainfall (mm)	710	710	710	710
Stored infiltration (%)	4.6	4	2.3-2.6	3.3
Seepage (%)	3.6-3.8	2.6-2.7	12.9-13	12.2
Evaporation (%)	91.6-91.8	92.5-92.6	82-82.6	84.4

6.2.2 Future cover performance

The performance of cover options 1-4 was assessed for an average, wet and dry year and is presented in Table 22-Table 25 respectively. A range is given representing the range of saturated hydraulic conductivity values that may be encountered in the covers if they were to be built on the TSF. Conservative (ie the worst performing) seepage values have been used across the range of saturated hydraulic conductivity values that were modelled. The maximum seepage which includes an error of 7% (observed in Section 6.2.1) is given in brackets.

Table 22 Summary of cover option 1 water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	117.3	471	1391.1
Stored infiltration (%)	~0	0.1-0.6	~0-0.3
Seepage (%)	~0 (7)	1.2 (8.2)	0.8 (7.8)
Actual evaporation (%)	96.8-100	98.9-99.8	98.9-100

Table 23 Summary of cover option 2 water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	117.3	471	1391.1
Stored infiltration (%)	~0	0.1-0.5	0.1-3.1
Seepage (%)	~0 (7)	0.3 (7.3)	0.1 (7.1)
Actual evaporation (%)	100	99.1-99.8	96.7-99.9

Table 24 Summary of cover option 3 cover water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	117.3	471	1391.1
Stored infiltration (%)	~0	~0-0.4	~0-0.1
Seepage (%)	~0 (7)	1.6 (8.6)	0.3 (7.3)
Actual evaporation (%)	100	98.1-99.7	99.7-100

Table 25 Summary of cover option 4 water balance for average, wet and dry years

	Dry year	Average year	Wet year
Rainfall (mm)	117.3	471	1391.1
Stored infiltration (%)	~0	0.1-0.4	~0-0.1
Seepage (%)	~0 (7)	1.3 (8.3)	1.6 (8.6)
Actual evaporation (%)	100	98.4-99.7	98.4-99.8

Comparison of Table 22-Table 25 shows that all cover options would likely limit seepage to less than 10% of cumulative rainfall. Cover option 1 and 2 have lower seepage and a higher stored infiltration than cover options 3 and 4, indicating that a 1 m thick ISL may provide better performance. A thicker ISL will also aid in the establishment of native vegetation and potentially further decrease seepage through transpiration. The lower rate of seepage in cover option 2 when compared to cover option 1 indicates that the CBs will also help to limit the potential for seepage as the air-filled voids of the CB will act as a physical barrier to infiltration.

Table 21 also shows that a 1 m ISL is likely to have improved performance when subject to periods of short duration, heavy rainfall. These conditions can occur during monsoonal storms which occasionally impact the Mine. Under these climatic conditions, cover option 3 and cover option 4 may have an unacceptable rate of seepage (>10%).

Cover option 1 and 2 are therefore the preferred cover options at this stage. This is due to their increased capability to limit rainfall infiltration into the tailings, as compared with cover option 3 and 4. The necessity of an RPL cannot be confirmed or rejected with confidence at this stage. Additional trials will be required to investigate this (see recommendations, Section 7.1). Cover options 1-4 will also need to be re-trialled with NAF waste rock in place of borrow subsoil (in the RPL and ISL), as either of these materials may be used in the final TSF cover (depending on NAF waste rock availability) (see recommendations, Section 7.1).

6.2.3 Performance of the cover options compared to industry examples

Australian literature that relates to cover geometry is typically for mono (ISL only) or duplex (an ISL underlain by an RPL) layer covers:

- Mt Whaleback Mine and Peak Gold Mine exemplify mono layer covers since the cover is an ISL only (Ayres et al. 2003, O'Kane et al. 2000, O'Kane & Walters 2003) (Figure 14).
- Kidston Mine, Cadia Mine, Century Mine, Endeavor Mine and Mary Kathleen Mine exemplify duplex covers as the covers utilise a RPL overlain by an ISL (Williams et al. 1997; Durham 2002; Wilson 2000, Rohde & Williams 2009, Rohde, Defferrard & Lord 2016; Rohde et al. 2017 & Lottermoser 2003) (Figure 14).

The ratio of evaporation to rainfall (evaporation:rainfall) exceeds two at all of the mines, meaning that store and release covers are appropriate for each mine (Figure 14 and Table 26).

Table 26 Summary of climate for Australian mines with cover trials

Location	Rainfall (mm)	Evaporation (mm)	Evaporation:Rainfall
Kidston Mine	700	2,800	4
Mt Whaleback Mine	320	3,000	~9
Cadia Mine	900	2,000	~2
Century Mine	544	2,700	~5
Endeavor Mine	400	1,200	3
Mary Kathleen Mine	420	2,800	~6.5

Figure 14 Location of mines with cover trials

Cover performance is difficult to determine from the literature with the reviewer often required to make some assumptions to estimate the performance of the cover (where performance relies on the estimation of seepage percentage from the base of the cover). Some examples of seepage that has been reported in the literature include (Figure 15):

- 2 m and 4 m mono layer cover options for Mt Whaleback Mine;
- 1.5-2 m duplex layer cover at Kidston Gold Mine;
- 2m duplex layer cover at Cadia Mine;
- 2 m duplex layer cover at Century Mine;
- 0.4-0.8 m duplex layer covers at Endeavor Mine; and
- 1.5 m duplex layer cover at Mary Kathleen Mine.

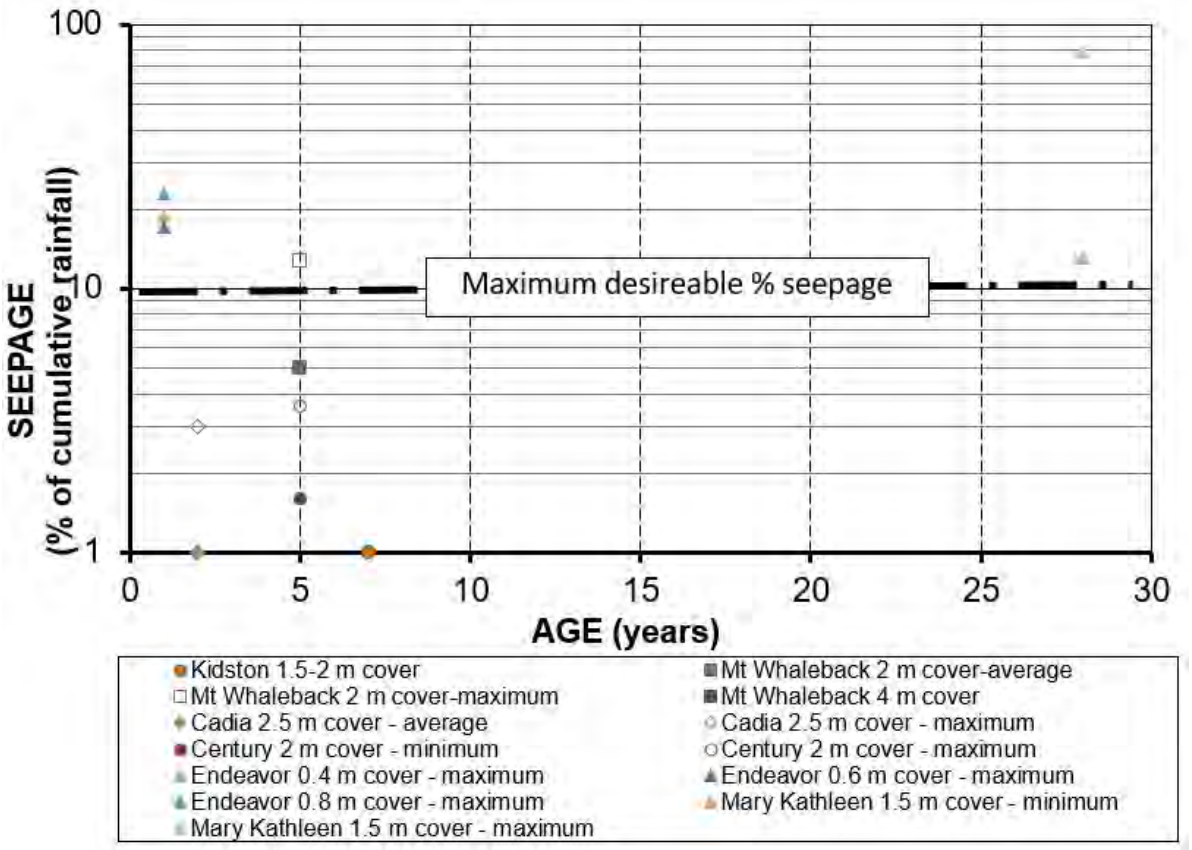

Figure 15 Performance of Australian cover trials

From Figure 15 it is notable that cover performance monitoring has only been generally reported for short periods of up to 7 years. The performance of the covers, from the estimation of seepage percentage, ranges from near zero for Kidston Mine (duplex layer cover) to nearly 30% for Mt Whaleback Mine (mono layer cover) and Mary Kathleen Mine (duplex layer cover). Century Mine which has the most comparable climate to the Mine (Table 26), has limited seepage to between 1.5-3.6%.

The maximum desirable percentage seepage rate shown in Figure 15 (10%) is approximately equivalent to 8.6×10^{-4} metres per second (m/s), being the approximate natural rate of groundwater recharge in semi-arid Australian climates (Cook et al. 2004).

The review suggests that the preferred covers would perform comparably to those in the literature and below the maximum desirable seepage rate. Option 3 and 4 would likely perform worse than maximum desirable seepage rate during short duration, high intensity rainfall events (eg monsoon conditions). This review also suggests that a 1 m thick ISL is likely required and that the optimum cover thickness for the Mine is likely between 1.2-2.3 m (depending on whether an RPL and/or CBs are included).

7.0 Conclusions and recommendations

The study has shown through the trials and a semi-calibrated model that the TSF cover will likely require a 1 m thick ISL to reduce the potential for seepage into the potentially contaminating tailings. A reduction of rainfall infiltration will limit the potential for environmental harm through ARD.

An environmental risk assessment was undertaken in conjunction with preliminary, uncalibrated modelling in SVFlux. The purpose of this was to determine the most suitable store and release cover options for the TSF (which would then progress to column trials). The preliminary model showed that cover option 2 was the preferred option. The availability of NAF waste rock for use in the TSF cover is unknown at this stage. Borrow subsoil was identified as a potential alternative material for use in the ISL and RPL. This material was therefore trialled in place of NAF waste rock in the trials.

The column trials were commissioned in December 2018 and were subjected to varying amounts of artificial rainfall (510-910 mm) over a six-month period to slowly saturate the trials and develop a maximum water balance. The total artificial rainfall applied to each cover varied due to the varying thicknesses and materials of the different covers and the subsequent requirements to generate appropriate wetting up and drying out data. The trials have not shown any signs of significant capillary rise. The water balance of the trials was measured by calibrated matric suction sensors and VWC sensors. Seepage from the base of the trials was measured by rain gauge tipping buckets. Seepage results were recorded for the purpose of completing the maximum water balances (Table 18). Seepage results are not indicative of potential future cover performance due to the varying amounts of rainfall applied to each cover option. The semi-calibrated model was used to compare cover performance.

Following the column trials, the maximum water balance was used to develop a semi-calibrated model in SVFlux. The model used SWCCs, saturated hydraulic conductivities and potential evaporation rates derived from the trials. The semi-calibrated model showed a good correlation to the observed results and it was accepted that the semi-calibrated model could be used to predict the long-term performance of the covers within a seepage error range of 4-7%.

Finally, the trials performance was simulated for a wet, average and dry year to predict the likely long-term performance of the four different covers had they been built on the TSF. The model was also run to simulate 710 mm of artificial rainfall applied to the trials (ie the artificial rainfall applied to cover option 3). The long-term prediction showed that a cover containing a 1 m thick ISL provides the best balance between rainfall infiltration storage and seepage. Seepage was predicted to be under 10% of annual rainfall in the long-term. The 710 mm of artificial rainfall model showed that the covers with a 0.5 m ISL are likely to experience high rates of seepage (>10% of annual rainfall) when subjected to short duration, high intensity rainfall (eg monsoonal conditions). This can be attributed to a lower infiltration storage capacity and as well as lower evaporation. A thicker ISL will also aid in the establishment of native vegetation and potentially further decrease seepage through transpiration. Cover option 1 and 2 are therefore the preferred cover options at this stage. Cover option 1 consists of:

- a 0.4 m CB layer of gap-graded NAF waste rock above the tailings at a density of 1.43 t/m^3;
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.31 t/m^3;
- a 1 m ISL of borrow subsoil above the RPL at a density of 1.64 t/m^3; and
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3.

Cover option 2 consists of:

- a 0.3 m CB layer of gap-graded NAF waste rock above the tailings at a density of 1.38 t/m^3;
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.27 t/m^3;
- a 0.3 m CB layer of gap-graded NAF waste rock above the RPL at a density of 1.38 t/m^3;
- a 1 m ISL of borrow subsoil above the CB layer at a density of 1.64 t/m^3; and
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3.

The necessity of an RPL cannot be confirmed or rejected with confidence at this stage. Additional trials are required and are discussed in Section 7.1. Cover options 1-4 will also need to be re-trialled with NAF waste rock in place of borrow subsoil (in the RPL and ISL), as either of these materials may be used in the final TSF cover (depending on NAF waste rock availability) (see recommendations, Section 7.1).

A comparison to Australian examples of mine site covers suggests that the preferred covers would perform comparably to those in the literature and below the maximum desirable seepage rate. Option 3 and 4 would likely perform above the maximum desirable seepage rate during short duration, high intensity rainfall events. This review also suggests that a 1 m thick ISL is likely required and that the optimum cover thickness for the Mine is likely between 1.2-2.3 m (depending on whether an RPL and/or CBs are included).

7.1 Recommendations

The recommendations made from this study are:

1. The *Conceptual Closure Plan* (MMG 2015) has the following material balance available:
    - 79,751 m^3 of soil (MMG 2015);
    - 25,445 m^3 of soil, rock and vegetation mulch; and
    - 3.5 Mt or 1,750,000 m^3 of NAF waste rock assuming a density of 2 t/m^3.

    A detailed study is required to identify the potential sources and total volumes of potential cover material.
2. As the ISL and RPL in the chosen cover may contain borrow subsoil or NAF waste rock (depending on NAF waste rock availability), it is recommended that cover options 1-4 are trialled with NAF waste rock substituted for borrow subsoil. These covers will then be subjected to an artificial rainfall program. These covers would therefore include:
    - Cover option 5:
        - a 0.4 m CB layer of NAF waste rock;
        - a 0.5 m RPL of NAF waste rock above the CB layer;
        - a 1 m ISL of NAF waste rock above the RPL; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 6:
        - a 0.3 m CB layer of NAF waste rock;
        - a 0.5 m RPL of NAF waste rock above the CB layer;
        - a 0.3 m CB layer of NAF waste rock above the RPL;
        - a 1 m ISL of NAF waste rock above the CB layer; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 7:
        - a 0.3 m CB layer of NAF waste rock;
        - a 0.5 m RPL of NAF waste rock above the CB layer;
        - a 0.3 m CB layer of NAF waste rock above the RPL;
        - a 0.5 m ISL of NAF waste rock above the CB layer; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 8:
        - a 0.5 m ISL of NAF waste rock; and
        - a 0.2 m topsoil layer above the ISL.
3. The necessity of an RPL cannot be confirmed or rejected for the covers in this report. Additional trials (following the trials in recommendation 2) are therefore recommended to eliminate this uncertainty. This will involve decommissioning two column trials and constructing the following covers. These trials will then be subjected to an artificial rainfall program.
    - Cover option 9:
        - a 0.5 m RPL of borrow subsoil;
        - a 1 m ISL of borrow subsoil above the RPL; and
        - a 0.2 m topsoil layer above the ISL.
    - Cover option 10:
        - a 1 m ISL of borrow subsoil; and

- a 0.2 m topsoil layer above the ISL.

These configurations could then be repeated for NAF waste rock in place of borrow subsoil if required.

4. Following the two sets of recommended trials, the covers of interest (based on the column trial results) should be moved to an uncovered position so that they are exposed to naturally occurring rainfall and evaporation. Vegetation should also be established on the trials. This will allow for a more thorough evaluation of the potential for capillary rise and the subsequent requirement for a CB. Periodic sampling of the trials could also be carried out. This will also allow the water balance to be further refined, including the prediction of long-term performance.
5. Once an area of the TSF is available, large field trials should then be established and monitored prior to building the preferred cover on the TSF. The final decision on cover thickness should be based on (field) monitoring data for infiltration and seepage.

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Appendix A – Stockpiled soil, borrow subsoil and tailings chemistry (MMG 2018)

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1907024**	Page	: 1 of 10
Client	: **MMG GROUP LTD**	Laboratory	: Environmental Division Brisbane
Contact	: CARL RIECK	Contact	: Customer Services EB
Address	: PO BOX 69 CLONCURRY QLD, AUSTRALIA 4824	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: DUGALD RIVER	Date Samples Received	: 19-Mar-2019 09:45
Order number	: 4200001897	Date Analysis Commenced	: 21-Mar-2019
C-O-C number	: ----	Issue Date	: 02-Apr-2019 08:32
Sampler	: NICK JAMSON		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 12		
No. of samples analysed	: 12		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.
- EA058 Emerson: V. = Very, D. = Dark, L. = Light, VD. = Very Dark
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).

Analytical Results

Sub-Matrix: DI WATER LEACHATE (Matrix: WATER)				Client sample ID	CB 1	CB 2	CB 3	Tailing 1	Tailings 2
				Client sampling date / time	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00
Compound	CAS Number	LOR	Unit		EB1907024-007	EB1907024-008	EB1907024-009	EB1907024-010	EB1907024-011
					Result	Result	Result	Result	Result
EG020W: Water Leachable Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.04**	**0.04**	**0.02**	**0.47**	**6.36**
Antimony	7440-36-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L		**0.004**	**0.003**	**0.003**	**0.005**	**0.005**
Barium	7440-39-3	0.001	mg/L		**0.250**	**0.346**	**0.845**	**0.278**	**0.480**
Bismuth	7440-69-9	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	**0.841**	**1.55**
Chromium	7440-47-3	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	7440-48-4	0.001	mg/L		<0.001	<0.001	<0.001	**0.123**	**0.193**
Copper	7440-50-8	0.001	mg/L		<0.001	**0.010**	<0.001	**0.054**	**0.178**
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	**1.82**	**2.15**
Lithium	7439-93-2	0.001	mg/L		**0.003**	**0.004**	**0.003**	**0.043**	**0.078**
Manganese	7439-96-5	0.001	mg/L		<0.001	<0.001	<0.001	**63.5**	**61.9**
Molybdenum	7439-98-7	0.001	mg/L		**0.001**	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	**0.535**	**0.681**
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L		**0.041**	**0.032**	**0.031**	**0.803**	**0.439**
Thallium	7440-28-0	0.001	mg/L		<0.001	<0.001	<0.001	**0.002**	<0.001
Thorium	7440-29-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Tin	7440-31-5	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Uranium	7440-61-1	0.001	mg/L		<0.001	<0.001	<0.001	**0.003**	**0.051**
Vanadium	7440-62-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.005	mg/L		**0.035**	**0.065**	**0.076**	**220**	**593**
Boron	7440-42-8	0.05	mg/L		**0.19**	**0.44**	**0.15**	**0.12**	**0.19**
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	<0.05
EG035W: Water Leachable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Analytical Results

Sub-Matrix: DI WATER LEACHATE (Matrix: WATER)				Client sample ID	Tailings 3	----	----	----	----
				Client sampling date / time	02-Dec-2018 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EB1907024-012	--------	--------	--------	--------
					Result	----	----	----	----
EG020W: Water Leachable Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**10.4**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L		<0.001	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L		**0.004**	----	----	----	----
Barium	7440-39-3	0.001	mg/L		**0.251**	----	----	----	----
Bismuth	7440-69-9	0.001	mg/L		<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L		**1.41**	----	----	----	----
Chromium	7440-47-3	0.001	mg/L		<0.001	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L		**0.156**	----	----	----	----
Copper	7440-50-8	0.001	mg/L		**0.438**	----	----	----	----
Lead	7439-92-1	0.001	mg/L		**2.52**	----	----	----	----
Lithium	7439-93-2	0.001	mg/L		**0.075**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L		**55.0**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L		<0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L		**0.593**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L		<0.01	----	----	----	----
Silver	7440-22-4	0.001	mg/L		<0.001	----	----	----	----
Strontium	7440-24-6	0.001	mg/L		**0.367**	----	----	----	----
Thallium	7440-28-0	0.001	mg/L		<0.001	----	----	----	----
Thorium	7440-29-1	0.001	mg/L		<0.001	----	----	----	----
Tin	7440-31-5	0.001	mg/L		<0.001	----	----	----	----
Uranium	7440-61-1	0.001	mg/L		**0.054**	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L		<0.01	----	----	----	----
Zinc	7440-66-6	0.005	mg/L		**537**	----	----	----	----
Boron	7440-42-8	0.05	mg/L		**0.17**	----	----	----	----
Iron	7439-89-6	0.05	mg/L		**0.20**	----	----	----	----
EG035W: Water Leachable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	----	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Topsoil 1	Topoil 2	Topsoil 3	ISL 1	ISL 2
			Client sampling date / time	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00
Compound	CAS Number	LOR	Unit	EB1907024-001	EB1907024-002	EB1907024-003	EB1907024-004	EB1907024-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.2	8.2	8.3	8.4	8.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	100	123	91	237	102
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	10.7	16.6	12.5	17.6	17.4
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Reddish Brown (5YR 3/4)	Dark Brown (7.5YR 3/2)	Dark Brown (7.5YR 3/2)	Dark Brown (7.5YR 3/3)	Dark Brown (7.5YR 3/3)
Texture	----	-	-	Sand	Sandy Loam	Clayey Sand	Clayey Sand	Clayey Sand
Emerson Class Number	EC/TC	-	-	8	4	4	4	4
EA150: Particle Sizing								
+75µm	----	1	%	72	46	59	62	59
+150µm	----	1	%	59	38	49	48	46
+300µm	----	1	%	51	33	43	40	39
+425µm	----	1	%	48	32	41	38	38
+600µm	----	1	%	45	31	38	37	36
+1180µm	----	1	%	40	29	35	34	35
+2.36mm	----	1	%	31	26	29	28	32
+4.75mm	----	1	%	17	19	20	18	29
+9.5mm	----	1	%	<1	<1	<1	<1	26
+19.0mm	----	1	%	<1	<1	<1	<1	<1
+37.5mm	----	1	%	<1	<1	<1	<1	<1
+75.0mm	----	1	%	<1	<1	<1	<1	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	1	20	15	18	18
Silt (2-60 µm)	----	1	%	23	21	23	17	19
Sand (0.06-2.00 mm)	----	1	%	43	32	31	35	30
Gravel (>2mm)	----	1	%	33	27	31	30	33
Cobbles (>6cm)	----	1	%	<1	<1	<1	<1	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.41	2.32	2.37	2.28	2.27
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	7.4	6.8	7.8	8.9	8.5
ø Exchangeable Magnesium	----	0.2	meq/100g	1.0	0.9	1.0	1.8	1.4

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Topsoil 1	Topoil 2	Topsoil 3	ISL 1	ISL 2
			Client sampling date / time	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00
Compound	CAS Number	LOR	Unit	EB1907024-001	EB1907024-002	EB1907024-003	EB1907024-004	EB1907024-005
				Result	Result	Result	Result	Result
ED006: Exchangeable Cations on Alkaline Soils - Continued								
ø Exchangeable Potassium	----	0.2	meq/100g	**0.3**	**0.3**	**0.3**	**0.4**	**0.6**
ø Exchangeable Sodium	----	0.2	meq/100g	<0.2	<0.2	<0.2	<0.2	<0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	**8.7**	**8.1**	**9.2**	**11.1**	**10.5**
ø Exchangeable Sodium Percent	----	0.2	%	<0.2	<0.2	<0.2	<0.2	<0.2
ø Calcium/Magnesium Ratio	----	0.2	-	**7.6**	**7.7**	**7.4**	**5.0**	**6.2**
ø Magnesium/Potassium Ratio	----	0.2	-	**3.0**	**2.6**	**3.4**	**4.2**	**2.2**
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	**20**	**20**	**20**	**140**	**10**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	**20**	<10
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	**4.6**	<0.1	<0.1	<0.1
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**7.8**	**17.7**	**1.8**	**79.5**	**11.1**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**7.8**	**22.3**	**1.8**	**79.5**	**11.1**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	**460**	**360**	**350**	**670**	**560**
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	**470**	**380**	**350**	**750**	**570**
EK080: Bicarbonate Extractable Phosphorus (Colwell)								
Bicarbonate Ext. P (Colwell)	----	5	mg/kg	**14**	**17**	**15**	<5	**8**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	ISL 3	CB 1	CB 2	CB 3	Tailing 1
			Client sampling date / time	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00
Compound	CAS Number	LOR	Unit	EB1907024-006	EB1907024-007	EB1907024-008	EB1907024-009	EB1907024-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.6	----	----	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	----	-407	-399	-438	226
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	105	----	----	----	----
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	----	10.9	10.4	10.4	2.2
NAG (pH 4.5)	----	0.1	kg H2SO4/t	----	<0.1	<0.1	<0.1	106
NAG (pH 7.0)	----	0.1	kg H2SO4/t	----	<0.1	<0.1	<0.1	140
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	----	430	429	456	16.7
ANC as CaCO3	----	0.1	% CaCO3	----	43.9	43.8	46.6	1.7
Fizz Rating	----	0	Fizz Unit	----	5	5	5	1
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	11.9	----	----	----	----
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Brown (7.5YR 3/3)	----	----	----	----
Texture	----	-	-	Clayey Sand	----	----	----	----
Emerson Class Number	EC/TC	-	-	4	----	----	----	----
EA150: Particle Sizing								
+75µm	----	1	%	60	----	----	----	----
+150µm	----	1	%	44	----	----	----	----
+300µm	----	1	%	34	----	----	----	----
+425µm	----	1	%	31	----	----	----	----
+600µm	----	1	%	29	----	----	----	----
+1180µm	----	1	%	25	----	----	----	----
+2.36mm	----	1	%	19	----	----	----	----
+4.75mm	----	1	%	8	----	----	----	----
+9.5mm	----	1	%	<1	----	----	----	----
+19.0mm	----	1	%	<1	----	----	----	----
+37.5mm	----	1	%	<1	----	----	----	----
+75.0mm	----	1	%	<1	----	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	ISL 3	CB 1	CB 2	CB 3	Tailing 1
				Client sampling date / time	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00
Compound	CAS Number	LOR	Unit		EB1907024-006	EB1907024-007	EB1907024-008	EB1907024-009	EB1907024-010
					Result	Result	Result	Result	Result
EA150: Soil Classification based on Particle Size									
Clay (<2 µm)	----	1	%		18	----	----	----	----
Silt (2-60 µm)	----	1	%		18	----	----	----	----
Sand (0.06-2.00 mm)	----	1	%		43	----	----	----	----
Gravel (>2mm)	----	1	%		21	----	----	----	----
Cobbles (>6cm)	----	1	%		<1	----	----	----	----
EA152: Soil Particle Density									
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3		2.35	----	----	----	----
ED006: Exchangeable Cations on Alkaline Soils									
ø Exchangeable Calcium	----	0.2	meq/100g		10.4	----	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g		1.8	----	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g		0.4	----	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g		<0.2	----	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g		12.6	----	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%		<0.2	----	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-		5.7	----	----	----	----
ø Magnesium/Potassium Ratio	----	0.2	-		4.0	----	----	----	----
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		20	----	----	----	----
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		----	0.74	0.98	0.57	7.94
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		<10	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		0.5	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		14.2	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		14.7	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	20	mg/kg		870	----	----	----	----
EK062: Total Nitrogen as N (TKN + NOx)									
^ Total Nitrogen as N	----	20	mg/kg		880	----	----	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)									

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	ISL 3	CB 1	CB 2	CB 3	Tailing 1
				Client sampling date / time	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00	02-Dec-2018 00:00
Compound	CAS Number	LOR	Unit		EB1907024-006	EB1907024-007	EB1907024-008	EB1907024-009	EB1907024-010
					Result	Result	Result	Result	Result
EK080: Bicarbonate Extractable Phosphorus (Colwell) - Continued									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		**6**	**----**	**----**	**----**	**----**
EN60: Bottle Leaching Procedure									
Final pH	----	0.1	pH Unit		**----**	**6.9**	**9.2**	**9.0**	**5.4**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Tailings 2	Tailings 3	----	----	----
			Client sampling date / time	02-Dec-2018 00:00	02-Dec-2018 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB1907024-011	EB1907024-012	--------	--------	--------
				Result	Result	----	----	----
EA009: Nett Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**232**	**219**	**----**	**----**	**----**
EA011: Net Acid Generation								
pH (OX)	----	0.1	pH Unit	**2.1**	**2.2**	**----**	**----**	**----**
NAG (pH 4.5)	----	0.1	kg H2SO4/t	**120**	**112**	**----**	**----**	**----**
NAG (pH 7.0)	----	0.1	kg H2SO4/t	**149**	**132**	**----**	**----**	**----**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**3.6**	**3.1**	**----**	**----**	**----**
ANC as CaCO3	----	0.1	% CaCO3	**0.4**	**0.3**	**----**	**----**	**----**
Fizz Rating	----	0	Fizz Unit	**0**	**0**	**----**	**----**	**----**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**7.69**	**7.25**	**----**	**----**	**----**
EN60: Bottle Leaching Procedure								
Final pH	----	0.1	pH Unit	**4.8**	**4.4**	**----**	**----**	**----**

Certificate of Analysis

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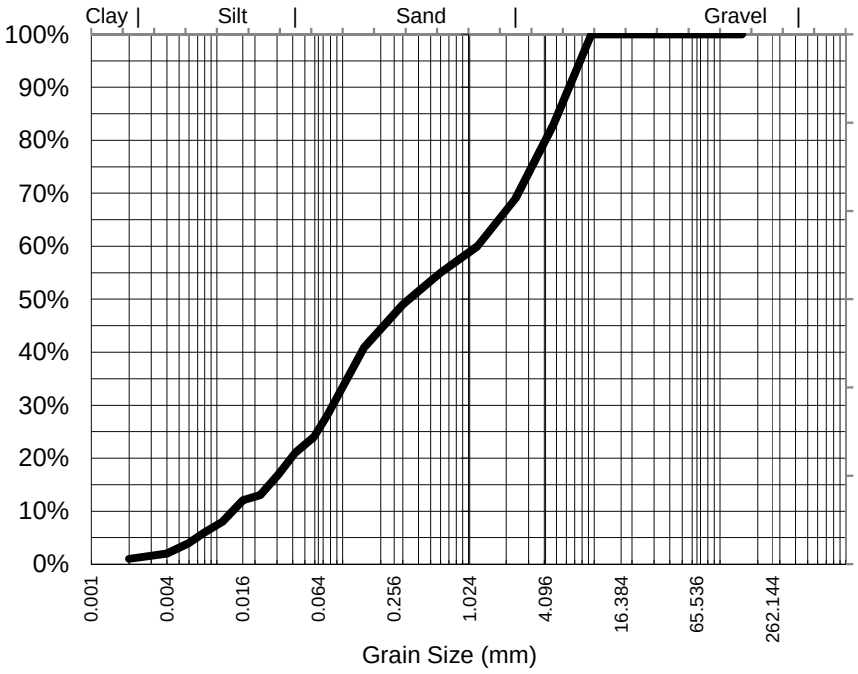
ALS Environmental

Brisbane, QLD

CLIENT:	CARL RIECK	**DATE REPORTED:**	29-Mar-2019
COMPANY:	MMG GROUP LTD	**DATE RECEIVED:**	19-Mar-2019
ADDRESS:	PO BOX 69 CLONCURRY QLD, 4824	**REPORT NO:**	EB1907024-001 / PSD
PROJECT:	Dugald River	**SAMPLE ID:**	Topsoil 1

Particle Size Distribution



Particle Size (mm)	Percent Passing
9.50	100%
4.75	83%
2.36	69%
1.18	60%
0.600	55%
0.425	52%
0.300	49%
0.150	41%
0.075	28%
Particle Size (microns)	
75	28%
59	24%
42	21%
22	13%
11	8%
6	4%
2	1%

Median Particle Size (mm)*	0.342

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Loss on Pretreatment NA

Sample Description:

Test Method: AS1289.3.6.3 2003

Soil Particle Density (<2.36mm) 2.41 (2.45)* g/cm3

Analysed: 25-Mar-19

Limit of Reporting: 1%

Dispersion Method Shaker

Hydrometer Type ASTM E100

NATA Accreditation: 825 Site: Newcastle
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Satish Trivedi
Soil Chemist
Authorised Signatory

Certificate of Analysis

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ALS Environmental

Brisbane, QLD

CLIENT:	CARL RIECK	**DATE REPORTED:**	29-Mar-2019
COMPANY:	MMG GROUP LTD	**DATE RECEIVED:**	19-Mar-2019
ADDRESS:	PO BOX 69 CLONCURRY QLD, 4824	**REPORT NO:**	EB1907024-002 / PSD
PROJECT:	Dugald River	**SAMPLE ID:**	Topoil 2

Particle Size Distribution

Particle Size (mm)	Percent Passing
9.50	100%
4.75	81%
2.36	74%
1.18	71%
0.600	69%
0.425	68%
0.300	67%
0.150	62%
0.075	54%
Particle Size (microns)	
75	44%
56	41%
40	38%
21	30%
11	26%
5	23%
2	20%

Median Particle Size (mm)*	0.075

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:		**Analysed:**	25-Mar-19
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:		**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.3 2003	**Hydrometer Type**	ASTM E100

Soil Particle Density (<2.36mm) 2.32 (2.45)* g/cm3

NATA Accreditation: 825 Site: Newcastle
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Satish Trivedi
Soil Chemist
Authorised Signatory

Certificate of Analysis

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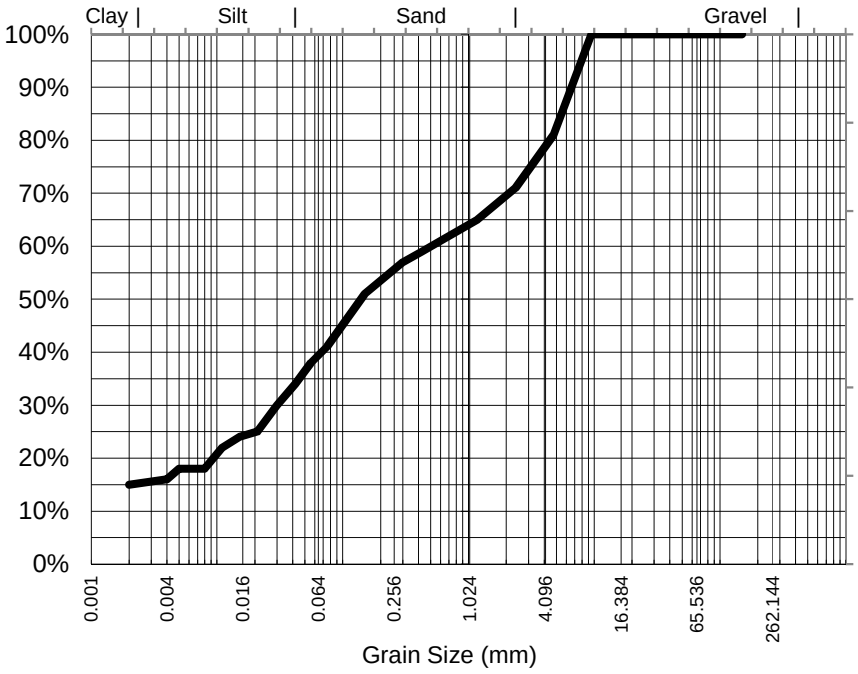
ALS Environmental

Brisbane, QLD

CLIENT:	CARL RIECK	**DATE REPORTED:**	29-Mar-2019
COMPANY:	MMG GROUP LTD	**DATE RECEIVED:**	19-Mar-2019
ADDRESS:	PO BOX 69 CLONCURRY QLD, 4824	**REPORT NO:**	EB1907024-003 / PSD
PROJECT:	Dugald River	**SAMPLE ID:**	Topsoil 3

Particle Size Distribution



Particle Size (mm)	Percent Passing
9.50	100%
4.75	81%
2.36	71%
1.18	65%
0.600	61%
0.425	59%
0.300	57%
0.150	51%
0.075	41%
Particle Size (microns)	
75	41%
56	38%
42	34%
21	25%
11	22%
5	18%
2	15%

Median Particle Size (mm)*	0.143

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:		**Analysed:**	25-Mar-19
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:		**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.3 2003	**Hydrometer Type**	ASTM E100

Soil Particle Density (<2.36mm) 2.37 (2.45)* g/cm3

NATA Accreditation: 825 Site: Newcastle
This document is issued in accordance with NATA's accreditation requirements. Accredited for compliance with ISO/IEC 17025. This document shall not be reproduced, except in full.

Satish Trivedi
Soil Chemist
Authorised Signatory

Certificate of Analysis

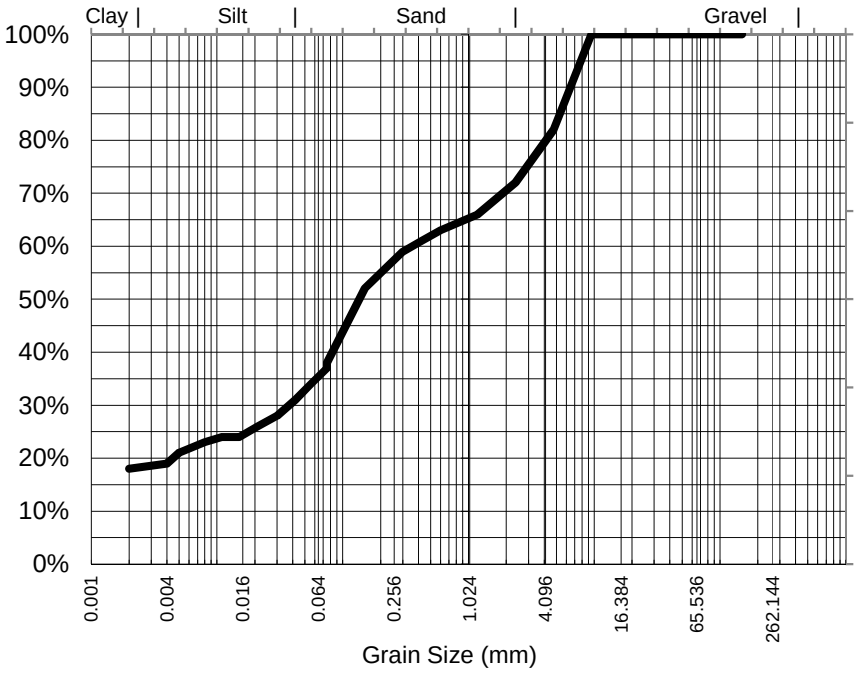
ALS Laboratory Group Pty Ltd
2 Byth Street, Stafford, QLD 4053
pH 07 3552 8678
fax 07 3352 3662
samples.brisbane@alsenviro.com

ALS Environmental

Brisbane, QLD

CLIENT:	CARL RIECK	**DATE REPORTED:**	29-Mar-2019
COMPANY:	MMG GROUP LTD	**DATE RECEIVED:**	19-Mar-2019
ADDRESS:	PO BOX 69 CLONCURRY QLD, 4824	**REPORT NO:**	EB1907024-004 / PSD
PROJECT:	Dugald River	**SAMPLE ID:**	ISL 1

Particle Size Distribution



Particle Size (mm)	Percent Passing
9.50	100%
4.75	82%
2.36	72%
1.18	66%
0.600	63%
0.425	61%
0.300	59%
0.150	52%
0.075	38%
Particle Size (microns)	
75	37%
56	34%
42	31%
21	26%
11	24%
5	21%
2	18%

Median Particle Size (mm)*	0.139

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:		**Analysed:**	25-Mar-19
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:		**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.3 2003	**Hydrometer Type**	ASTM E100

Soil Particle Density (<2.36mm) 2.28 (2.45)* g/cm3

NATA Accreditation: 825 Site: Newcastle
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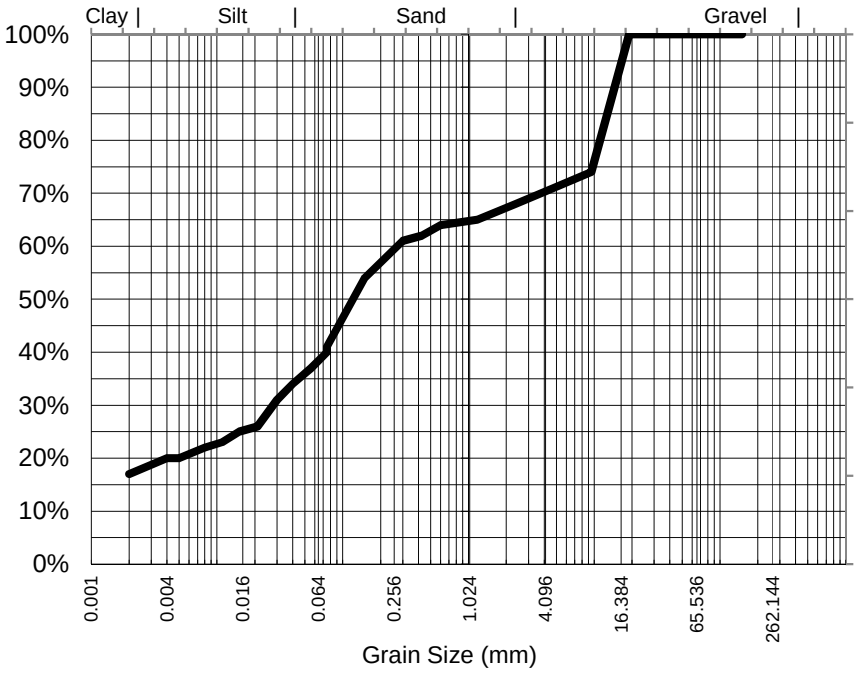
ALS Environmental

Brisbane, QLD

CLIENT:	CARL RIECK	**DATE REPORTED:**	29-Mar-2019
COMPANY:	MMG GROUP LTD	**DATE RECEIVED:**	19-Mar-2019
ADDRESS:	PO BOX 69 CLONCURRY QLD, 4824	**REPORT NO:**	EB1907024-005 / PSD
PROJECT:	Dugald River	**SAMPLE ID:**	ISL 2

Particle Size Distribution



Particle Size (mm)	Percent Passing
19.0	100%
9.50	74%
4.75	71%
2.36	68%
1.18	65%
0.600	64%
0.425	62%
0.300	61%
0.150	54%
0.075	41%
Particle Size (microns)	
75	40%
56	37%
40	34%
21	26%
11	23%
5	20%
2	17%

Median Particle Size (mm)*	0.127

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Loss on Pretreatment NA

Sample Description:

Test Method: AS1289.3.6.3 2003

Soil Particle Density (<2.36mm) 2.27 (2.45)* g/cm3

Analysed: 25-Mar-19

Limit of Reporting: 1%

Dispersion Method Shaker

Hydrometer Type ASTM E100

NATA Accreditation: 825 Site: Newcastle
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Satish Trivedi
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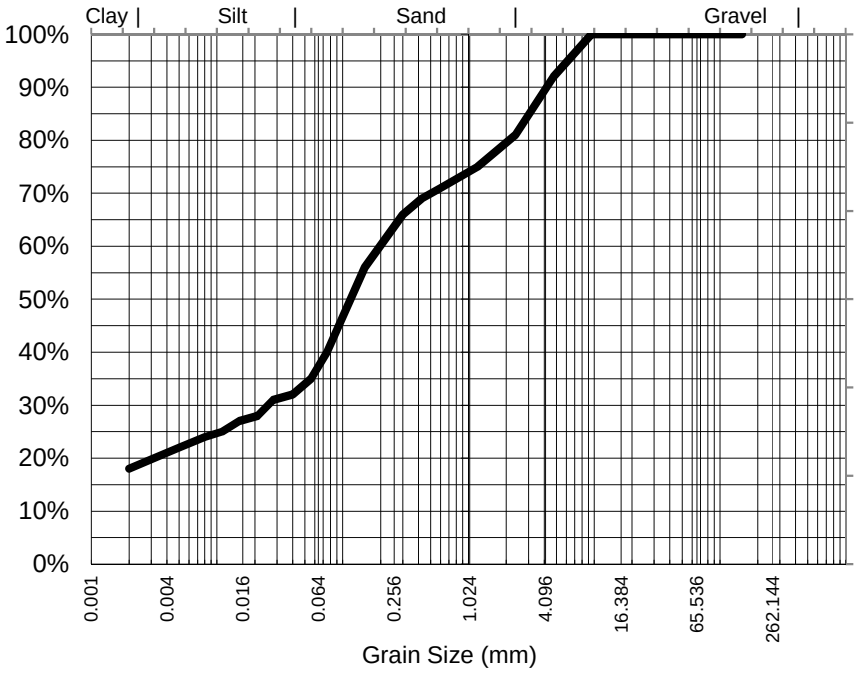
ALS Environmental

Brisbane, QLD

CLIENT:	CARL RIECK	**DATE REPORTED:**	29-Mar-2019
COMPANY:	MMG GROUP LTD	**DATE RECEIVED:**	19-Mar-2019
ADDRESS:	PO BOX 69 CLONCURRY QLD, 4824	**REPORT NO:**	EB1907024-006 / PSD
PROJECT:	Dugald River	**SAMPLE ID:**	ISL 3

Particle Size Distribution



Particle Size (mm)	Percent Passing
9.50	100%
4.75	92%
2.36	81%
1.18	75%
0.600	71%
0.425	69%
0.300	66%
0.150	56%
0.075	40%
Particle Size (microns)	
75	40%
56	35%
40	32%
21	28%
11	25%
5	22%
2	18%

Median Particle Size (mm)*	0.122

Samples analysed as received.

** Soil Particle Density results fell outside the scope of AS 1289.3.6.3. Typical sediment SPD values used for calculations and consequently, NATA endorsement does not apply to hydrometer results*

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:		**Analysed:**	25-Mar-19
Loss on Pretreatment	NA	**Limit of Reporting:**	1%
Sample Description:		**Dispersion Method**	Shaker
Test Method:	AS1289.3.6.3 2003	**Hydrometer Type**	ASTM E100

Soil Particle Density (<2.36mm) 2.35 (2.45)* g/cm3

NATA Accreditation: 825 Site: Newcastle
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Satish Trivedi
Soil Chemist
Authorised Signatory

Appendix B – Borrow subsoil and tailings physical characterisation (MMG 2018)

Permeability - Constant Head Method

TEST IN ACCORDANCE WITH IN-HOUSE PROCEDURE 7.1.1

SAMPLE PREPARATION IN ACCORDANCE WITH

☒AS 1289.5.1.1 ☐CONSOLIDATED

ATC Williams

Client: MMG Dugald River ..... **NATA Report No.: R10219** .....

Address: Dugald River Mine, PO Box 69, ... **Job No.:** 108003.39 .....

Cloncurry QLD 4824.....

Project: Dugald River - Soils and Tailings Testing ..... **Location:** QLD .....

Sample Register No.	03019		
Sample Description	Soils Sample Screened on 19mm sieve Size		

Sample as Prepared

Dry Density @ 95% Compaction	(t/m^3)	1.93		
Moisture Content	(%)	10.0		
Bulk Density (wet)	(t/m^3)	2.12		

Test Conditions

Surcharge (kPa)	18.0		
Sample Height (mm)	60.0		
Test Dry Density (t/m^3)	1.91		
Water Used	Melbourne Tap Water		
Conductivity of Water (µS/cm)	60		
Hydraulic Gradient	29.7		

Test Results

Permeability @ 20°C (m/s)	7.4×10^{-10}		
Final Moisture Content (%)	12.6		

Test Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

The test results relate only to the items tested.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 6 to 12/03/2019

Name of Signatory John Walker Date Reported: 20/03/2019

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Particle Size Distribution Results

TEST IN ACCORDANCE WITH AS 1289

☑ Method 3.6.1 ☑ Method 3.6.3

☑ Oven Drying Method 2.1.1

ATC Williams

Client: MMG Dugald River

Address: Dugald River Mine, PO Box 69, Cloncurry QLD 4824

Project: Dugald River - Soils and Tailings Testing

NATA Report No.: R09819

Job No.: 108003.39

Register No.: 03019

Location: QLD

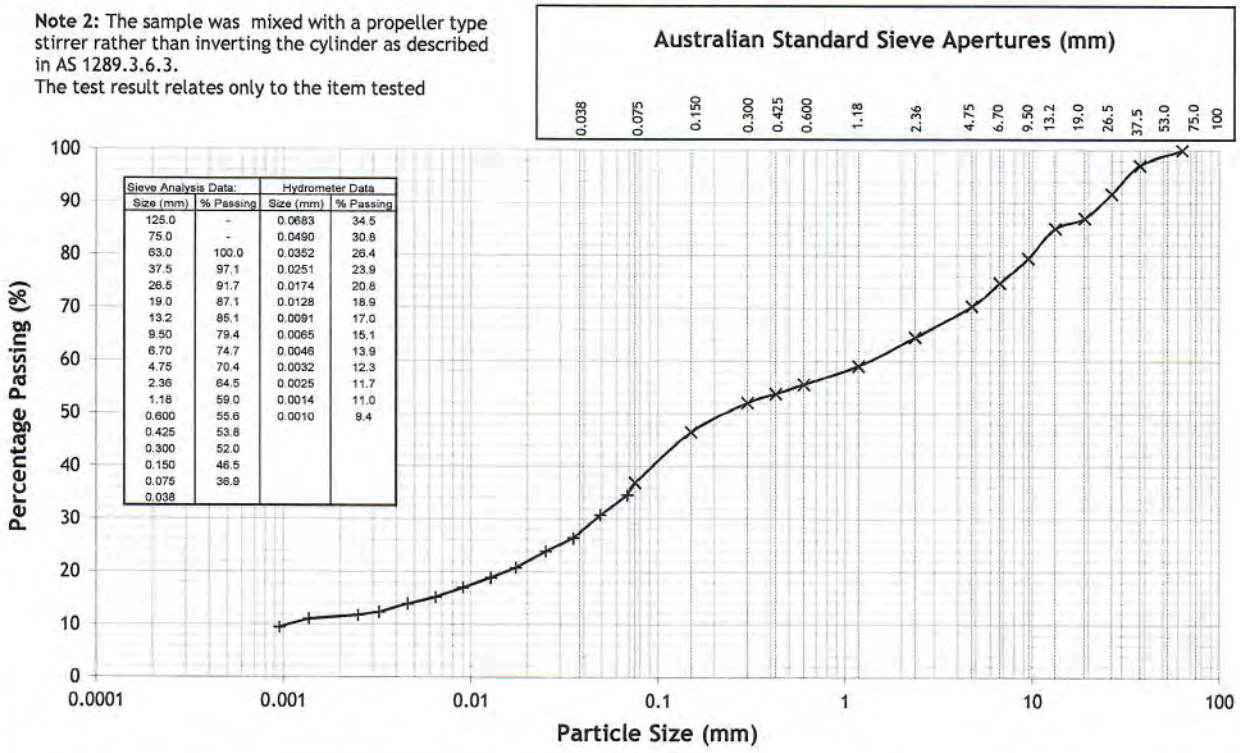
Sample Description: Soil Sample	Borehole No: ☐	Test Pit Depth: ☐

Dispersion Method used: Mechanical Stirrer for 1 minute **Hydrometer Type Used:** ASTM 152H

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1 Clause 6.5.4 ☑ Sample provided by the Client

Note 1: The sample was oven-dried during sample preparation and not air-dried as stated in AS 1289.3.6.3

Note 2: The sample was mixed with a propeller type stirrer rather than inverting the cylinder as described in AS 1289.3.6.3.
The test result relates only to the item tested



Sieve Analysis Data:		Hydrometer Data	
Size (mm)	% Passing	Size (mm)	% Passing
125.0	-	0.0683	34.5
75.0	-	0.0490	30.8
63.0	100.0	0.0352	26.4
37.5	97.1	0.0251	23.9
26.5	91.7	0.0174	20.8
19.0	87.1	0.0128	18.9
13.2	85.1	0.0091	17.0
9.50	79.4	0.0065	15.1
6.70	74.7	0.0046	13.9
4.75	70.4	0.0032	12.3
2.36	64.5	0.0025	11.7
1.18	59.0	0.0014	11.0
0.600	55.6	0.0010	9.4
0.425	53.8		
0.300	52.0		
0.150	46.5		
0.075	36.9		
0.038			

CLAY	SILT			SAND			GRAVEL			COBBLES
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
0.002	0.006	0.02	0.06	0.2	0.6	2	6	20	60	

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: John Walker Date Tested: 4 to 7/03/2019

Name of Signatory: John Walker Date Reported: 20/03/2019

NATA ACCREDITED FOR TECHNICAL COMPETENCE

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Form RSN 004.16 (PSD)
Date of Issue: August 2018

Soil Dry Density/Moisture Content Relation

TEST IN ACCORDANCE WITH AS 1289

☑ Method 5.1.1 (STANDARD)

☐ Method 5.2.1 (MODIFIED)

Moisture Content in accordance with AS 1289.2.1.1

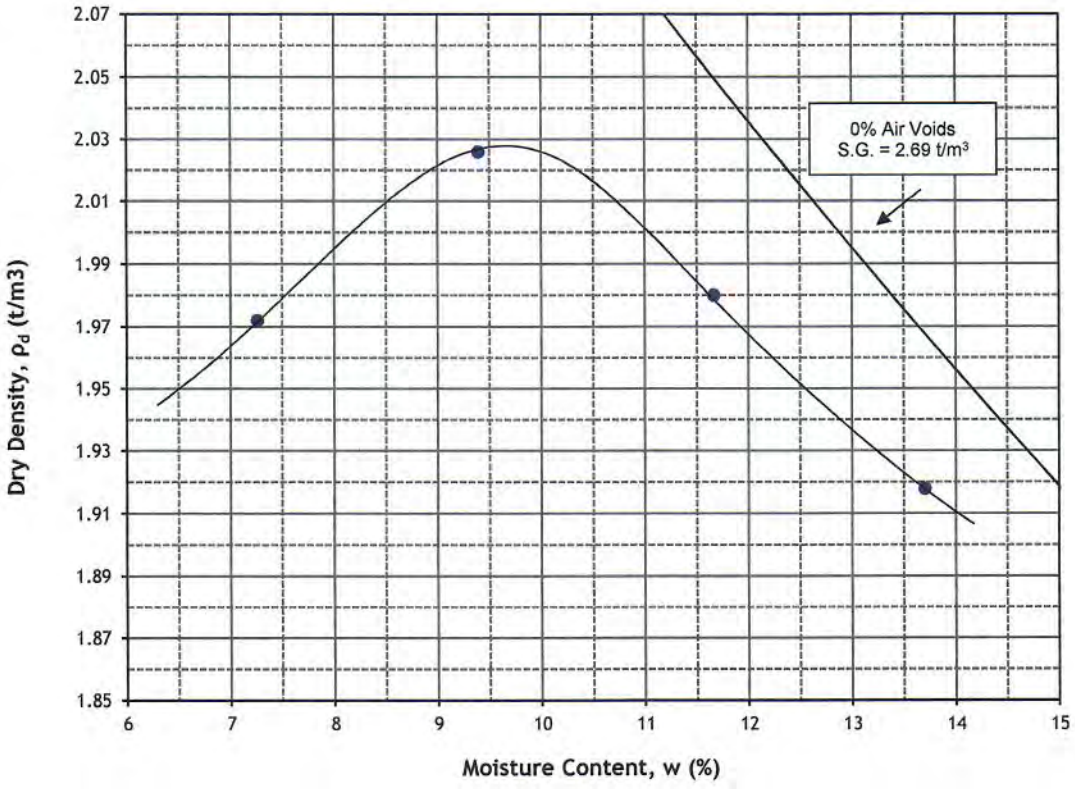
ATC Williams

Client:	MMG Dugald River	**NATA Report No.:**	R10119
Address:	Dugald River Mine, PO Box 69, Cloncurry QLD 4824	**Job No.:**	108003.39
		Register No.:	03019
Project:	Dugald River - Soils and Tailings Testing	**Location:**	QLD

Sample Description: Soils Sample - Screened on 19mm sieve for determination of Standard MDD/OMC for laboratory permeability testing	Borehole/Pit No: ☐	Compaction Mould - A Screened Sample

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1 Clause 6.5.4

☑ Sample provided by the Client



Maximum Dry Density = 2.03 t/m³ Optimum Moisture Content = 9.5 %

NATA ACCREDITED LABORATORY NUMBER: 3372

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: John Walker Date Tested: 1 to 6/03/2019

Name of Signatory: John Walker Date Reported: 20/03/2019

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Determination of the Soil Particle Density of a Soil

ATC Williams

TEST IN ACCORDANCE WITH AS 1289.3.5.1

Client: MMG Dugald River ..... **NATA Report No.: R09619** .....

Address: Dugald River Mine, PO Box 69, ... **Job No.:** 108003.39 .....

Cloncurry QLD 4824.....

Project: Dugald River - Soils and Tailings Testing ..... **Location:** QLD .....

Register Number	Sample Description	Test Temperature (°C)	% of Sample >2.36 mm	Particle Density (g/cm^3)
03019	Soils Sample - Passing 2.36mm Sieve Size	23.5	None	2.70 *
03019	Soils Sample - Retained 2.36mm Sieve Size	26.5	100	2.69 x
03019	Soils Sample - Full Grading	-	35.5	2.69 #

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

* = apparent average soil particle density - particle size less than 2.36 mm

X = apparent average soil particle density - particle size greater than 2.36 mm

\# = soil particle density of the total sample

The test results relate only to the items tested.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 4 to 6/03/2019

Name of Signatory John Walker Date Reported: 20/03/2019

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Form RSN 003.7
Date of Issue: August 2018

Permeability - Constant Head Method

TEST IN ACCORDANCE WITH IN-HOUSE PROCEDURE 7.1.1

SAMPLE PREPARATION IN ACCORDANCE WITH

☒AS 1289.5.1.1 ☐CONSOLIDATED

ATC Williams

Client: MMG Dugald River ..... **NATA Report No.: R10319** .....

Address: Dugald River Mine, PO Box 69, ... **Job No.:** 108003.39 .....

Cloncurry QLD 4824.....

Project: Dugald River - Soils and Tailings Testing ..... **Location:** QLD .....

Sample Register No.	03119		
Sample Description	Tailings Sample		

Sample as Prepared

Dry Density @ 95% Compaction	(t/m^3)	1.60		
Moisture Content	(%)	18.8		
Bulk Density (wet)	(t/m^3)	1.90		

Test Conditions

Surcharge (kPa)	21.6		
Sample Height (mm)	60.0		
Test Dry Density (t/m^3)	1.58		
Water Used	Melbourne Tap Water		
Conductivity of Water (µS/cm)	60		
Hydraulic Gradient	19.5		

Test Results

Permeability @ 20°C (m/s)	4.1×10^{-08}		
Final Moisture Content (%)	27.8		

Test Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

The test results relate only to the items tested.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 6 to 8/03/2019

Name of Signatory John Walker Date Reported: 20/03/2019

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Particle Size Distribution Results

TEST IN ACCORDANCE WITH AS 1289

☑ Method 3.6.1 ☑ Method 3.6.3

☑ Oven Drying Method 2.1.1

ATC Williams

Client: MMG Dugald River

Address: Dugald River Mine, PO Box 69, Cloncurry QLD 4824

Project: Dugald River - Soils and Tailings Testing

NATA Report No.: R09919

Job No.: 108003.39

Register No.: 03119

Location: QLD

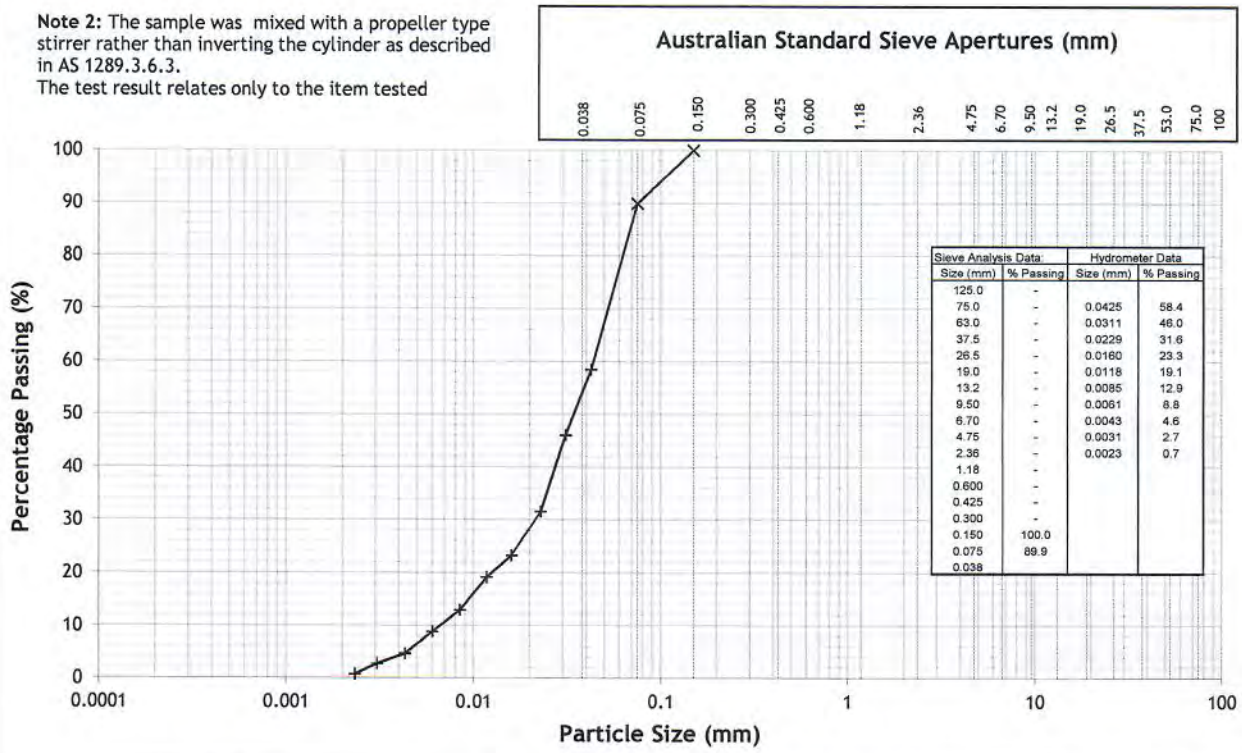
Sample Description: Tailings Samples	Borehole No: ☐	Test Pit Depth: ☐

Dispersion Method used: Mechanical Stirrer for 1 minute **Hydrometer Type Used:** ASTM 152H

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1 Clause 6.5.4 ☑ Sample provided by the Client

Note 1: The sample was oven-dried during sample preparation and not air-dried as stated in AS 1289.3.6.3

Note 2: The sample was mixed with a propeller type stirrer rather than inverting the cylinder as described in AS 1289.3.6.3.
The test result relates only to the item tested



Sieve Analysis Data		Hydrometer Data	
Size (mm)	% Passing	Size (mm)	% Passing
125.0	-		
75.0	-	0.0425	58.4
63.0	-	0.0311	46.0
37.5	-	0.0229	31.6
26.5	-	0.0160	23.3
19.0	-	0.0118	19.1
13.2	-	0.0085	12.9
9.50	-	0.0061	8.8
6.70	-	0.0043	4.6
4.75	-	0.0031	2.7
2.36	-	0.0023	0.7
1.18	-		
0.600	-		
0.425	-		
0.300	-		
0.150	100.0		
0.075	89.9		
0.038			

CLAY	SILT			SAND			GRAVEL			COBBLES
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
	0.002	0.006	0.02	0.06	0.2	0.6	2	6	20	60

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: .....

Name of Signatory: John Walker

Date Tested: 12 to 14/03/2019

Date Reported: 20/03/2019

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Soil Dry Density/Moisture Content Relation

TEST IN ACCORDANCE WITH AS 1289

☑ Method 5.1.1 (STANDARD)

☐ Method 5.2.1 (MODIFIED)

Moisture Content in accordance with AS 1289.2.1.1

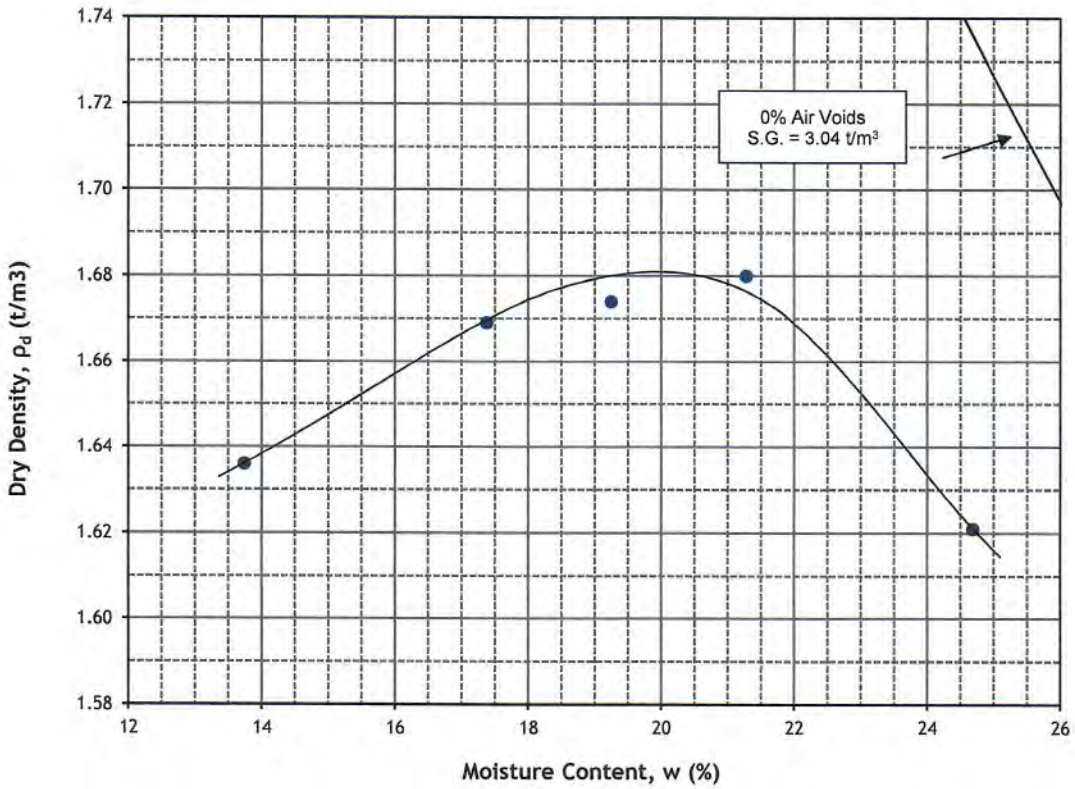
ATC Williams

Client:	MMG Dugald River	**NATA Report No.:**	**R10019**
Address:	Dugald River Mine, PO Box 69, Cloncurry QLD 4824	**Job No.:**	108003.39
		Register No.:	03119
Project:	Dugald River - Soils and Tailings Testing	**Location:**	QLD

Sample Description: Tailings Sample	Borehole ☐ No:	Test Pit ☐ Depth:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1 Clause 6.5.4

☑ Sample provided by the Client



Maximum Dry Density = 1.68 t/m^3 Optimum Moisture Content = 20.0 %

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: John Walker Date Tested: 4 to 6/03/2019

Name of Signatory: John Walker Date Reported: 20/03/2019

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Form RSN 007.10 (Comp)
Date of Issue: August 2018

Determination of the Soil Particle Density of a Soil

ATC Williams

TEST IN ACCORDANCE WITH AS 1289.3.5.1

Client: MMG Dugald River ..... **NATA Report No.:** R09719 .....

Address: Dugald River Mine, PO Box 69, ... **Job No.:** 108003.39 .....

Cloncurry QLD 4824.....

Project: Dugald River - Soils and Tailings Testing ..... **Location:** QLD.....

Register Number	Sample Description	Test Temperature (°C)	% of Sample >2.36 mm	Particle Density (g/cm^3)
03119	Tailings Sample - Full Grading	22.9	None	3.04 #

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

* = apparent average soil particle density - particle size less than 2.36 mm

X = apparent average soil particle density - particle size greater than 2.36 mm

\# = soil particle density of the total sample

The test results relate only to the items tested.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 4 to 6/03/2019

Name of Signatory John Walker Date Reported: 20/03/2019

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Form RSN 003.7
Date of Issue: August 2018

Classification (Atterberg Limits)

ATC Williams

TEST IN ACCORDANCE WITH AS 1289 - CONE PENETROMETER

Client: MMG Dugald River ..... **NATA Report No.: R09519** .....

Address: Dugald River Mine, PO Box 69, ... **Job No.:** 108003.39 .....

Cloncurry QLD 4824.....

Project: Dugald River - Soils and Tailings Testing ..... **Location:** QLD .....

Register Number	Sample Description	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Classification Group Symbol
03019	Soils Sample	26	17	9	-	CL
03119	Tailings Sample	29	21	8	-	CL

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

The test results relate only to the items tested.

Test Methods:

☐	Liquid Limit	AS 1289.3.9.1 (Standard - Penetrometer Method)
☒	Liquid Limit	AS 1289.3.9.2 (One Point - Penetrometer Method)
☒	Plastic Limit	AS 1289.3.2.1
☒	Plasticity Index	AS 1289.3.3.2 (Cone Plasticity Index)
☐	Linear Shrinkage	AS 1289.3.4.1
☒	Moisture Content	AS 1289.2.1.1

Sample Preparation:

☐	Natural Moisture	☒	Air Dried	☐	Oven Dried	☐	Unknown
☐	Wet Sieved	☒	Dry Sieved	☐	Unsieved		

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ..... Date Tested: 27 Feb to 5 March 2019

Name of Signatory: John Walker Date Reported: 19/03/2019

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Form RSN 002.9 (Atterbergs-Soils)
Date of Issue: August 2018

Moisture Content of a Soil

ATC Williams

TEST IN ACCORDANCE WITH AS 1289.2.1.1

Client: MMG Dugald River ..... **NATA Report No.: R09419** .....

Address: Dugald River Mine, PO Box 69, ... **Job No.:** 108003.39 .....

Cloncurry QLD 4824.....

Project: Dugald River - Soils and Tailings Testing ..... **Location:** QLD.....

Register Number	Sample Description	Condition	Moisture Content (%)
03019	Soils Sample	As Received	2.1
03119	Tailings Sample	As Received	7.3

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

The test results relate only to the items tested.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

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Approved Signatory ..... Date Tested: 27/02/2019

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Form RSN 001.9
Date of Issue: August 2018

Appendix C – MMG risk evaluator matrix

APPENDIX A: RISK RATING TABLES

A.1 CONTROL EFFECTIVENESS

Each Critical Control must be assessed against its Critical Control Design to determine effectiveness using the Table below. The Control Self-Assessment considers adequacy of Control Design standards, data from Control Execution and Control verification activities and control failures.

Control Self-Assessment Rating	Control Effectiveness Guide
Effective	Control Design requirements are being met and have been assessed as adequate, effectively operated and require no further improvement. There has been no evidence of control failure.
Partially Effective	Control Design requirements are largely being met however there have been instances of isolated control failure and/or areas for improvement have been identified.
Not Effective	There are systemic issues with the Control Design requirements and/or repeatable execution of the control. Improvements are required to enable the control to operate in a consistent, sustainable way.

A.2 OVERALL RISK EVALUATION (RISK CONTROL EFFECTIVENESS)

Each Material Risk must be evaluated to determine the overall effectiveness of the control environment. The Overall Risk Evaluation (Risk Control Effectiveness) must consider the Control Self-Assessment ratings of each of the Critical Controls, control failures, significant incidents, near misses, Internal Audit findings and other applicable learnings from across the organization or external industry experience.

Overall Risk Control Effectiveness Rating	Control Effectiveness Guide
Fully effective	Nothing more to be done except review and monitor the existing controls. Controls are well designed for the risk, address the root causes and Management believes that they are effective and reliable at all times.
Substantially effective	Most controls are designed correctly and are in place and effective. Some more work to be done to improve operating effectiveness or Management has doubts about operational effectiveness and reliability.
Partially effective	While the design of controls may be largely correct in that they treat most of the root causes of the risk, they are not consistently executed. or Some of the controls do not seem correctly designed in that they do not treat root causes, those that are correctly designed are operating effectively.
Largely ineffective	Significant control gaps. Either controls do not treat root causes or they do not operate at all effectively.
None or totally ineffective	Virtually no credible control. Management has no confidence that any degree of control is being achieved due to poor control design and/or very limited operational effectiveness.

A.3 LIKELIHOOD CRITERIA

Use this table to determine the likelihood of the event occurring resulting in the severity which is being used in the calculation of Risk Level taking into account current preventative controls and their effectiveness.

Likelihood	Business	Projects	Likelihood Category
	Based on MMG and industry experience and expected conditions, the risk event	Based on MMG and industry experience and expected conditions, with similar studies or projects, the risk event	
Almost Certain	Could be incurred more than once in a year	Could be expected to occur more than once during the study or project delivery	**F**
Likely	Could be incurred over a 1-2 year period	Could easily be incurred and has generally occurred in similar studies or projects	**E**
Possible	Could be incurred within a 5 year period	Has been incurred in a minority of similar studies or projects	**D**
Unlikely	Could be incurred within a 5-20 year period	Has been known to happen, but only rarely	**C**
Rare	Could be incurred within a 20-50 year period	Has not occurred in similar studies or projects but could	**B**
Very Rare	Could be incurred in a period > 50 years	Conceivable, but only in extreme circumstances	**A**

A.4 RISK LEVEL

Likelihood Rating							
	F	Medium	Medium	High	Very High	Very High	Very High
	E	Low	Medium	High	High	Very High	Very High
	D	Low	Medium	Medium	High	High	Very High
	C	Low	Low	Medium	Medium	High	High
	B	Low	Low	Low	Medium	Medium	High
	A	Low	Low	Low	Low	Medium	Medium
		1	**2**	**3**	**4**	**5**	**6**
		Consequence Rating					

A.5 CONSEQUENCE CRITERIA

Maximum Foreseeable Loss (MFL) it is the total plausible maximum impact on MMG considering the consequences that could arise if all existing controls were ineffective or missing.

Consequence level rating should be chosen on the basis of the expected or most likely impact on MMG taking into account current mitigating controls and their effectiveness.

Rating	Direct and/or Consequential Financial Loss (USD millions)	Planned production throughput (Days)	Fraud or theft (USD millions)	Safety and People	Environment	Legal Compliance
6	>100	>28	>10	▪ >2 Fatalities ▪ International NGO or National Government intervention in response to multiple community fatalities resulting from mining related activities or disputes	▪ Regional, offsite environmental impact requiring long-term recovery (years) with irreversible residual damage ▪ Species extinction or permanent impairment of ecosystem function or biodiversity value within site ▪ Irreversible loss/damage to site or item of significant cultural heritage value	▪ Regulatory or operating licence non-compliance, or any incident or circumstance with a probable fine of > USD 30 million ▪ Civil claim with damages of >100million ▪ Imprisonment of company executive ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of > USD 30 million
5	>50 – 100	>14 - 28	>5 - 10	▪ 1 – 2 Fatalities ▪ 1 or more Community Fatalities resulting from mining related activities or disputes	▪ Prolonged or severe, offsite environmental impact requiring long-term clean-up (years). ▪ Extensive unconfined, on lease impact requiring long-term clean-up (months-years) leaving residual damage ▪ Change to ecosystem function or biodiversity value within site ▪ Irreversible damage to site or item of significant cultural heritage value	▪ Regulatory or operating licence non-compliance, or any incident or circumstance with a probable fine of USD 15 - 30million or potential trigger for loss of licence. ▪ Civil claim with damages of more than USD 50 -100 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of USD 15-30 million
4	>10 – 50	>7 - 14	>3 – 5	▪ Permanent disabling injury or illness ▪ Multiple Lost Time Injuries ▪ Multiple Community Medical Treatment Injuries resulting from mining related activities or disputes	▪ Major, offsite, environmental impact requiring medium-term clean-up (months). ▪ Onsite confined impact requiring significant clean-up effort (years) ▪ Temporary impairment of an ecosystem function or any kill/loss of a listed or protected species ▪ Repairable damage to site or item of significant cultural heritage value	▪ Regulatory or operating licence non-compliance with a maximum potential fine of USD 10-<15 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of USD 10-<15 million
3	>5 – 10	>3 - 7	>1 – 3	▪ Single Lost Time Injury / Illness ▪ Reversible disability / disabling illness(es) ▪ Single Community Medical Treatment Injury resulting from mining related activities or disputes	▪ Reversible offsite environmental impact, requiring short-term clean-up (weeks) ▪ Onsite, confined, reversible environmental impact, requiring medium term (weeks-months) clean-up	▪ Regulatory or operating licence non-compliance with a maximum potential fine of USD 5 - <10 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of USD 5-<10 million
2	1-5	1 - 3	0.5 - 1	▪ Medical Treatment Injury / Illness(es) ▪ Restricted Work Injury(ies)	▪ Low, confined, reversible environmental impact ▪ Short term (less than a week) clean-up	▪ Regulatory or operating licence non-compliance with a maximum potential fine of less than USD 5 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of < USD 5 million
1	<1	<1	< 0.5	▪ First aid treatment	▪ Very low, reversible environmental impact confined to a small area within operations ▪ Prompt (within a shift) clean-up	▪ Breach of site standard or direction. ▪ Breach of community agreement or accord

1. "Significant incidents" are shaded.

Appendix D – Preliminary modelling method and rationale

Appendix D

Preliminary modelling method and rationale

D.1 Capillary break design

The primary cover, reported in the Mine *Environmental Impact Statement*, is a 1.9 m thick store and release cover and is depicted in Figure 7.

D.1.1 CB

The primary cover includes a CB, for the purpose of preventing/limiting the potential for capillary rise of constituents into the cover from the underlying tailings. The performance of the CB requires solute transport modelling, which has not been included in this assessment. However, for the CB to function properly it will need to remain unsaturated. Therefore, it must be placed above the tailings and below the RPL to prevent/limit infiltration entering the layer. Further, it must be sufficiently thick so that tailings do not 'bleed' through the layer during placement and it must also be designed so that fines from the ISL and RPL above do not migrate into the layer over time. Infiltration and/or fines migration have the potential to fill the CB pores over time which will provide a pathway for constituents to move from the tailings into the cover.

Thickness

Capillary rise in a continuous pore is related to its diameter ie the smaller the pore diameter the higher the capillary rise potential. Fredlund and Rahardjo (1993) have described the capillary rise potential as being approximately equal to one-tenth of matric suction. There are a number of factors that will impact on the capillary rise potential including pore distribution, pore shape and continuity. For a pore to reach its maximum capillary rise potential the pore would need to have a continuous meniscus. A continuous meniscus will only exist at matric suctions between the air-entry value (AEV) and water-entry value (WEV) (refer to Appendix H for notes on how to interpret a SWCC).

Using a pedotransfer function (Fredlund and Xing 1994), we can estimate the AEV is ~2 kilopascals (kPa) and the WEV is ~6 kPa resulting in a capillary rise potential of 0.2-0.6 m

Management of fines

In order to limit the potential for internal migration of fines, the CB will need to be designed as a rock filter following the criteria set by Bertram (1940) and the US Army Corp of Engineers (1977). Both methods for filter design are reported in Cedergren (1977).

Generally, the CB will need to be constructed as two layers ie a 0.3 m gap graded gravel underlain by 0.3 m clean filter sand. It should be noted that the filter design criteria must be applied to the layers of the CB and to the final layer of the CB and the overlying ISL.

D.2 Cover options analysis

The purpose of this section is to present a semi-quantified options assessment for alternative covers for the rehabilitation of the TSF.

The alternative cover analysis is presented in Table 27. The alternative covers analysis was carried out to identify the potential advantages and disadvantages or risks associated with each alternative cover. The options have been ranked based on the following criteria:

- vegetation establishment;
- PAWC;
- infiltration potential;
- root penetration depth;
- water storage potential;
- capillary rise potential; and
- cost.

a Result

The semi-quantified options assessment presented in Table 27 shows that Option B, A, E ranked highest of the options:

- Option B — the Primary Cover with a two-layer CB based on the review presented in Section D.1.1.
- Option A — the Primary Cover.
- Option E — Option B with only half of the ISL thickness.

Table 27 Alternative covers options analysis

Option		Cover option 1	Cover option 2	(C)	(D)	Cover option 3	(F)	(G)	(H)	Cover option 4	(J)
Description		Primary Cover	Cover option 1 + two-layer CB	Century Mine cover	Half (A)	Half cover option 2	Half (C)	(B) - RPL	Half (A/B) - RPL	Half (A/B) - RPL - CB	(C) - RPL - CB
Layer	Unit										
Topsoil	m	0.20, 50% cover	0.20, 50% cover	-	0.20, 50% cover	0.20, 50% cover	-	0.20, 50% cover	0.20, 50% cover	0.20, 50% cover	-
ISL	m	1.00	1.00	1.50-2.00	0.50	0.50	0.75	1.00	0.50	0.50	1.50-2.00
RPL	m	0.50	0.50	0.25	0.50	0.50	0.25	0.00	0.00	0.00	0.00
CB	m	0.40	0.60	-	0.40	0.60	-	0.60	0.60	0.00	0.00
Total	m	1.90-2.10	2.10-2.30	1.75-2.25	1.40-1.60	1.60-1.80	1.00	1.60-1.80	1.10-1.30	0.70	1.50-2.00
Advantages		-	Improved CB performance.	Proven. Increased PAWC.	Low cost.	Low cost. Improved CB performance.	Low cost.	Improved CB performance. Low cost.	Improved CB performance. Low cost.	Lowest cost.	Low cost. Increased PAWC.
Disadvantages		High cost. CB performance may be compromised.	High cost.	No vegetation establishment medium (soil.) Potential desiccation cracking of RPL.	Decreased PAWC. Decreased infiltration storage. CB performance may be compromised.	Decreased PAWC. Decreased infiltration storage.	No vegetation establishment medium (soil). Decreased PAWC. Decreased infiltration storage. Potential desiccation cracking of RPL. No restriction to capillary rise	No restriction to seepage.	Decreased PAWC. Decreased infiltration storage. No restriction to seepage.	No vegetation establishment medium (soil). Decreased PAWC. Decreased infiltration storage. No restriction to seepage. No restriction to capillary rise	No vegetation establishment medium (soil). No restriction to seepage. No restriction to capillary rise.
Ranking criteria											
PAWC		2	2	1	4	4	3	2	4	4	1
Vegetation establishment		1	1	4	1	1	4	1	1	4	4
Infiltration potential		1	1	2	1	1	2	4	4	4	4
Root penetration depth		2	2	1	4	4	3	2	4	4	1
Water storage potential		1	3	2	5	4	8	4	7	9	6
Capillary rise potential		2	1	4	2	1	4	1	1	4	4
Cost		9	7	8	5	6	2	6	3	1	4
Ranking points		16	15	21	18	17	23	18	20	26	23
Overall ranking		2	1	6	4	3	7	4	5	8	7

D.3 Method

D.3.1 Model set-up

The model was developed in one dimension and calculates the upward and downward movement of rainfall infiltration/seepage in the cover; it assumes no surface run off or run on and allows ponding at the surface of the cover.

The model was run for the Primary Cover, Option B, Option E and Option I from Table 27 to allow a comparison of the Primary Cover to:

- a cover option that has a CB designed as a two-layer rock filter;
- a cover option that has only half the thickness of the ISL;
- a cover option that has only half the thickness of the ISL and no RPL or CB.

The purpose of the modelling exercise is to arrive at an assessment of how thick the ISL should be and to make a determination on whether a RPL or CB is required.

b Model dimensions

The models were developed to replicate the structures described in Table 27 and had total thicknesses of:

- Primary Cover — 2.1 m;
- Option B — 2.3 m;
- Option E — 1.8 m; and
- Option I — 0.7 m.

c Mesh geometry

The model automatic mesh generation and automatic mesh refinement algorithms were used to generate the finite element mesh in the model.

d Initial conditions

Duration

The model was initially run for a 128-year period using patched climate data from SILO for Cloncurry Airport (the primary model run).

The model was run for a dry, average and wet year based on the 128 year patched SILO climate. That is:

- dry — 25th quartile — corresponding to ~307 mm of rainfall which was closest to 1980;
- average — the average — corresponding to 460 mm of rainfall which was closest to 1987; and
- wet — the wettest on record — corresponding to 1,156 mm of rainfall which was closest to 1974.

Steady state conditions

The steady state model run allowed the initial head condition within the model to reach a hydrostatic condition. The result of the steady state model run was used as the initial head condition for the dry, average and wet year scenarios.

Physical characteristics

The model requires SWCCs. A SWCC is the relationship between VWC and matric suction for each layer of the model. The model layers were built as per Table 27 using SWCCs derived from the pedotransfer function (Fredlund and Zing 1994).

The saturated hydraulic conductivity of the ISL was estimated to be 9.96×10^{-6} m/s, the saturated hydraulic conductivity for the RPL was 2.89×10^{-6} m/s and the saturated hydraulic conductivity of CB (waste rock) was estimated to be 2.89×10^{-5} m/s based on test results from Century Min (noting that the MMG 2018 physical characterisation data was not available at the time of preliminary modelling).

The saturated hydraulic conductivity of the sand used in CB was estimated to be ~2.31×10^{-5} m/s using the method described by Rawles et al. (1983).

Hydraulic conductivity is the ability of the cover and tailings to transmit rainfall infiltration through the internal pore space and is defined by the rainfall infiltration velocity. The model derives unsaturated hydraulic conductivity curves from the SWCCs and the saturated hydraulic conductivity.

A schematic representation of each model is shown in Figure 16.

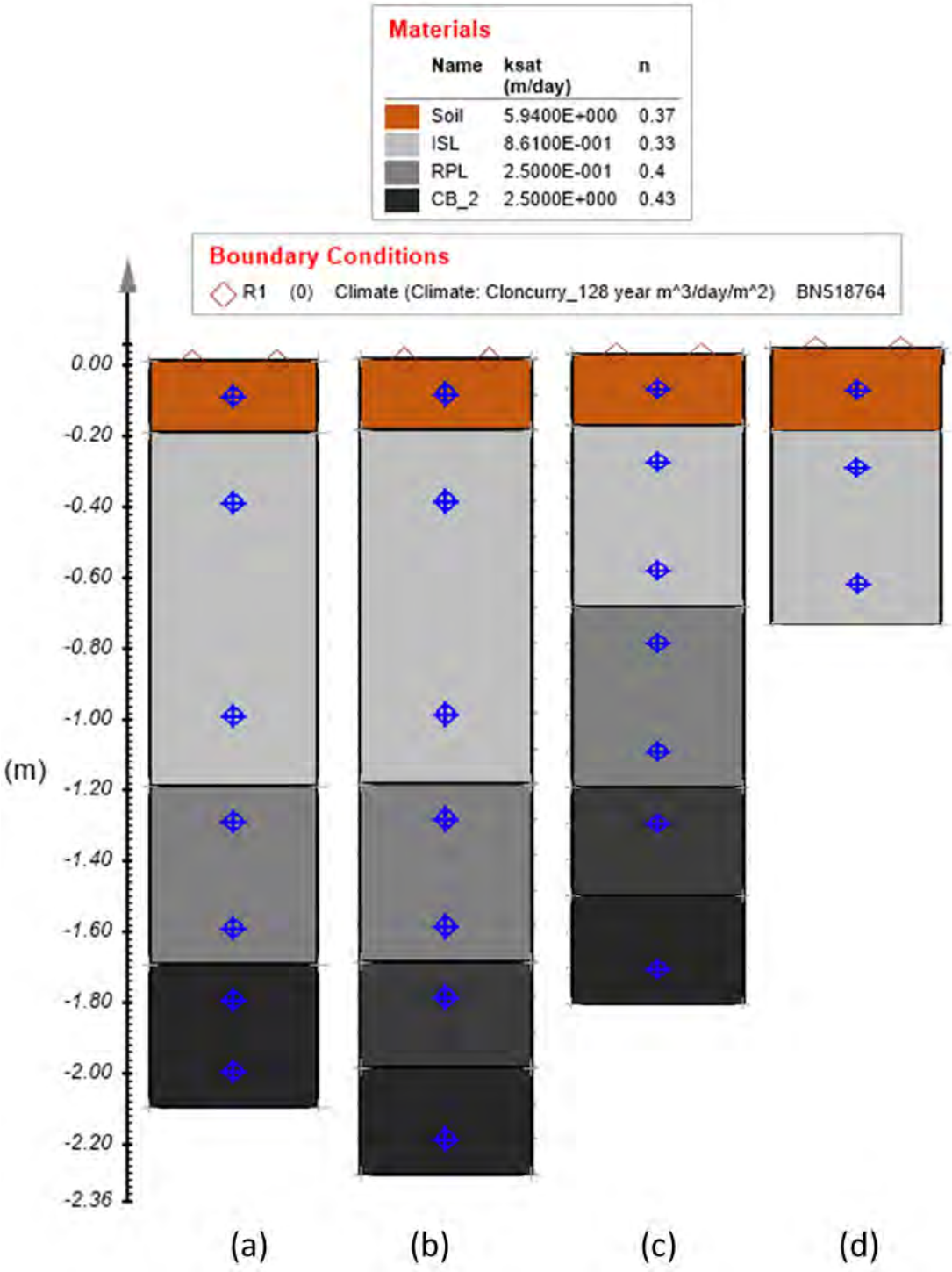


Figure 16 Model cross section (a) Primary Cover (b) Option B (c) Option E (d) Option I

Appendix E – Matric suction sensor calibration method

The following methodology was used to calibrate the matric suction sensors:

1. Dry sensors in bucket of silicon beads for 48 hours (hrs).
2. Oven-dry all soil and tailings samples at 105°C for 24 hours. This is equivalent to 1,000,000 kPa of matric suction.
3. Place silicon dried sensors into oven dried soil and allow to come to equilibrium for 24 hrs. After 24 hrs the ΔT is measured by wiring sensors to the data logger. Measured ΔT is equivalent to matric suction at 1,000,000 kPa.
4. Dismantle and place sensors into a water chamber for 24 hours to completely saturate sintered ceramic heads. After 24 hours the ΔT is measured by wiring sensors to the data logger. Measured ΔT is equivalent to matric suction at 0 kPa. Sensors are not saturated under vacuum conditions as this will not be achievable prior to in-situ installation. Calibration aimed to replicate in-situ conditions as much as practicable.
5. Place air dried soil and tailings into cement mixer and wet up to saturation. Soil is laid out on a free draining table to allow excess water to drain off (this was the air-entry value/field capacity). This step takes about 12 hours to complete. Soil is then packed into jars to a density equal to field density. The sensors are allowed to come to equilibrium for 6 hours. After 6 hours the ΔT is measured by wiring sensors to the data logger. Measured ΔT is equivalent to matric suction at 10 kPa. Matric suction is confirmed by sub-sampling.
6. Sensors are then allowed to dry over a 6 day cycle with samples collected from close to the sensor on every other day. ΔT is measured at the time of sampling. Sample temperature is allowed to come to equilibrium at approximately 25°C prior to sub-sampling.
7. Total suction is measured directly on all sub-samples using a water potential dew-point meter. Matric suction is calculated from EQ A.1 and EQ A.2.

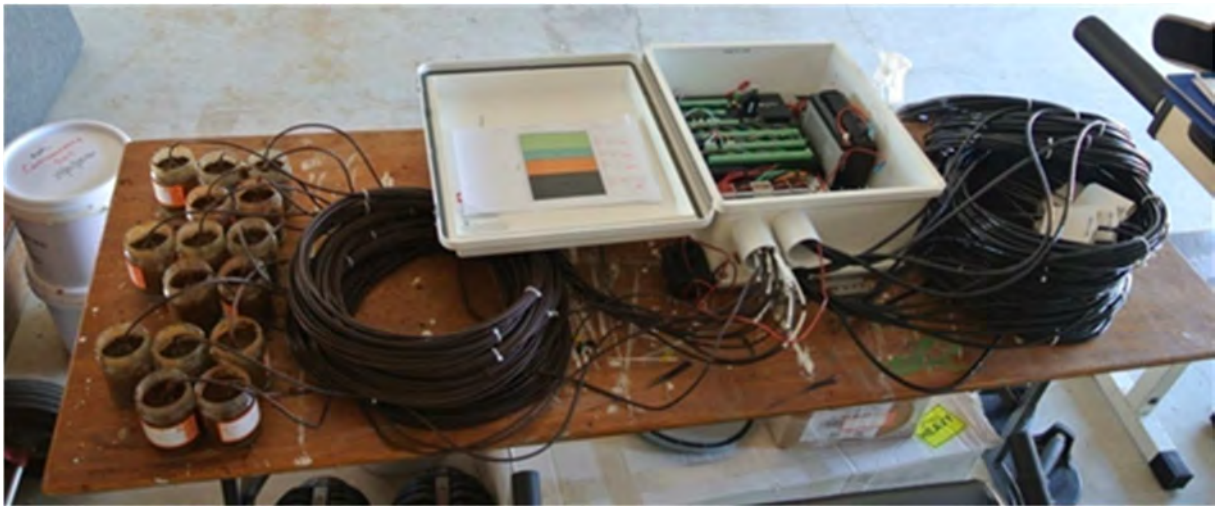
Total Suction = Matric suction + Osmotic suction EQ A.1

Osmotic Suction = 0.36 × EC (deciSemens per metre (dS /m)) EQ A.2

The ΔT is measured by reading the heating element temperature at one second and 30 seconds via a thermocouple embedded within the sensor head adjacent to the heating element.

Photograph 3 illustrates the experiment set up for calibration. Matric suction sensors are embedded at the expected field density and wired to the data logger ready for measuring the ΔT.

Figure 17 illustrates the relationship between the calibration methodology and the SWCC. The calibration method was used to derive a four-point calibration function spanning the full range of expected matric suctions that may be encountered in-situ.



Photograph 3 Matric suction sensor calibration

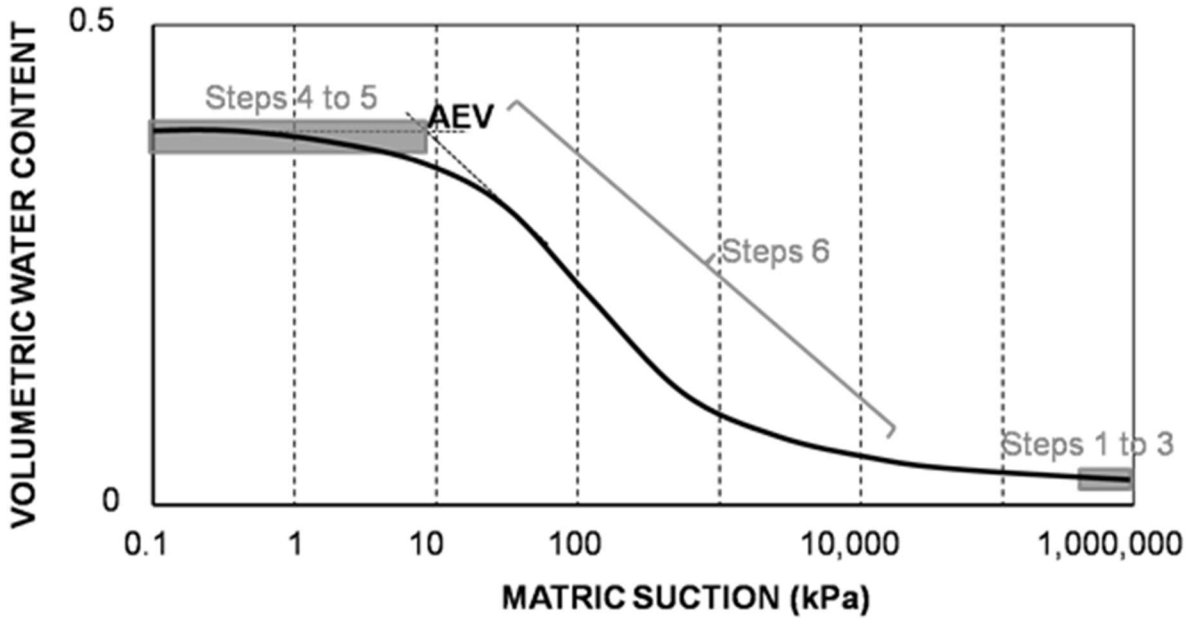


Figure 17 Generalised SWCC illustrating which part of the SWCC are measured by the calibration method

Appendix F – Matric suction sensor calibration results

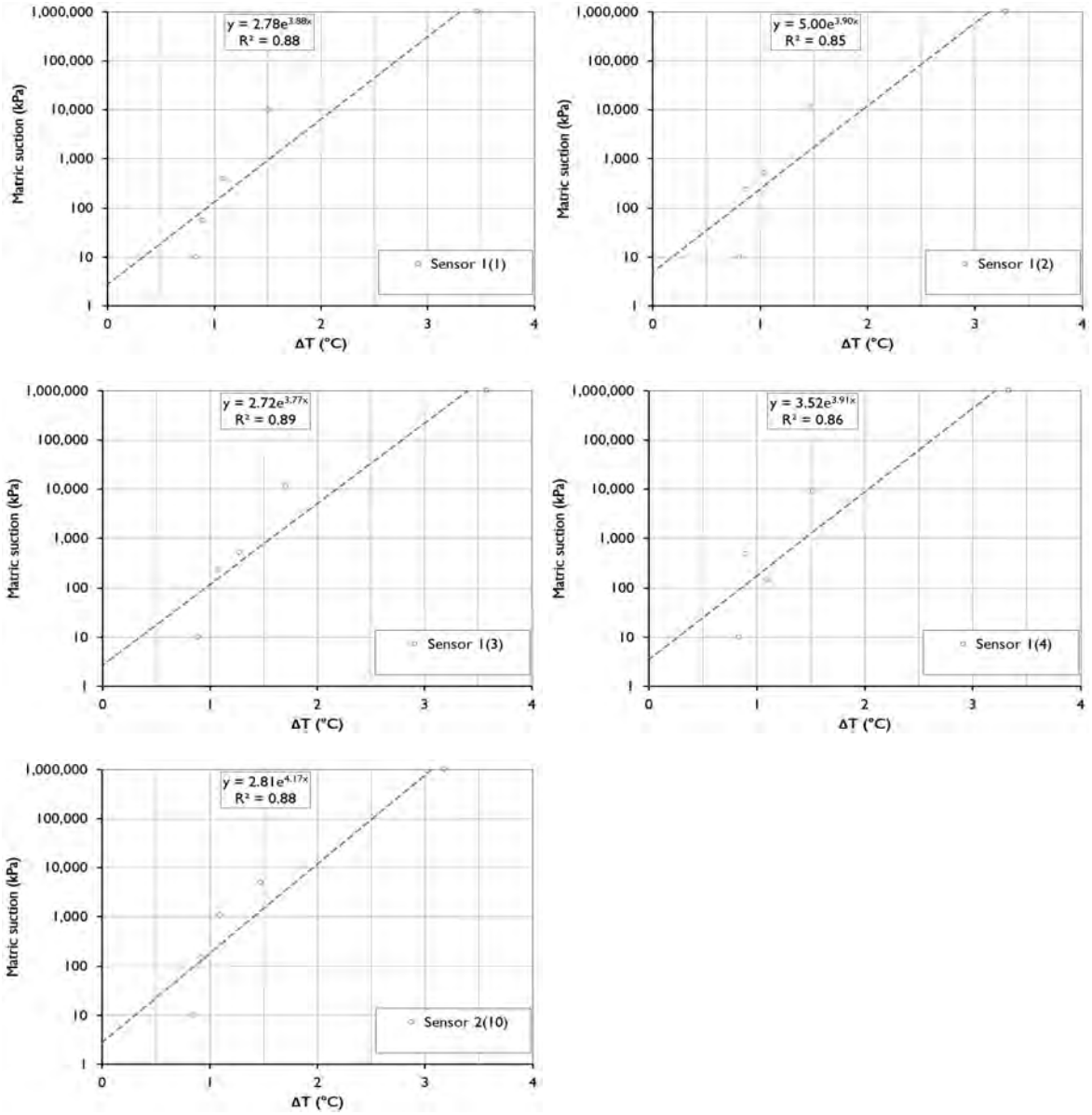


Figure 18 Cover option 1 matric suction sensor calibration curves

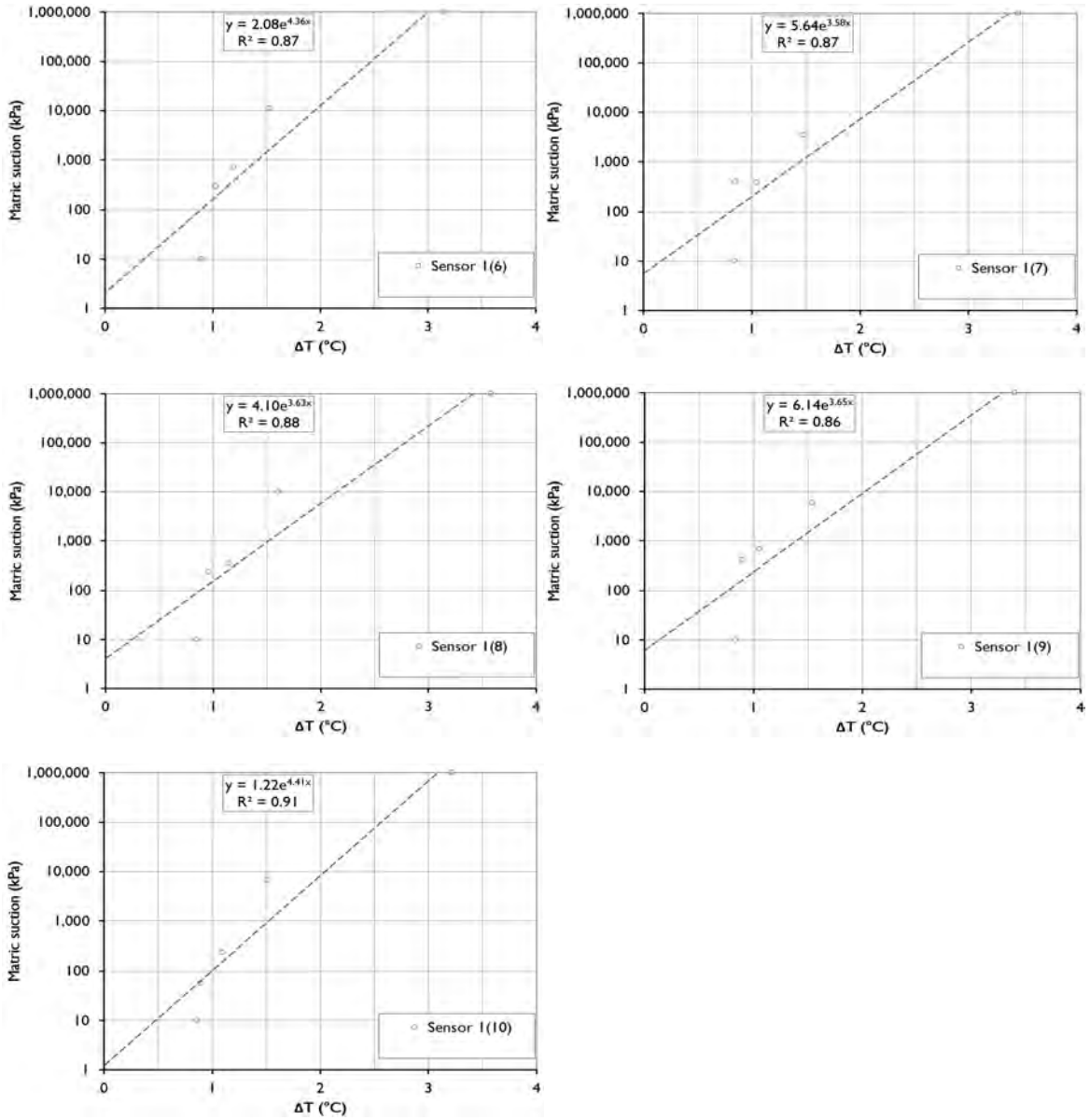


Figure 19 Cover option 2 matric suction sensor calibration curves

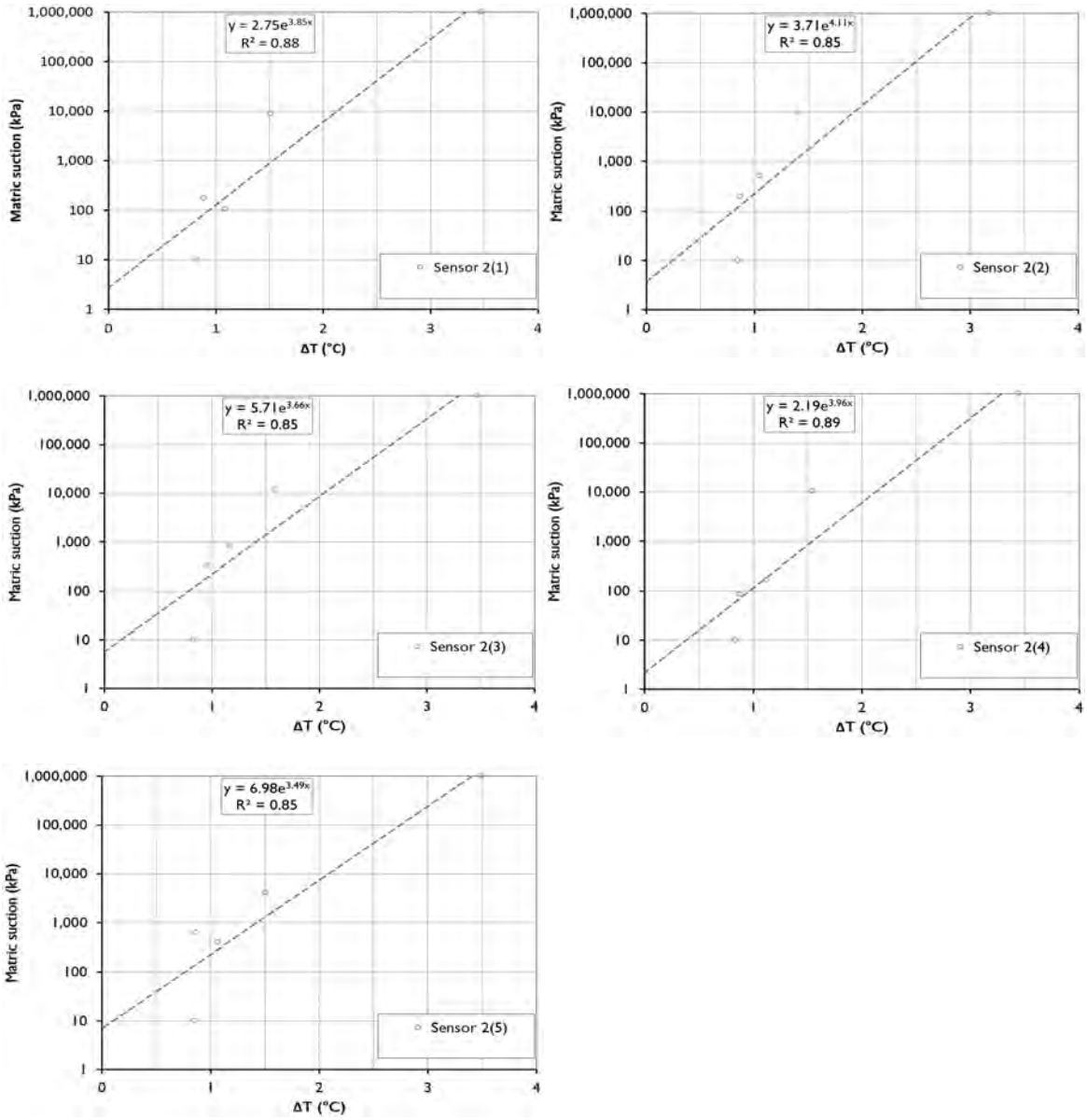


Figure 20 Cover option 3 matric suction sensor calibration curves

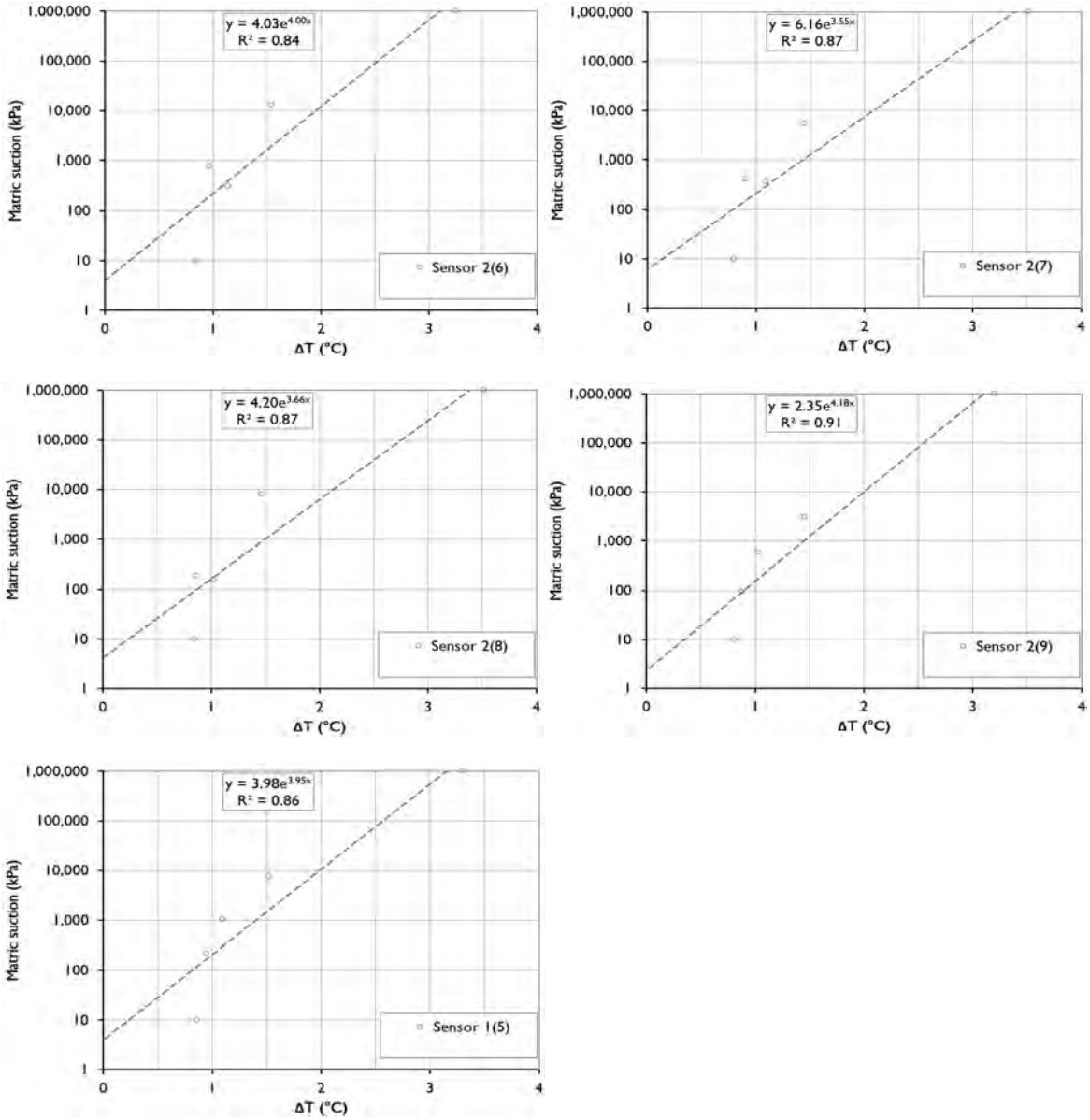


Figure 21 Cover option 4 matric suction sensor calibration curves

Appendix G – VWC and matric suction sensor results

Appendix G

VWC and matric suction sensor results

G.1 Matric suction

Figure 22 presents the matric suction results for the trials. Matric suction results for the tailings layer are not discussed as the in-situ data did not generate a complete SWCC (ie the relationship between VWC and matric suction in the tailings was not fully defined). Figure 22 shows that:

- the topsoil and CB layers are initially dry with matric suctions close to 1,000,000 kPa;
- the ISLs are initially dry with matric suctions between 1,000 kPa to 10,000 kPa;
- the RPLs are initially dry with matric suctions between 5,000 kPa to 200,000 kPa;
- upon wetting of the trials with artificial rainfall events, cover option 1 (Figure 22a):
    - the topsoil layer starts wetting up after 30 mm of rainfall before becoming saturated after 310 mm of rainfall (~100 kPa). Infiltration reaches the bottom of the ISL and top of the RPL after 310 mm of rainfall before becoming saturated after 510 mm of rainfall (~100 kPa). The bottom of the RPL and the CB both remain dry before becoming saturated after 510 mm of rainfall (~100 kPa and ~80 kPa respectively).
- upon wetting of the trials with artificial rainfall events, cover option 2 (Figure 22b):
    - the middle of the ISL starts wetting up after 150 mm of rainfall before reaching saturation after 510 mm of rainfall (~120 kPa). The RPL and both CBs remain dry before becoming saturated after 510 mm of rainfall.
- upon wetting of the trials with artificial rainfall events, cover option 3 (Figure 22c):
    - the middle of the ISL starts wetting up after 90 mm of rainfall before reaching saturation after 510 mm of rainfall. The top of the RPL and the upper CB were close to saturation after 150 mm of rainfall before reaching saturation after 510 mm of rainfall. The bottom of the RPL and the lower CB remain dry before becoming saturated after 510 mm of rainfall (~80 kPa and ~50 kPa respectively).
- upon wetting of the trials with artificial rainfall events, cover option 4 (Figure 22d):
    - the topsoil begins wetting up after 30 mm of rainfall before reaching saturation after 510 mm of rainfall (~100 kPa). The ISL begins wetting up after 90 mm of rainfall before reaching saturation after 510 mm of rainfall (~85 kPa).

The trials oscillate between near-saturated and unsaturated throughout. Once saturation was reached, however; the trials all trend towards near-saturated with time because the rate of artificial rainfall addition exceeds the rate of evaporation.

G.2 VWC

Figure 23a to Figure 23d presents the VWC results for cover option 1 to cover option 4 respectively. Artificial rainfall is shown as an inset on the figure. The VWC results for the trials mirror the wetting and drying trends discussed in Section G.1 for matric suction and are not discussed further in this report.

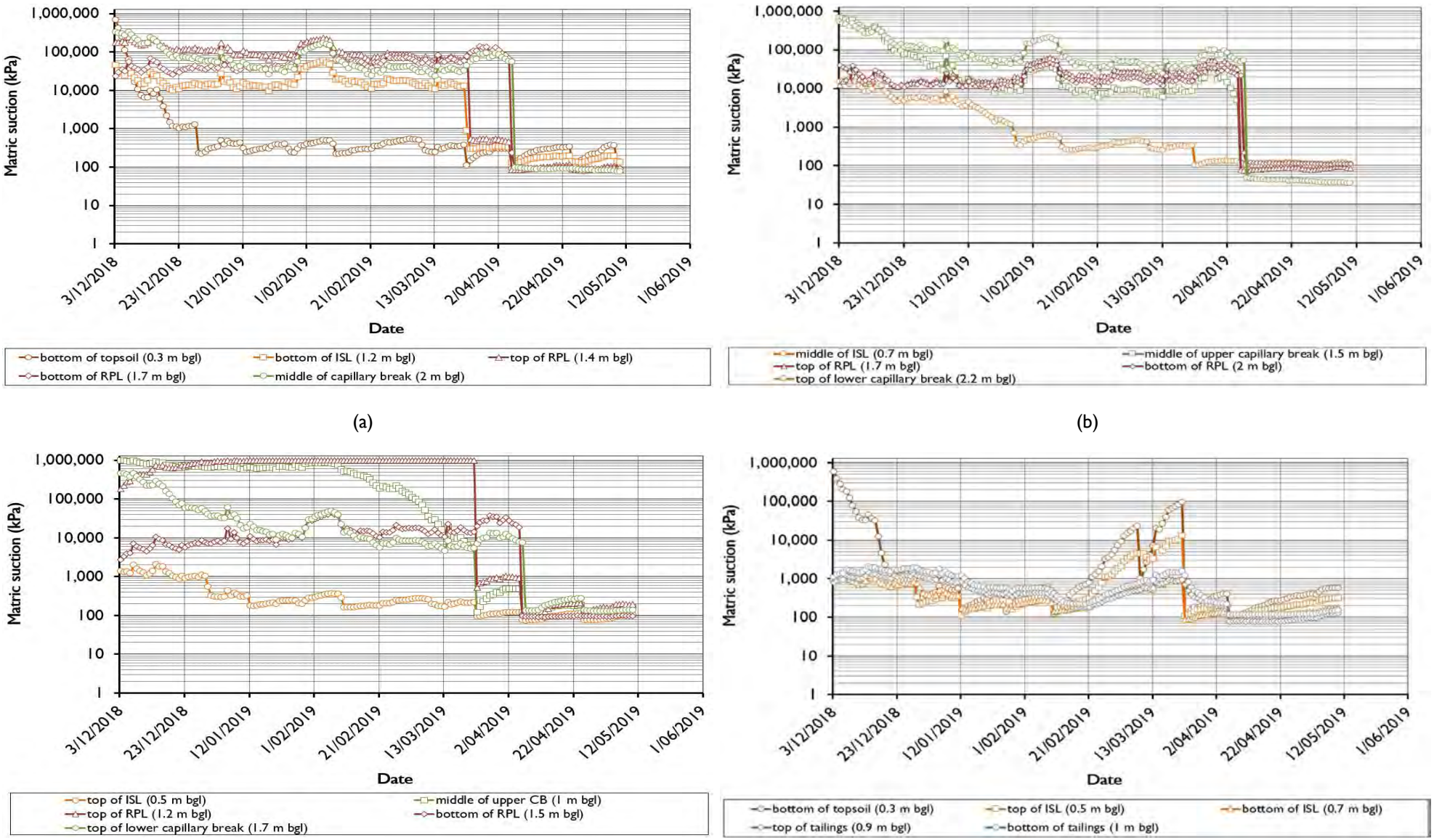


Figure 22 The trials matric suction results

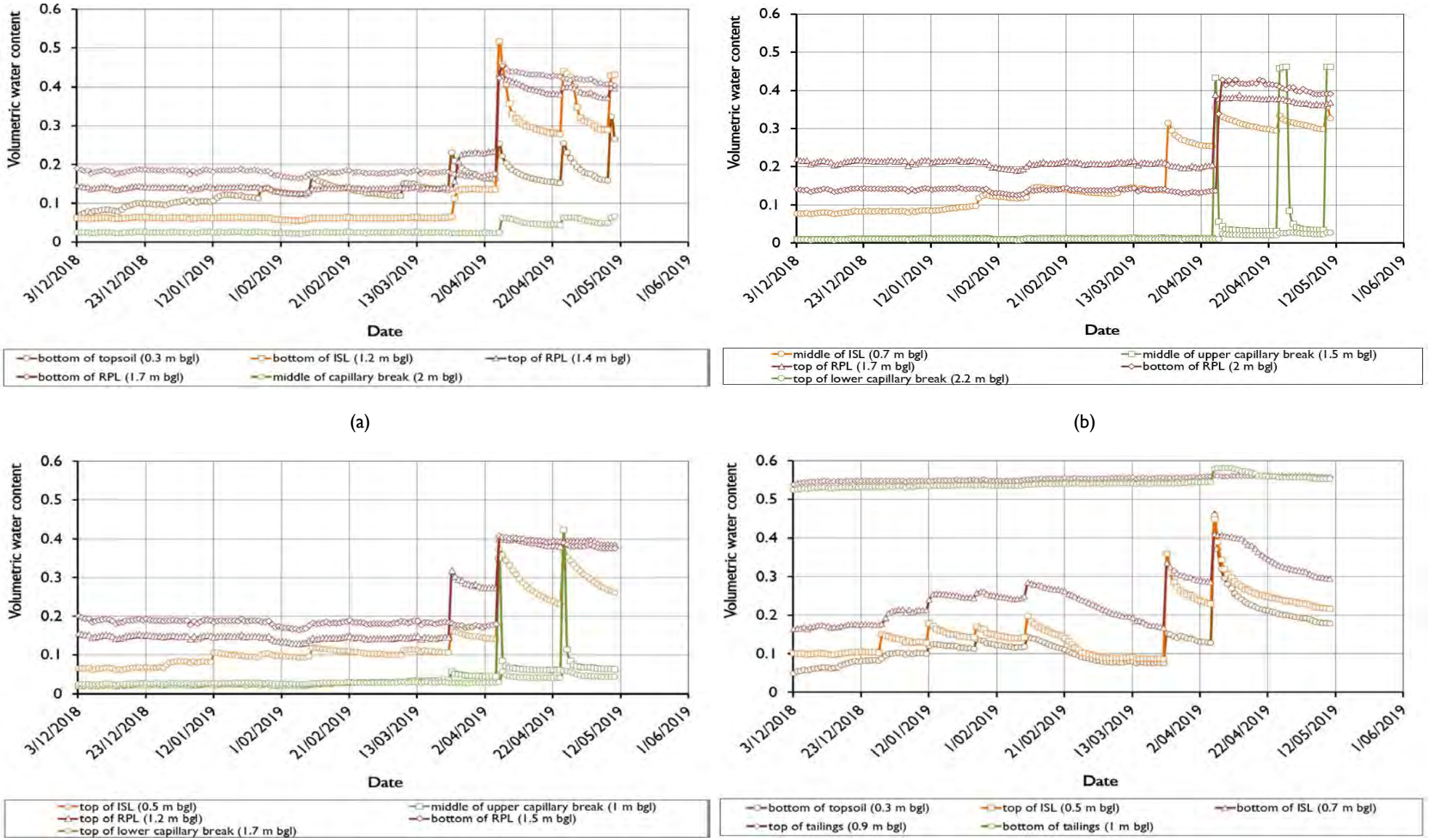


Figure 23 The trials VWC results

Appendix H – Interpretation of SWCCs

The SWCC is fundamental to understanding unsaturated soil mechanics. It is a plot of soil water, conventionally in terms of volumetric water content = volume of water/total volume; but it could also be in terms of degree of saturation = volume of water/volume of voids; or gravimetric moisture content = mass of water/mass of solids, expressed as a %.

The key elements of the soil water characteristic curve are the following (Figure 24).

- The intercept on the vertical axis represents near-saturated conditions at the test density (the higher the density the lower the intercept, and increasing the density will induce drainage).
- The break in the curve at a high degree of saturation or high water content, referred to as the air-entry value (AEV) on drying, beyond which the material is unable to remain saturated, and air starts to replace any further moisture lost from the pores of the material. Up to the AEV, the material is essentially saturated (degree of saturation S > 85%) and suction effects can be ignored. The capillary rise in metres at the AEV = AEV/9.81.
- The slope of the curve at matric suctions higher than the AEV. The flatter the curve, the more water the material is able to store, and the harder it is to dewater (that is, the higher the applied pressure required to effect dewatering). Over this portion of the curve, matric (or capillary) suction and liquid water flow dominate.
- The break in the curve at a low degree of saturation or low water content, referred to as the water-entry value (WEV) on re-wetting, beyond which osmotic suction and water vapour flow dominate. The WEV is the suction at which the material starts to rapidly wet up on re-wetting. As the material dries beyond the WEV, the salt concentration of the diminishing pore water increases and so too does the osmotic suction. Beyond the WEV, further dewatering is more difficult to achieve, as evidenced by the flatter curve. Evaporation continues unabated to about 3,000 kPa suction, thereafter decreasing at an increasing rate and ceasing at a suction of about 100,000 kPa.
- The oven-dry (zero moisture) state corresponds to a suction of 1,000,000 kPa, for all materials.
- There is a hysteresis between drying and re-wetting cycles. As a soil desaturates, moisture is first lost from the largest pores, with residual moisture retreating to ever-finer pores, requiring ever-higher matric suctions to remove it. As a soil re-wets, the largest pores saturate first, with the finer pores saturating last, but at much lower matric suctions than were required to drain them during the drying cycle.

Over the suction range up to about 1,000 kPa, matric (or capillary) suctions dominate, while above about 1,000 kPa the increasing concentration of salts in the pore water mean that osmotic (or solute) suctions come to dominate. Most soil-like materials exist at a suction of < 10,000 kPa, and hence matric suction usually dominates. An exception is salt pan deposits and hypersaline tailings.

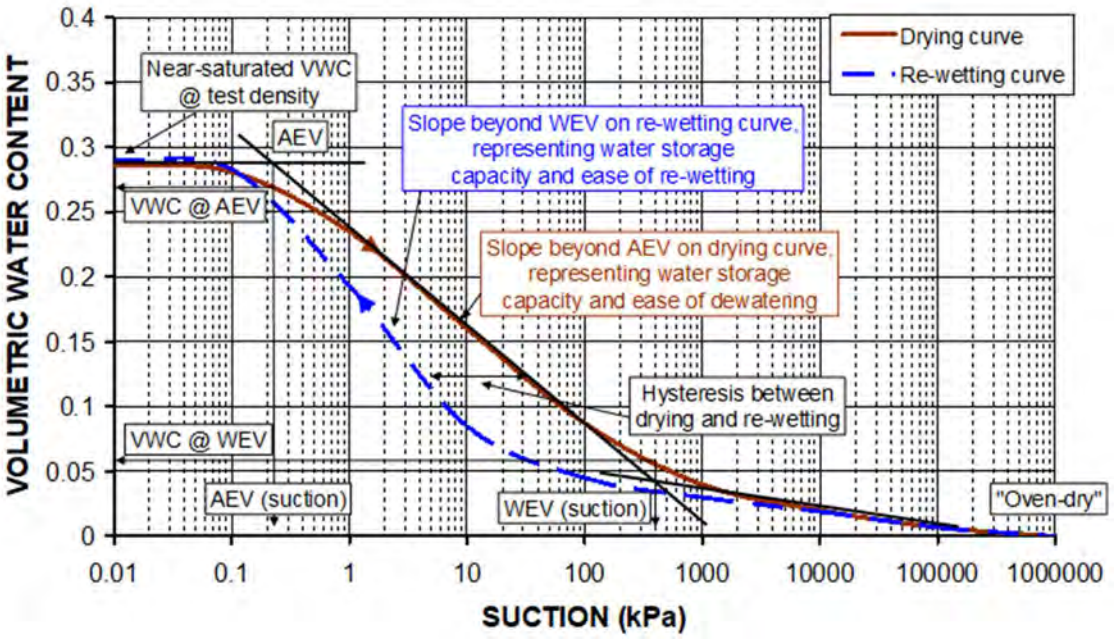
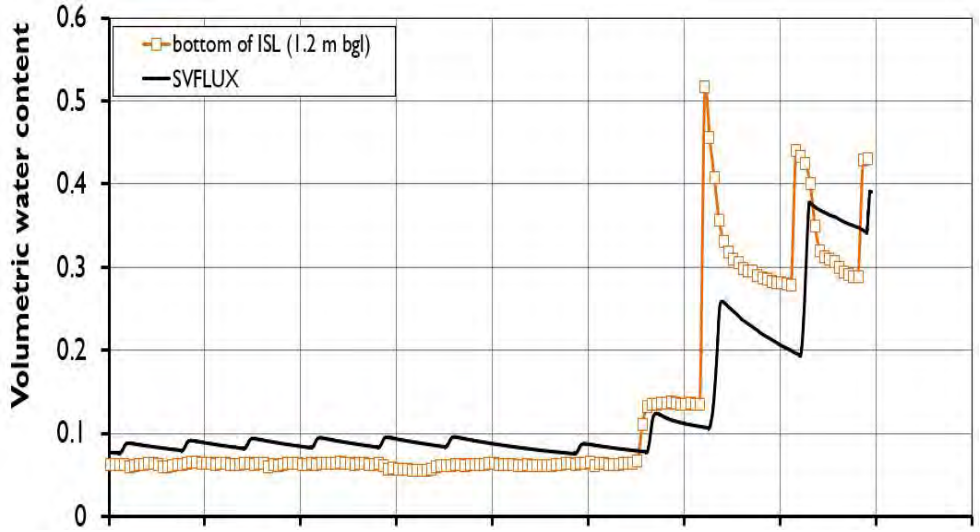


Figure 24 Key elements of the SWCC

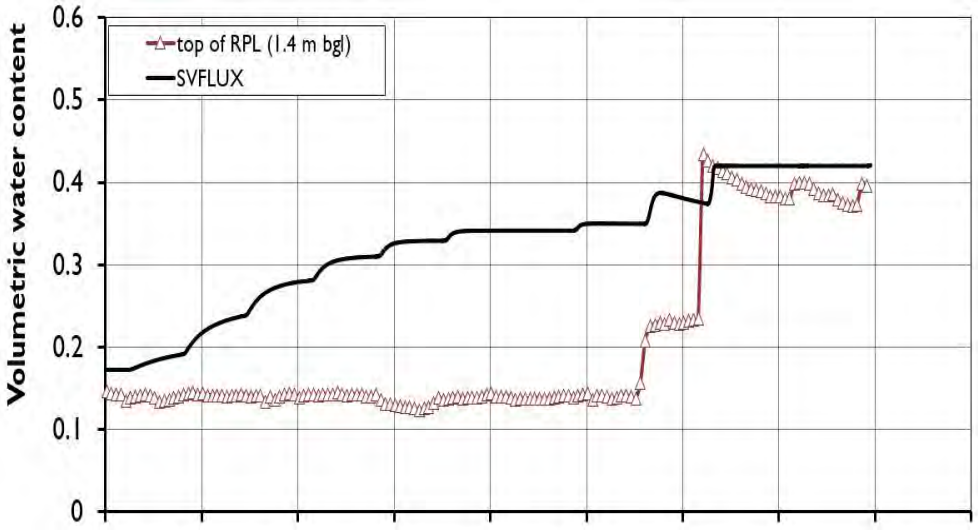
Appendix I – Additional model results compared to the trials

In Figure 25:

- Figure 25a shows the results of model bottom of ISL VWC prediction compared to the in-situ results for cover option 1;
- Figure 25b shows the results of model top of RPL VWC prediction compared to the in-situ results for cover option 1;
- Figure 25c shows the results of model bottom of RPL VWC prediction compared to the in-situ results for cover option 1;
- Figure 25d shows the results of model middle of CB VWC prediction compared to the in-situ results for cover option 1;
- Figure 25e shows the results of model middle of ISL VWC prediction compared to the in-situ results for cover option 2;
- Figure 25f shows the results of model middle of upper CB VWC prediction compared to the in-situ results for cover option 2;
- Figure 25g shows the results of model top of RPL VWC prediction compared to the in-situ results for cover option 2;
- Figure 25h shows the results of model bottom of RPL VWC prediction compared to the in-situ results for cover option 2;
- Figure 25I shows the results of model top of lower CB VWC prediction compared to the in-situ results for cover option 2;
- Figure 25 shows the results of model topsoil VWC prediction compared to the in-situ results for cover option 4;
- Figure 25k shows the results of model top of ISL VWC prediction compared to the in-situ results for cover option 4; and
- Figure 25l shows the results of model bottom VWC prediction compared to the in-situ results for cover option 4;


bottom of ISL (1.2 m bgl)
SVFLUX
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

(a)


top of RPL (1.4 m bgl)
SVFLUX
Volumetric water content
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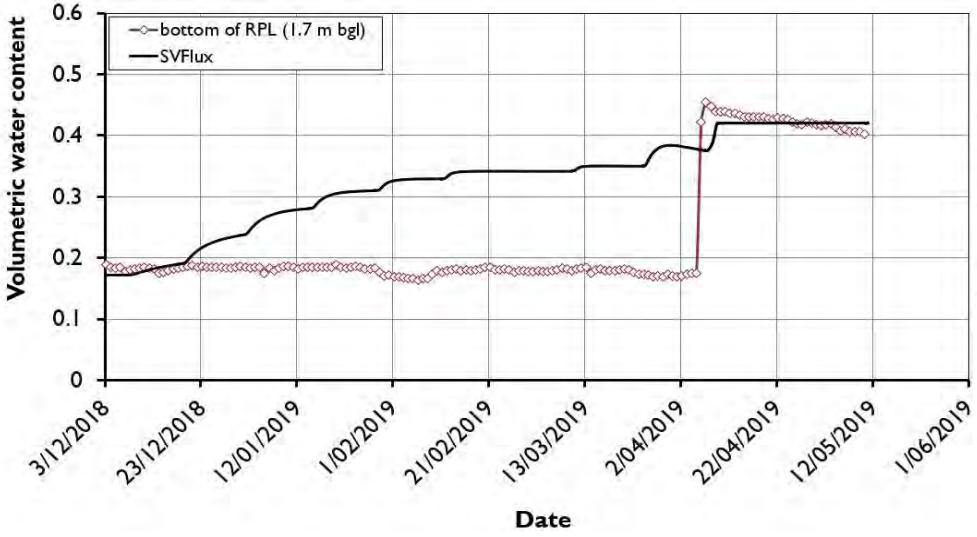
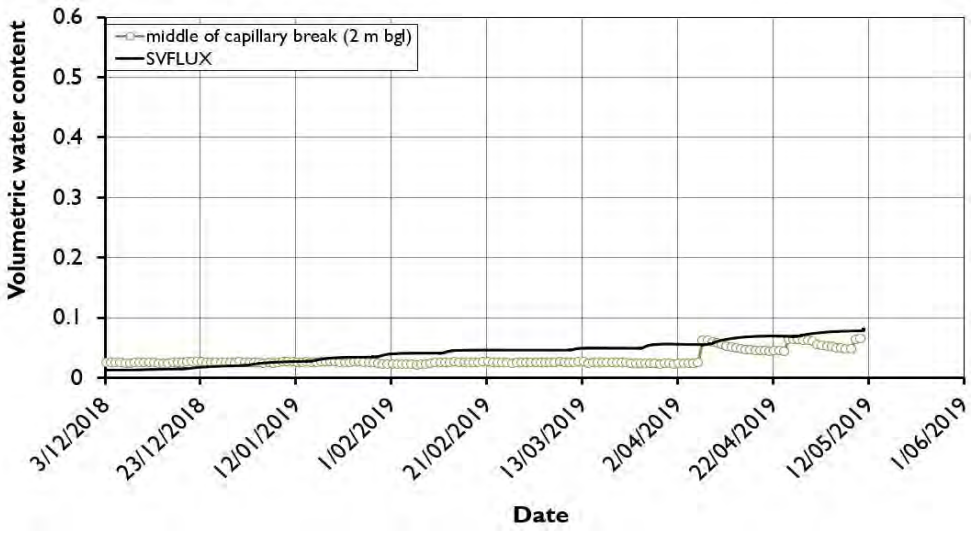
0.5
0.4
0.3
0.2
0.1
0

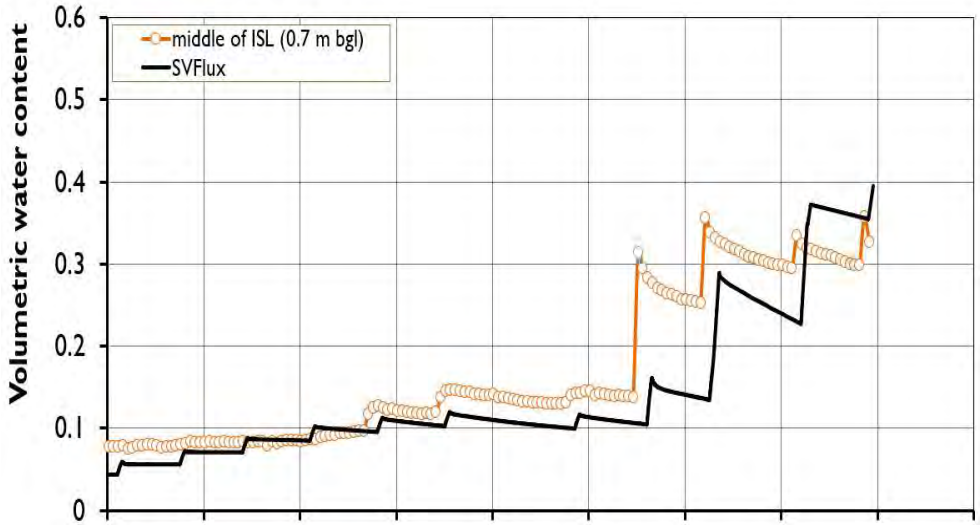
(b)


bottom of RPL (1.7 m bgl)
SVFlux
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
3/12/2018
23/12/2018
12/01/2019
1/02/2019
21/02/2019
13/03/2019
2/04/2019
22/04/2019
12/05/2019
1/06/2019
Date

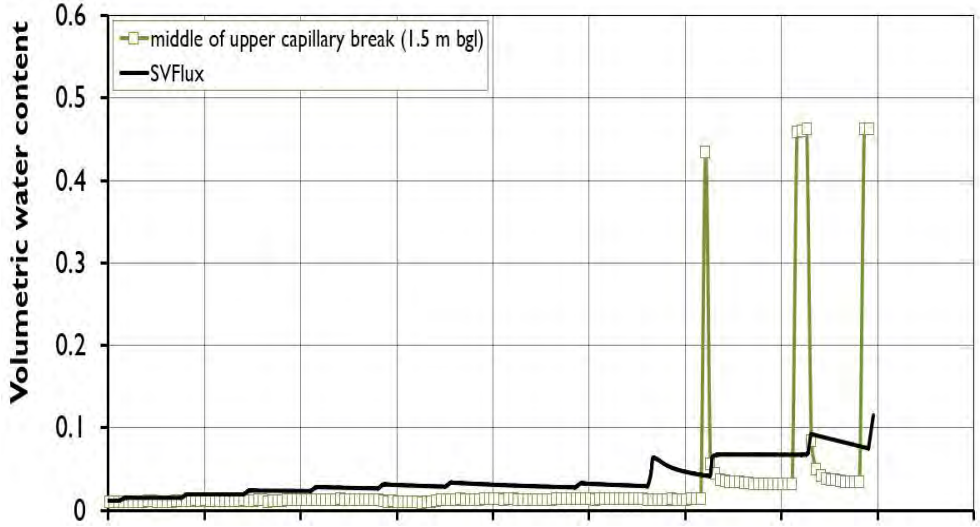
(c)


middle of capillary break (2 m bgl)
SVFLUX
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
3/12/2018
23/12/2018
12/01/2019
1/02/2019
21/02/2019
13/03/2019
2/04/2019
22/04/2019
12/05/2019
1/06/2019
Date

(d)


middle of ISL (0.7 m bgl)
SVFlux
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0

(e)


middle of upper capillary break (1.5 m bgl)
SVFlux
Volumetric water content
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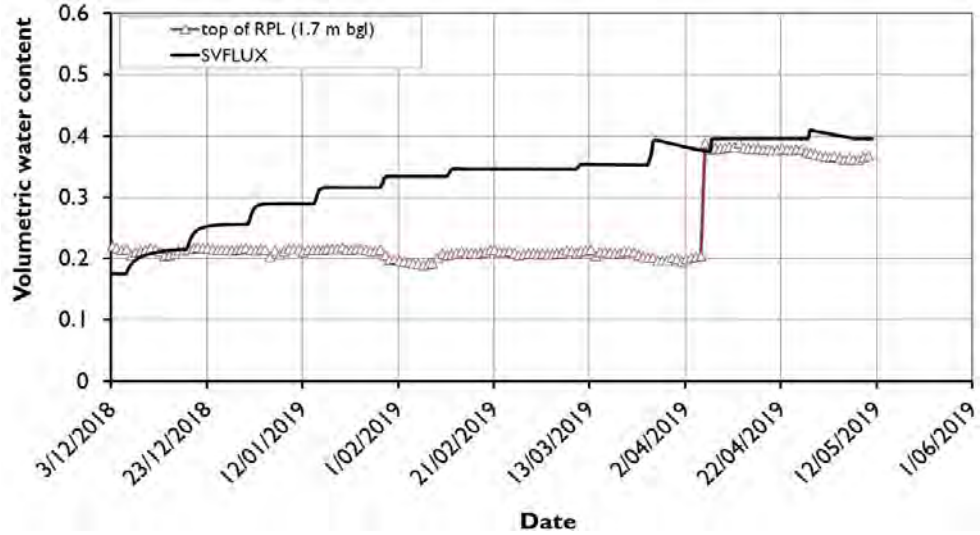
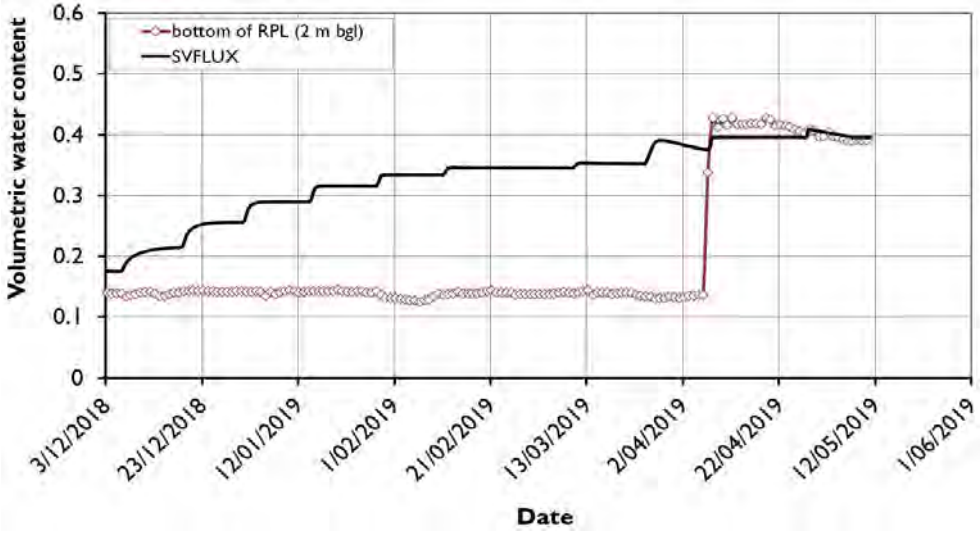
0.5
0.4
0.3
0.2
0.1
0

(f)


top of RPL (1.7 m bgl)
SVFLUX
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
3/12/2018
23/12/2018
12/01/2019
1/02/2019
21/02/2019
13/03/2019
2/04/2019
22/04/2019
12/05/2019
1/06/2019
Date

(g)


bottom of RPL (2 m bgl)
SVFLUX
Volumetric water content
0.6
0.5
0.4
0.3
0.2
0.1
0
3/12/2018
23/12/2018
12/01/2019
1/02/2019
21/02/2019
13/03/2019
2/04/2019
22/04/2019
12/05/2019
1/06/2019
Date

(h)

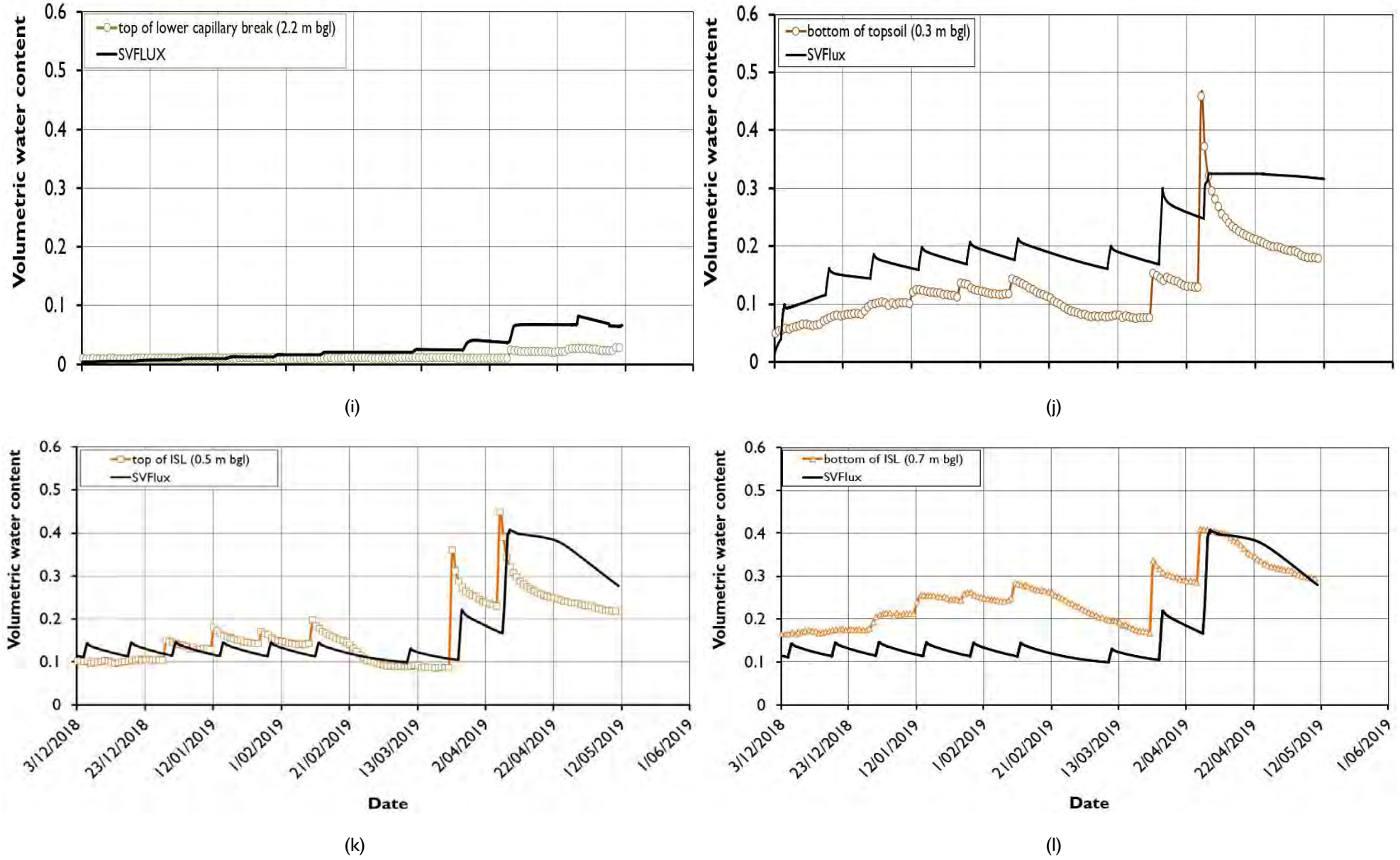


Figure 25 Model results compared to the trials

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About SGM environmental Pty Limited

We are a boutique consulting firm of experienced leading industry experts working with our clients and their stakeholders to develop and deliver innovative solutions to complicated challenges that create enduring value.

SGM environmental Pty Limited (SGME) was established to provide services in soil science, geochemistry, mine closure and environmental approvals and science cost efficiently. When you engage SGME you engage a partner to your business, priding themselves on:

- Positivity — We won't back down from a project because it's difficult. We thrive on the challenge.
- Trust — We say what we mean and we will deliver on our promises. We will advocate strongly for you.
- Innovation — We will always look for new ways to help and create enduring value because that is what friends do when they work together.
- Safety — We will share mutual responsibility to prevent harm and promote wellbeing.

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Australian Locations

Brisbane

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Appendix J: Conceptual Cover System Options

MEMORANDUM

TO	Dirk McNicoll, Amy Harburg; Kate Brosnan; Robert James	**COMPANY**	MMG Dugald River Mine
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PROJECT TITLE	Dugald River Mine – TSF Conceptual Closure Design		
SUBJECT	DRM – Landform Conceptual Design – Conceptual Cover System Options		
DATE	19 March 2025	**OUR REF**	240189.M05 Rev1

1 INTRODUCTION

MMG Dugald River Pty Ltd (MMG) is an underground lead and zinc mining operation, located approximately 60 kilometres (km) northwest of Cloncurry in North West Queensland. It is owned and operated by MMG, a wholly owned subsidiary of MMG Australia Limited.

Dugald River Mine (DRM) is authorised by the Department of Environment, Tourism, Science and Innovation (DETSI) under Environmental Authority (EA) EPML00731213 and resides on 40 Mining Leases (ML) and one Mineral Development Lease (MDL).

MMG proposes to increase the capacity of the TSF by raising the crest height of the main embankment (the Stage 3 embankment raise design concept) **[1]**. This constitutes a major amendment of the EA, triggering the requirements for updated Progressive Rehabilitation and Closure Plan (PRCP) and PRCP Schedule.

ATC Williams Pty Ltd (ATCW) has been engaged by MMG to develop a conceptual closure design for the TSF. The conceptual closure design must be consistent with the approved PRCP **[2]**, and meet the minimum information requirements in the PRCP Guideline **[3]**. The closure design includes landform design, cover system design and erosion modelling. This memorandum has been prepared to outline the cover system options considered and background information used to define the cover systems developed.

2 MATERIAL CHARACTERISATION

2.1 Tailings

A review of existing tailings geochemistry completed by Environmental Geochemistry International Pty Ltd (EGi) was undertaken to inform performance objectives of the cover system. EGI completed static and kinetic analysis of a tailings solids sample **[8]**, and in 2024, ATCW undertook an updated geochemical review of the sampling **[9]**.

Based on the outcomes of these studies, tailings have the potential to leach metal and metalloids and are considered Potentially Acid Forming (PAF). They contain a high sulphide content, mainly comprised of pyrite (or pyrrhotite) as well as some sphalerite and galena not recovered during processing. The net acid producing potential (NAPP) of the tailings was estimated to be approximately 86 kg H2SO4/t, which represents a high capacity for acid generation if the tailings were to be exposed to atmospheric conditions within the TSF. It is also highlighted that the tailings possess some buffering capacity, and as such, current contaminant concentrations (in seepage or supernatant) may not be representative of long term conditions.

With respect to metals, zinc, manganese, lead, and cadmium were typically one or two orders of magnitude higher than the corresponding metal concentrations reported for the tailings liquor and thereby represent significant mobilisation from the solid phase as a consequence of sulphide oxidation and the initial acidification of the tailings.

Recognising the risk of AMD and/or NMD, the cover system is required to limit rainfall infiltration into the tailings to decrease seepage and mobilisation of oxidation products from the PAF tailings

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that may impact surface water. Cover system components which will address these closure requirements are discussed further in **Section 3**.

2.2 Cover Materials

In 2024, a borrow investigation was undertaken to characterise site soils, as outlined in "TSF Cover Soils Geotechnical Investigation" **[10]** . The investigation comprised excavating 22 test pits to the west of the TSF. The test pits were excavated to refusal. Samples from the test pits were taken for laboratory testing. A summary of key observations from the investigation are summarised as follows:

- Generally surface soils range from 0.5m to 1.6m in depth. Below surface soils, weathered rock was encountered.
- Soils were consistently a sandy gravel, expected to have reasonably high permeability.
- No material with a high fines content was identified except in one test pit (TP10).
- The depth of topsoil was limited (typically less than 100mm).

A more extensive investigation could identify additional material (both in quantity or type, e.g. clays) however based on available information and past studies, surface soils are relatively consistent across the site. Outcomes from the 2024 investigation are consistent with historical investigations (which were undertaken to identify suitable material for embankment construction). On this basis, the outcomes of the 2024 investigation (and considering past investigations) have been used to inform the cover system options as follows:

- Clay, as a potential low permeability layer would be difficult to source onsite. Therefore, a geosynthetic liner may be required as a component of the cover system to limit infiltration.
- Soil profiles are generally shallow, therefore it would be critical to optimise the thickness of the cover system to limit the extent of the borrow area footprint.
- Limited topsoil is available, some soil amelioration of the subsoil may be required to support vegetation establishment.

3 PREVIOUS COVER SYSTEM DESIGNS

3.1 2015 ATCW

In 2015, ATCW designed a conceptual cover system for the TSF **[4]**. The conceptual cover system design as reported in the PRCP is a single capillary break cover and includes the following layers, in sequence from the surface:

- **Topsoil (0.1-0.2m)** – soil stripped from within the impoundment area at the time of construction will be placed on top of the cover system. Good quality topsoil within the TSF impoundment areas is scarce and therefore is unlikely to be sufficient to cover the entire surface. Topsoil will need to be spread thinly and in patches depending on the quantities available.
- **Waste Rock Cover (1m)** – A low water flux cover system will be constructed over the sealing layer consisting of a non-acid forming waste rock layer. Waste rock will be loosely paddock dumped over the sealing layer and then roughly smoothed out with a dozer to encourage infiltration without pooling.
- **Sealing Layer (0.5m)** – low permeability compacted earthfill constructed above the capillary break layer to limit water infiltration. This material may need to be sourced from either the non-acid forming weathered waste rock dumps or general earthfill borrow pits located within the project boundaries.
- **Capillary Break (0.3m)** – mainly coarse, non-acid forming waste rock placed directly over the tailings. The purpose of this layer is to prevent the rise of salts from the underlying tailings to the sealing layer above.

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3.2 Column Cover System Trials

SGME previously developed and instrumented column cover system trials **[5]**. Following the completion of the column cover system trials, data was used to semi-calibrate a cover system model. Based on the outcome of the trials, SGME recommended the following conceptual cover options:

- Option 1 – Single Capillary Break:
  - A 0.4 m Capillary Break (CB) layer of gap-graded NAF waste rock above the tailings;
  - A 0.5 m Reduced Permeability Layer (RPL) of borrow subsoil above the CB layer; and
  - A 1 m Infiltration Storage Layer (ISL) of borrow subsoil above the RPL; and
  - A 0.2 m topsoil layer above the ISL.
- Option 2 – Double Capillary Break:
  - A 0.3 m CB layer of gap-graded NAF waste rock above the tailings;
  - A 0.5 m RPL of borrow subsoil above the CB layer;
  - A 0.3 m CB layer of gap-graded NAF waste rock above the RPL;
  - A 1 m ISL of borrow subsoil above the CB layer; and
  - A 0.2 m topsoil layer above the ISL.

SGME stated that the necessity of the RPL cannot be confirmed or rejected and recommended that additional trials are undertaken, which adopt NAF waste rock in place of the borrow subsoil (in the RPL and ISL), as either of these materials may be used in the final cover system for the TSF.

The semi-calibrated modelling suggested that option 1 and 2 would reduce net percolation to less than 10% of cumulative annual rainfall.

4 COVER SYSTEM CONFIGURATIONS

4.1 Objectives

Potential cover system options have been developed based on the inferred geochemical characterisation of the tailings and the availability of cover materials. As outlined in **Section 2.1**, significant risk with respect to AMD and NMD exist from the tailings. The cover system is therefore required to:

- Minimise infiltration to the maximum extent, such that seepage from the TSF is minimised.
- Minimise capillary rise from the tailings into the cover system, thereby contaminating the cover soils.
- Be physically stable
- Be chemically stable
- Be able to sustain agreed Post-Mining Land Use (PMLU) of native vegetation **[2]**.

4.2 Cover systems

A number of potential cover systems have been identified and are proposed to be modelled to assess their relative performance regarding net percolation and determine which option(s) would meet the closure objectives.

The International Network for Acid Prevention's (INAP's) Global Acid Rock Drainage Guide (GARD Guide) **[6]** suggests that a store and release cover system is the most suitable for the climate, as shown in **Figure 1**. A store and release cover allows sufficient rainfall to infiltrate into the cover system profile (i.e., into both topsoil and Infiltration Storage Layer (ISL)) to support vegetation. Water is released from the cover system through evapotranspiration (evaporation and plant transpiration). A store & release cover may also incorporate a Reduced Permeability Layer (RPL) to further decrease Net Percolation into the underlying tailings.

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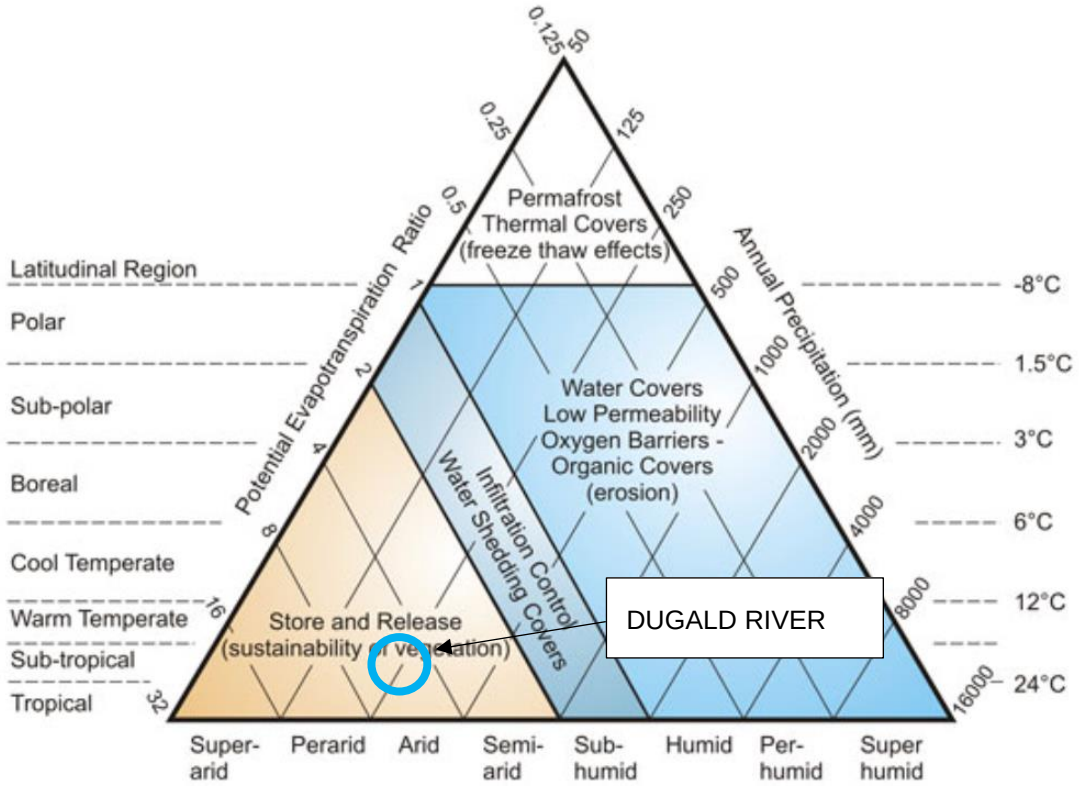
Based on the GARD Guide, a store and release cover system will be considered, however recognising the limited availability of site soils (quantity of ISL, lack of RPL), and the environmental risk from the tailings, alternative configurations are also considered.

FIGURE 1 CLIMATE TYPES AND SUITABLE COVERS (GARD GUIDE)



A description of key cover elements is provided in **Table 1.**

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TABLE 1: FUNCTION OF COVER LAYERS

Layer	Abbreviation	Purpose	Source and Description
Topsoil	Topsoil	Support vegetation.	Borrow area, to be located adjacent to the TSF.
Infiltration Storage Layer	ISL	Store moisture to support vegetation growth and limit downward flux into the tailings.	This material would be sourced from a borrow located near the TSF, and comprise the subsoil, being the material immediately beneath the topsoil and above the weathered rock.
Reduced Permeability Layer	RPL	Limit flux through the cover system into the tailings.	Provide a barrier beneath the ISL to reduce percolation into the underlying tailings material and PAF waste rock when the overlying storage capacity is exceeded.
Capillary Break Layer	CB	Disrupt the upward and downward movement of water (and hence salt) through capillary action by providing a change in pore size distribution.	To comprise a clean gravel product. A manufactured material, sourced from a licenced quarry or crushed and screened NAF waste rock.
Geomembrane (GCL/HDPE)	GM	Low permeability barrier, to be used in the absence of an RPL, if required.	To be installed by qualified installers.

The cover system configurations considered are summarised as follows and the profiles depicted in **Table 2**. It is noted that the thickness of layers in **Table 2** are based on similar project experience and would be refined and optimised at subsequent design stages

Cover 1: Store and release cover system that comprises topsoil, Infiltration Storage Layer (ISL), and Reduced Permeability Layer (RPL). This option is generally consistent with the cover system recommended by the GARD guide, although as previously noted, no material has been identified on-site which would meet the requirements of a low-permeability layer.

Cover 2: Single capillary break cover system (PRCP). Cover 2 adopts a similar profile to Cover 1, however also incorporates a capillary break. Depending on the outcomes of the modelling, a capillary break may be required to prevent capillary rise. Cover 2 also comprises a RPL which will be difficult to source onsite.

Cover 3: Cover 3 adopts a similar profile to Cover 2, however also includes a Geosynthetic Clay Liner (GCL), recognising clay may be difficult to source on site. Cover 3 also includes a capillary break as the GCL will not prevent capillary rise.

Cover 4: Cover 4 includes a HDPE liner, which would prevent infiltration and capillary rise. The RPL and capillary break have therefore been omitted for option 4.

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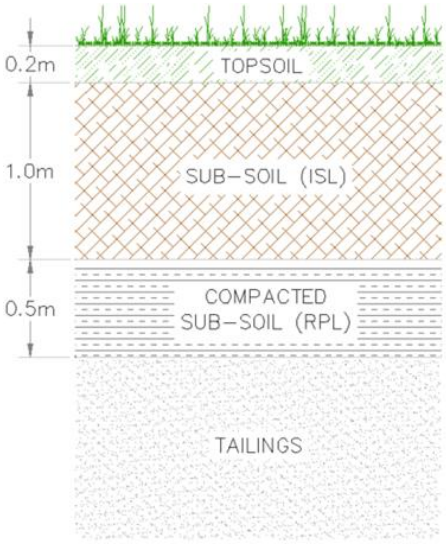
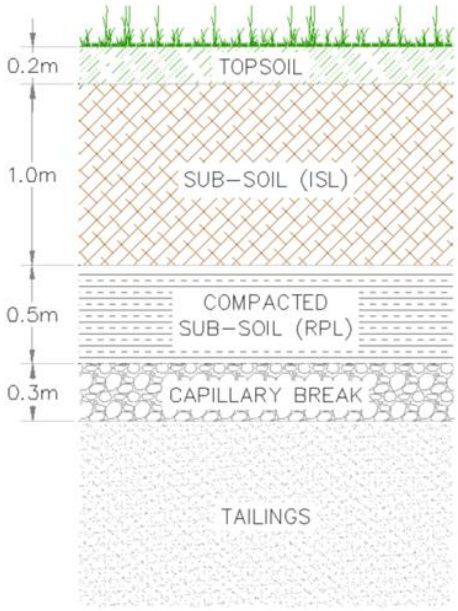
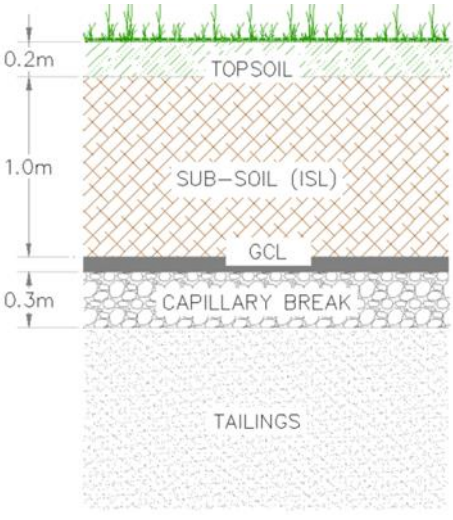
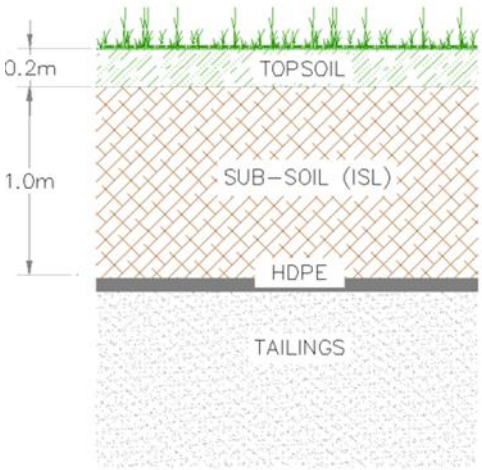
TABLE 2: COVER SYSTEM CONFIGURATIONS

COVER 1: STORE AND RELEASE	COVER 2: CAPILLARY BREAK (PRCP)
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL)	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL) • 0.3 m Capillary Break
	
COVER 3: GCL	**COVER 4: HDPE**
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • GCL • 0.3 m Capillary Break	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • HDPE
	

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5 SCHEDULE OF QUANTITIES

Material quantities for each of the cover systems identified are summarised in **Table 3**. Assumptions made in developing the material quantities are as follows:

- Quantities are based on the conceptual final surface developed by ATCW**[12].**
- No bulking factors have been included, all material quantities for earthen materials are as placed
- 10% wastage has been included for the GCL and HDPE materials
- Finalisation of material quantities is subject to cover system modelling as discussed in **Section 6**.

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TABLE 3: COVER SYSTEM CONFIGURATIONS

Layer	Description	Thickness(m)*		Material Quantities			
			Units	Cover System 1 Store and Release	Cover 2 Capillary Break	Cover 3 GCL	Cover 4 HDPE
Topsoil	Haul from borrow area, place and spread without compaction.	0.2	m³	170,200	170,200	170,200	170,200
Infiltration storage layer	Haul from borrow area, place and spread without compaction.	1	m³	851,000	851,000	851,000	851,000
Reduced permeability layer	Haul from borrow area, place, moisture condition and compact to specified density	0.5	m³	425,500	425,500		
Capillary break	Source, spread to specified thickness	0.3	m³		255,300	255,300	
GCL	Source and install in accordance with manufactures guidelines	NA	m²			936,100	
HDPE	to be installed by licenced lining contractor.	NA	m²				936,100

Notes:
no bulking factors have been applied. All quantities are as placed.
Thickness of each layer is subject to finalisation of cover system modelling
10% wastage included in estimate for GCL and HDPE

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6 CONCLUSION

Without an appropriate cover system, Dugald River tailings have the potential to generate acid mine drainage and/or neutral mine drainage following closure of the facility. Key objectives of the cover system are therefore to limit infiltration of meteoric and surface water through the cover system into the tailings and to prevent capillary rise of tailings pore water into the vegetation-supporting layers of the cover system.

To address infiltration, a low permeability layer is required in the cover system profile. Based on the outcomes of the geotechnical investigation **[10]**, availability of low-permeability materials on site appears limited. In the absence of low-permeability materials in sufficient quantity, a geosynthetic liner (eg. GCL or HDPE) may be required and will be assessed as potential cover system options.

To address capillary rise, a capillary break will likely be required, dependant on the outcomes of cover system modelling. A capillary break layer would comprise a clean, gravel aggregate product either manufactured on site or imported. Recognising the quantity required and cost associated with manufacturing or importing gravel, a geomembrane (Eg. HDPE) would prevent capillary rise and will therefore also be assessed. It is highlighted that a GCL would not prevent capillary rise.

A general observation from the geotechnical investigation was that the *in situ* depth and available quantity of surface soils is limited. Based on this outcome, it will be critical to reduce the quantity of cover soils required, while still meeting the closure requirements. Currently, a nominal topsoil depth of 0.2m for all cover systems has been included, consistent with the current PRCP **[2].** Recognising that natural topsoil depths are <100mm, sourcing a sufficient quantity to rehabilitate the TSF will be difficult. Reducing the topsoil depth from 200mm to 100mm in the numerical mode is unlikely to show a material difference in modelling results. The reduction should be assessed by a suitable soil scientist to determine likely impacts to vegetation, and potential mitigation measures to adequately support vegetation establishment.

The four cover systems identified have been prepared based on the available site information and closure objectives. The performance of each of these cover systems is currently being assessed by ATCW in a desktop study to evaluate their relative performance in meeting objectives. The outcomes from this study will be used to select a preferred cover system from the options identified.

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[4] ATCW (2015). “Tailings Storage Facility: Revised Concept Design”, Ref 108003.20-R01. ATC Williams Pty Ltd.

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[9] ATCW (2024). “Updated geochemical review of tailings”, Ref 108003-68 L01 Rev 0. ATC Williams Pty Ltd.

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[11] DISR & DFAT, 2016. “Risk Management: Leading Practice Sustainable Development Program for the Mining Industry”. Department of Industry, Science and Resources, and Department of Foreign Affairs and Trade.

[12] ATCW (2025). “DRM - Preliminary TSF Closure Landform Design (Surface)”, Ref 240189-M02. ATC Williams Pty Ltd.

Appendix K: Concept Stormwater Closure Plan and Site-wide Closure Landform

MEMORANDUM

TO	Robert James, Amy Harburg, Kate Brosnan	**COMPANY**	MMG Dugald River
FROM	Ashley Chiam	**OFFICE**	Brisbane
EMAIL	AshleyC@atcwilliams.com.au	**PHONE**	07 3352 7222
PROJECT TITLE	DRM – PRCP supporting studies		
SUBJECT	Concept stormwater closure plan and site-wide closure landform		
DATE	1 April 2025	**OUR REF**	240288-M02 Task 4 and 5

1 INTRODUCTION

1.1 Background

Minerals and Metals Group Pty Ltd (MMG) owns and operates Dugald River Mine (DRM) under the current Environmental Authority (EA) *EPML00731213* **[1]** and Progressive Rehabilitation and Closure Plan (PRCP) schedule PRCP-*EPML00731213-V2* (approved 22 October 2024) . DRM is located approximately 60 km northwest of Cloncurry, Queensland.

ATC Williams Pty Ltd (ATCW) has been engaged by MMG in providing supporting studies in relation to the recently proposed Environmental Authority Amendment (EAA) for the existing EA, specifically in relation to the recently approved PRCP by Wulguru Technical Services Pty Ltd (WTS) for the DRM site **[2]**. The EAA was completed in relation to several modifications proposed to occur onsite including a Stage 3 raise for the tailings storage facility (TSF) of which ATCW provided a conceptual design for to MMG in 2024 **[3].**

1.2 Purpose

The purpose of this Technical Memorandum is to provide a conceptual closure surface water management and a site-wide final closure landform for the DRM site.

1.3 Existing site layout

The existing site layout and features/infrastructure of DRM Process Area are as shown in **DIAGRAM 1**. Other features (not shown) include a borrow pit directly north of the Run of Mine (ROM) Pad and Sewage Treatment Plant (STP) Evaporation Dam Stage 1 and Stage 2.

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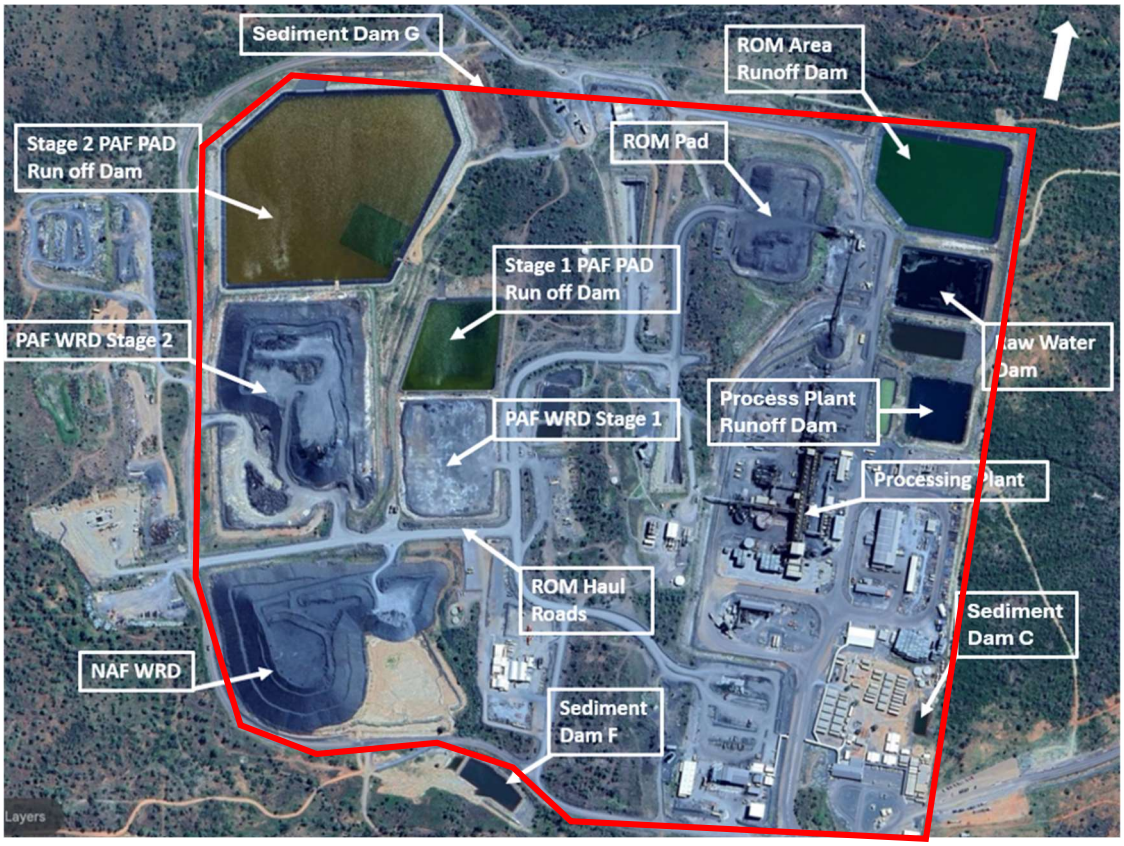
DIAGRAM 1: EXISTING SITE CONDITIONS



2 SITE WIDE CLOSURE LANDFORM AND STORMWATER AT CLOSURE

2.1 General

The conceptual 3D closure landform has been modelled via Muk3D in GDA2020 and generally adhere (where possible) to the pre-mining surfaces and in complies with their respective post closure mine use (PMLU) (refer to **Section 3**).

Where this is not viable such as for the TSF where ongoing containment of tailings is required beyond closure, the landform is shaped to be a self-shedding and stable landform that correspond with the surrounding natural environment.

2.2 Stormwater strategy at closure

The concept final landform ties-in with the concept stormwater strategy for closure, whereby in general, the major assumptions are:

- All active water infrastructure i.e. dams will be in-filled and graded, such that they become passive measures and surfaces post closure.
- Existing mine related drainage systems i.e. drains will be naturalised into the surrounding topography; and,
- the downstream natural drainage lines (as shown in **DIAGRAM 2)** will be restored and reconnected to upstream drainage lines, via the rehabilitated mine surface.

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DIAGRAM 2: NATURAL DRAINAGE LINES

As discussed in the Closure dewatering strategy Memorandum **[4]**, it is during the Execution phase of closure as areas are progressively rehabilitated where water management infrastructure such as dams and perimeter drains will still be required (prior to being fully decommissioned and fully incorporated into the final landform) to manage poor runoff water quality, in particular sediment loads. The key risks requiring stringent management include:

- Runoff peak flows and volume
- Erosion control
- Sediment control
- Discharge water quality

As such, detailed staging will be required to ensure that rehabilitation works manage the water quality until it meets release sediment load release criteria in accordance with the approved PMLU. To manage stormwater runoff as the site is progressively rehabilitated, the general sequence of shaping the site towards the final closure landform include:

- Decommissioning and removal of unnecessary infrastructure and hardstand areas at closure. All contaminated soils shall be removed and placed within the TSF.
- Trim and grade surfaces as well as naturalise drainage channels to reduce overall runoff and peak flows, reduce downstream flood risk, as well as limiting erosion risk.
- Revegetate disturbed areas to retard flowrates and reduce sediment runoff and erosion occurrences.
- Finalise naturalisation of drainage channels and connecting the site drainage with the downstream natural watercourses.

Furthermore, a separate Memorandum **[5]** has been prepared to detail the final TSF closure landform.

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3 POST MINE LAND USE

The concept final landform surfaces for each mine domain were broadly modelled in accordance with their respective Post Mine Land Use (PMLU) with the majority of site to be rehabilitated for 'low intensity grazing' with slopes <10%. PMLUs most suitable for areas with topography slopes >10% were previously determined to be native ecosystem. The PMLU for each domain is summarised in **TABLE 1**.

TABLE 1: PMLU FOR EACH MINE DOMAIN

Mine Domain		Post Mining Land Use (PMLU)
RA1	Ancillary infrastructure and services	Native ecosystem
RA2	Borrow pits and stockpiles	Low intensity grazing
RA3	Dams and diversion structures	Low intensity grazing
RA4	Mineralised waste	Low intensity grazing
RA5	Mining and processing area	Low intensity grazing
RA6	TSF	Native ecosystem
RA7	Renewable energy infrastructure	Native ecosystem

The specific rehabilitation measure for each RA i.e. assumptions and modelling methodology is described in the following sections.

3.1 RA1: Ancillary infrastructure and services

This RA includes the accommodation village, pipeline, and the access road between the accommodation village and the processing area (along the Knapdale Range).

- For the accommodation village, after the demolition of infrastructures, the existing topography can be stripped back by about 1 m and adhere to the pre-mine of approx. slope of 1.5% to the east/ south-east to form the closure landform (refer **DIAGRAM 4**).
- The road traversing through the Knapdale Range can be left as is.

DIAGRAM 3 provides the final closure landform for the accommodation area.

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DIAGRAM 3: CLOSURE LANDFORM SURFACE & STORMWATER (ACCOMODATION AREA)

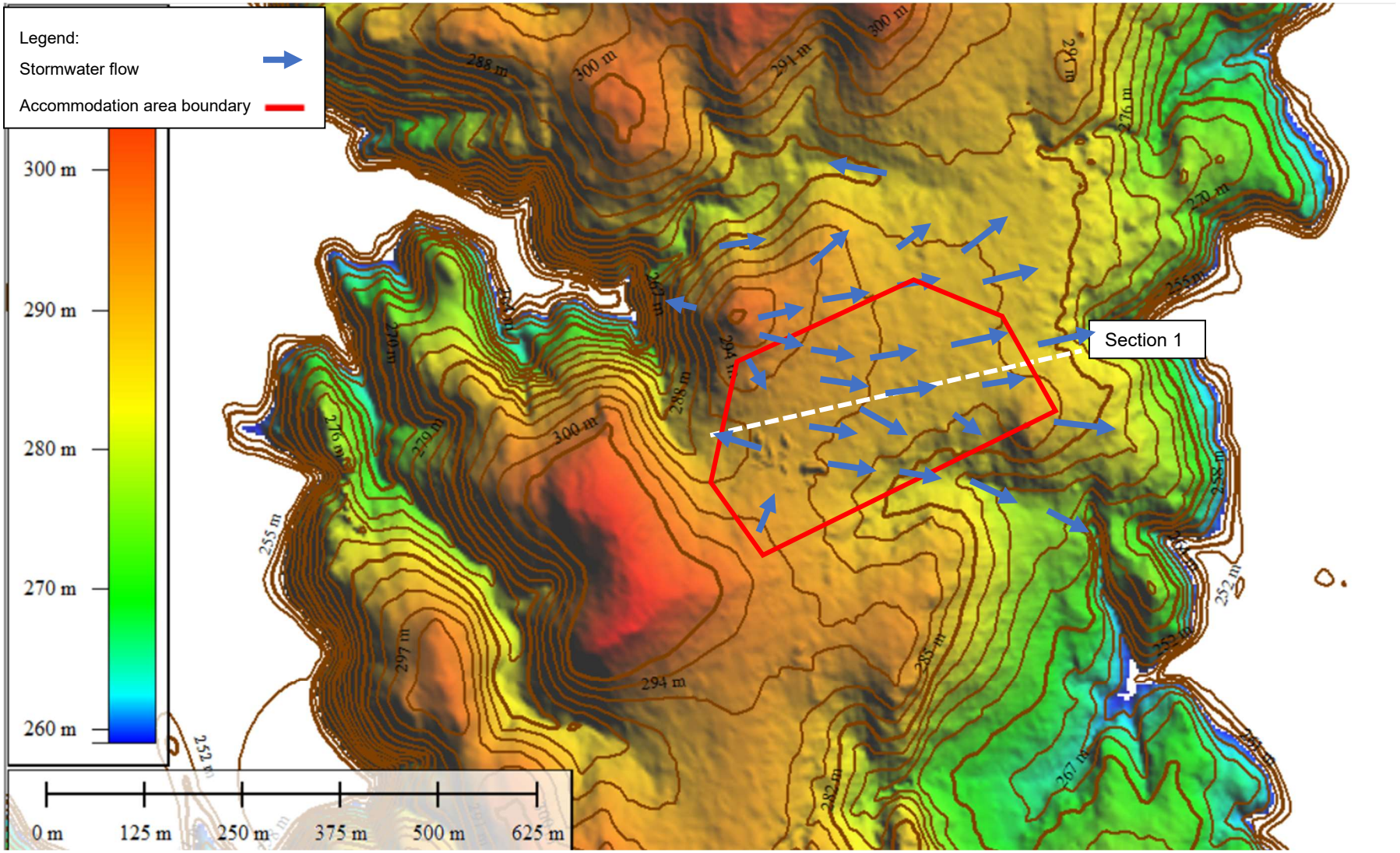

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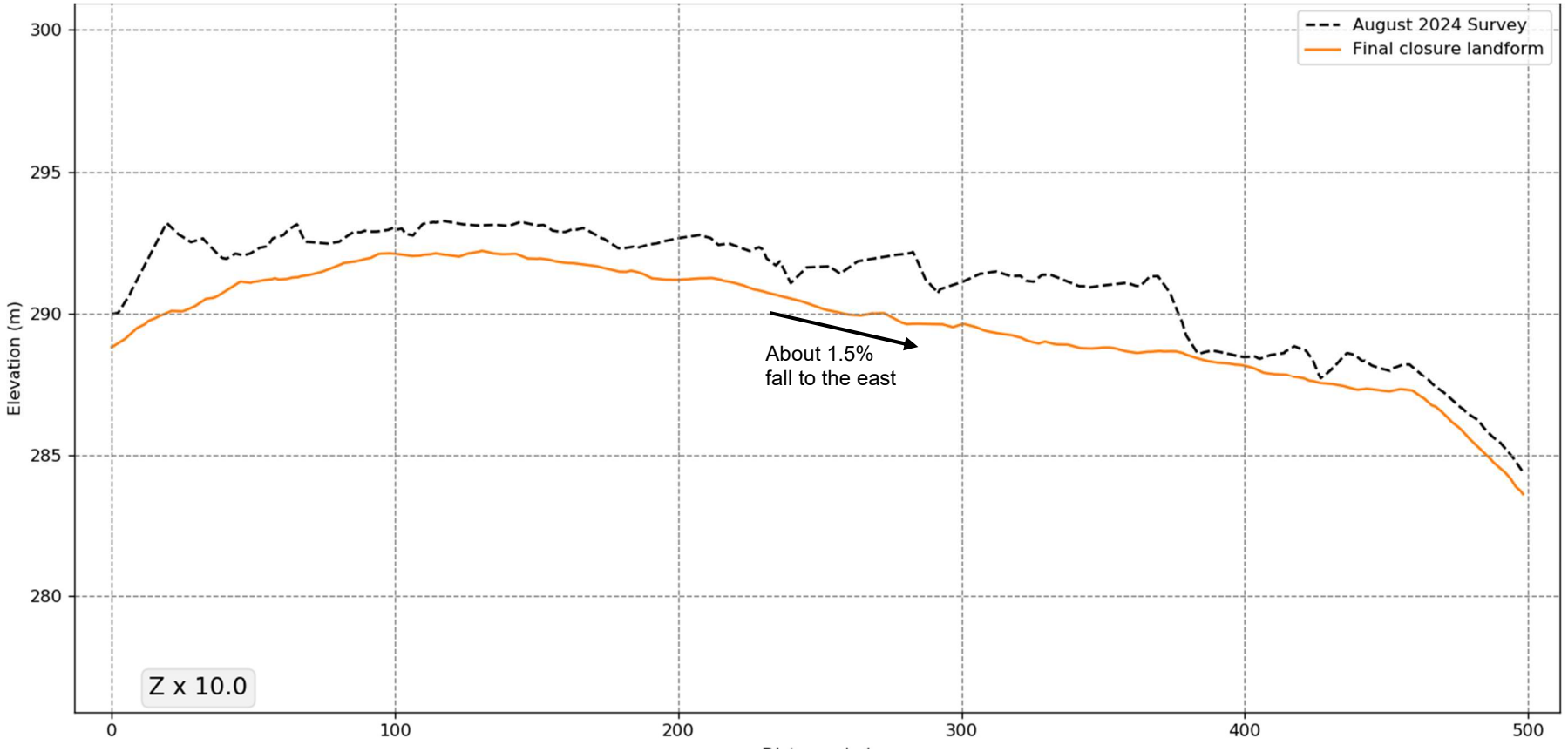
DIAGRAM 4: SECTION 1 (THROUGH THE ACCOMODATION AREA)



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3.2 RA2: Borrow pits and stockpiles

RA2 of the Project includes borrow pits and topsoil stockpiles located in several locations across the site. In general, the borrow pits and stockpiles once exhausted will be reshaped to pre-mine surfaces (as necessary) and revegetated suitable for cattle grazing. As an example, a 1.1% fall towards the east is expected for the borrow pit north of the processing area (refer **DIAGRAM 6**).

Based on the August 2024 survey, a rough estimate of the existing topsoil stockpiles is about 150,000 m^3 and these will be utilised for rehabilitation activities i.e. for the TSF and processing areas.

3.3 RA3: Dams and diversion structures

RA3 encompasses all stormwater infrastructures including diversion drains, sediment dams, PAF runoff dams, infrastructure runoff dams, STP dams, and raw water dams. It is understood that there are currently no formal landholder agreements to retain any dams onsite and therefore, all dam water shall be removed and filled with NAF or other suitable material. Accordingly, approximately 400,000 m^3 of NAF or other suitable filling material shall be required to fill all Dams.

The closure landform for RA3 was modelled in Muk3d and gently sloping at about 1%-2% to reinstate the pre-mine natural landform. The natural drainage features e.g. North Creek, Mine Trib Centre and Silvermine Creek, will also be reinstated and the footprint will be generally ripped and seeded for cattle grazing (refer **DIAGRAM 7**).

3.4 RA4: Mineralised waste

3.4.1 PAF WRD

All PAF material will be returned to the underground mine void and used as stope fill. The PAF pad is currently undergoing an extension to the east whereby the PAF Stage 1 dam will be filled-in to form the pad extension. It is understood that the PAF pad will consist of 1.5 m thick layer of compacted NAF rockfill overlain by 0.5m thick low permeability earthfill.

During rehabilitation, the overlaying PAF material shall be removed whilst the base material i.e. NAF and earthfill material may remain and trimmed to slope north/north-eastward to promote drainage towards the natural creek lines. The perimeter drains of the PAF pad that directs runoff into the PAF Stage 2 dam may be removed however the natural drainage diverting clean water may remain to continue directing flow towards the downstream natural watercourses. This is shown in **DIAGRAM 8**.

The RA4 the footprint will be generally ripped and seeded for cattle grazing.

3.4.2 NAF WRD

The NAF stockpile will be used as cover material for the TSF and to rehabilitate other areas on site including in-filling the dams. Therefore, the rehabilitation of the NAF WRD will only occur after the capping of the TSF and rehabilitation of other areas of the site.

A review of the pre-mine survey indicates that NAF area was of range 0.5% to 1.5%. Based on the PMLU of low intensity grazing for the NAF pad which requires grade of <10% whilst also encouraging water shedding plus minimising cut/fill volume requirements, the final landform for the NAF pad has been conceptual design to a grade of 2% in the south-east direction.

3.5 RA5: Mining and processing area

The mining and processing areas include the processing plant, ROM haul road and pad, the underground portals (north and south), sewage treatment plant, vehicle maintenance area and offices. The full list is provided in the PRCP under Section 3.3.1.

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All infrastructures including buildings, concrete pads, pipelines and electrical supply shall be demolished and removed followed by trimming and grading to direct surface water runoff towards the natural drainage lines. The portals shall be in-filled and sealed with PAF and other suitable materials.

The final landform of the processing areas including the northern borrow pit, dams, PAF and NAF pad and processing plants is shown in **DIAGRAM 5.**

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DIAGRAM 5: CLOSURE LANDFORM SURFACE & STORMWATER (PROCESSING AREA)

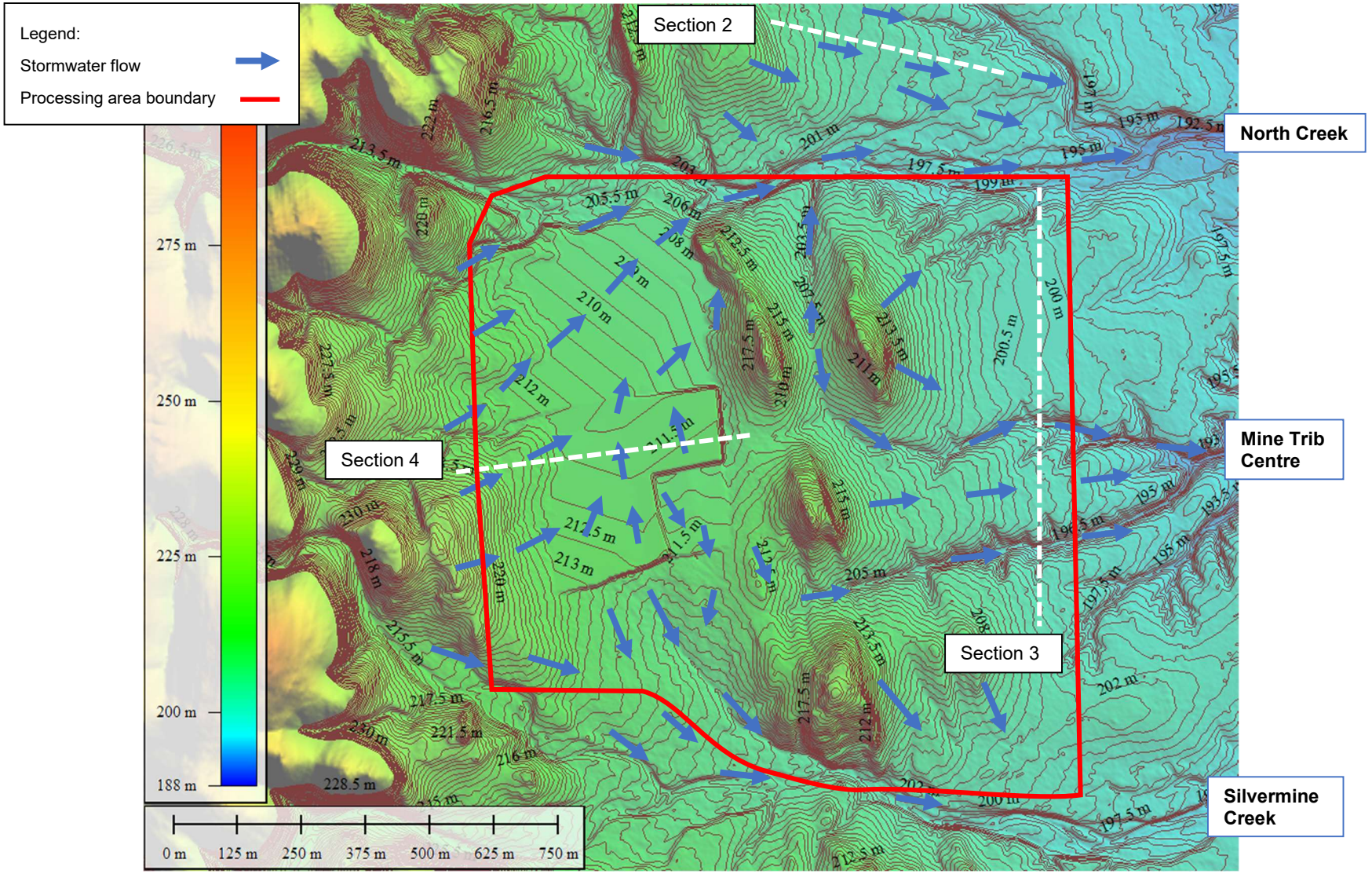

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DIAGRAM 6: SECTION 2 (THROUGH THE NORTHERN BORROW PIT AREA)

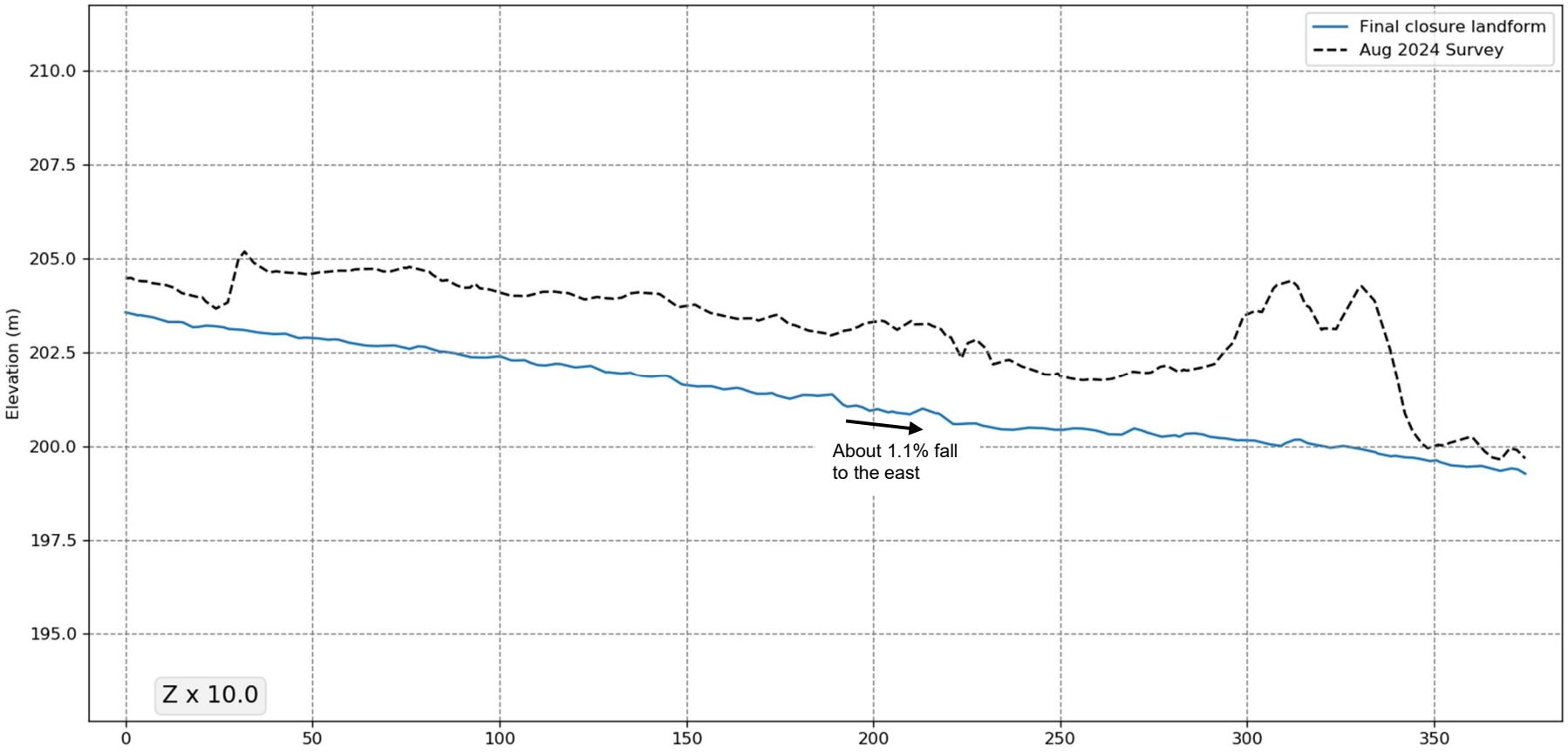

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DIAGRAM 7: SECTION 3 (THROUGH THE PROCESSING DAMS AREA)

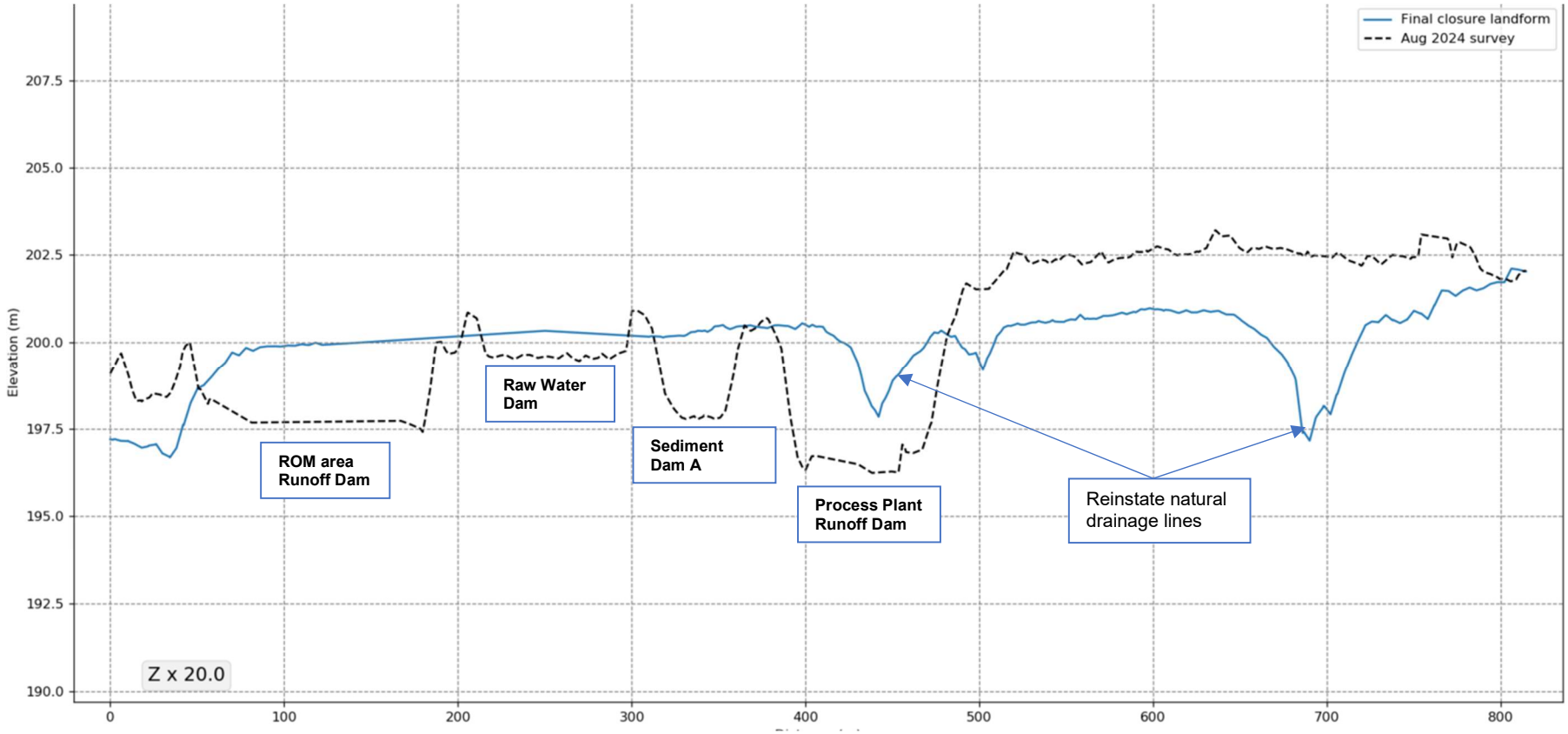

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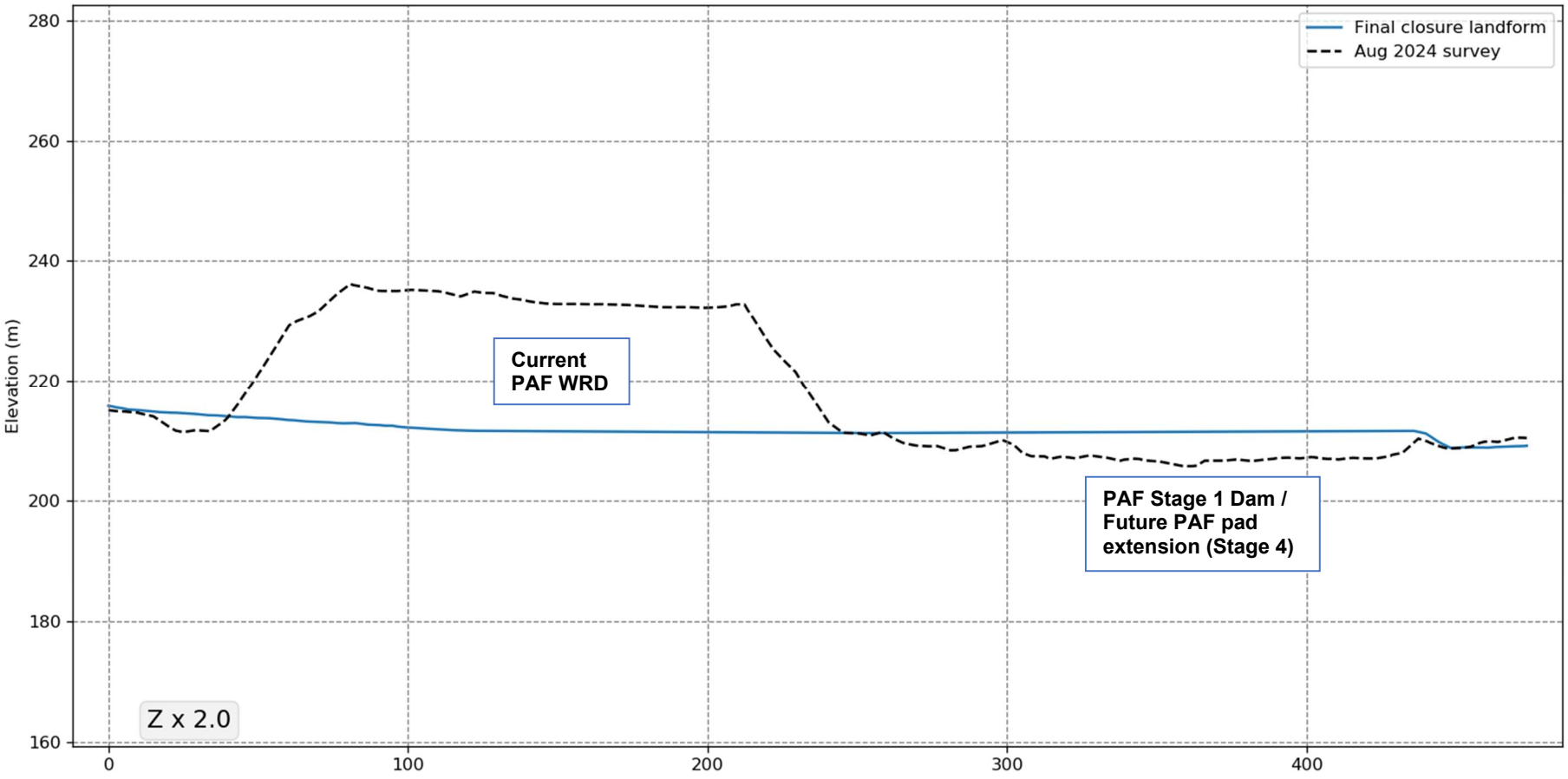
DIAGRAM 8: SECTION 4 (THROUGH THE PAF PAD)



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3.6 RA6: TSF

RA6 includes the tailings storage facility and the associated pipelines and the downstream seepage collection pond. As detailed in the TSF closure landform memo **[5]**, due to the existing tailings deposition strategy and the volume of water requiring removal prior to capping, reshaping and progressive capping of the TSF may be required to contour the TSF landform towards closure.

The main embankment will also be flattened to minimise ponding water in the TSF and increase long-term stability beyond closure.

3.7 RA7:Renewable energy infrastructure

RA7 includes the wind turbines and the ancillary infrastructure associated with the turbines. These infrastructures will be decommissioned and removed, followed by recontouring back to pre-mining surfaces and reinstatement of any natural drainage lines.

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4 CONCLUSION

The site-wide closure landform has been conceptually modelled to adhere to their respective post closure mine use (PMLU) and is generally shaped to the pre-mining surfaces and will also include restoration and connection with the downstream natural drainage lines. Therefore, all RA's is expected to achieve the final closure landforms that are safe, stable, non-polluting and sustain their respective PMLU.

Furthermore, it should also be noted that during the Execution phase of closure is where management of stormwater runoff will be required to manage poor runoff water quality. Therefore, the general sequence of shaping the site towards the final closure landform include:

- Decommissioning and removal of unnecessary infrastructure and hardstand areas at closure. All contaminated soils shall be removed and placed within the TSF.
- Trim and grade surfaces as well as naturalise drainage channels to reduce overall runoff and peak flows, reduce downstream flood risk, as well as limiting erosion risk.
- Revegetate disturbed areas to retard flowrates and reduce sediment runoff and erosion occurrences.
- Finalise naturalisation of drainage channels and connecting the site drainage with the downstream natural watercourses.

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[2] Wulguru Technical Services (2024) – Progressive Rehabilitation and Closure Plan Dugald River Mine (2024.02002 Version 5.0) October 2024.

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[4] ATC Williams (2025) Dugald River Mine – Additional PRCP Studies – Closure dewatering plan (240288-M01) January 2025.

[5] ATC Williams (2025) Dugald River Mine – TSF Conceptual Closure Design (240189-M02) February 2025.

Appendix L: Preliminary TSF Closure Landform Design (Surface)

MEMORANDUM

TO	Amy Harburg; Kate Brosnan; Robert James	**COMPANY**	MMG Dugald River Mine
FROM	Philippe Garneau	**OFFICE**	Brisbane
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PROJECT TITLE	Dugald River Mine – TSF Conceptual Closure Design		
SUBJECT	DRM - Preliminary TSF Closure Landform Design (Surface)		
DATE	20 February 2025	**OUR REF**	240189-M02 Task 5

1 INTRODUCTION

1.1 Background

Minerals and Metals Group Pty Ltd (MMG) owns and operates Dugald River Mine (DRM) under the current Environmental Authority (EA) *EPML00731213* **[1]**. DRM includes a Tailings Storage Facility (TSF) located in the Knapdale Range and is formed by a cross-valley embankment that dams a creek line. The facility is used to contain both process tailings and mine affected water.

With the recent proposed Stage 3 TSF embankment raise to RL 253.50 m **[2]**, a major amendment is triggered whereby approvals from the Department of Environment, Tourism, Science and Innovation (DETSI) is required. Therefore, an Environmental Authority Amendment (EAA) with respect to the TSF closure in the context of the Progressive Rehabilitation and Closure (PRC) Plan and Schedule is required **[4]**.

1.2 Purpose

ATC Williams Pty Ltd (ATCW) has been engaged by MMG in providing a conceptual TSF closure design in supporting the EAA submission to DETSI.

The purpose of this Technical Memorandum is to provide a conceptual TSF closure landform including considerations of progressive rehabilitation of the TSF and surface water management during closure for the recently proposed raised Stage 3 TSF.

2 CLOSURE DESIGN CONSIDERATIONS

2.1 Overview

The Stage 3 design report **[2]** indicates sub-aerial deposition of tailings at a slope of 0.5%. Sub-aqueous tailings deposition achieves slopes of 5.8% (upper portion) and 2.5% (lower portion). The as-deposited tailings landform presented in the Stage 3 design report **[2]** will require modification to allow for a self-shedding and stable final TSF landform. Several assumptions have been made for the modelling of the final TSF landform surface.

2.2 Assumptions

The general assumptions for the modelling of the final landform of the TSF includes:

- Tailings deposition will cease in the year 2043 with Stage 3 raise providing a total tailings capacity of 20.69 Mt.

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- No changes to the current deposition strategy, as described in the Stage 3 design report **[2]**.
- As per the previous TSF concept design report **[3]** and Section 3.3.3.3.6 of the PRCP **[4]** whereby the TSF final surface will be self-shedding, the beach slopes for the final TSF surface are:
  - Top 1/3 of beach = 1.5 %
  - Middle 1/3 of beach = 1.0 %
  - Bottom 1/3 of beach = 0.67 %

  This final landform is assumed to be achievable through a combination of progressively removing water from the TSF, tailings consolidation over time and resurfacing the tailings accordingly with earthwork equipment i.e. cut/fill.
- A final deposition/re-shaping of tailings at the embankment will be required to encourage water shedding through the outlet(s) on either side of the embankment.
- Upon the final tailing deposition in the year 2043, the operating pond volume of 4,070 ML (plus water within the site dams) will be progressively removed. The estimated timeframe to dispose of the water inventory within the TSF is 3-4 years **[5].**
  - To reduce the time spent to progressively remove operational water inventory from the TSF at the end of tailings deposition, options to progressively rehabilitate (to reduce catchment size), optimise tailings deposition strategy and/or remove operating pond/design storage allowance (DSA) volume should be explored. Options to reduce of water inventory prior to cessation of tailings deposition should be explored. Construction of the cover system over available areas of the TSF prior to cessation of tailings deposition could reduce the risk associated rehabilitation of the site.
- The Stage 2 spillway at elevation of RL 242.1 m (covered by Stage 3 embankment raise) will be reinstated for closure following reshaping of the embankment, acting as an outlet for the final TSF landform.

2.3 Closure Landform Design Objectives

The closure landform is developed to achieve a structure that is safe, stable and non-polluting through:

- Erosional stability.
- Geotechnical stability.
- Supporting and integrated to the design cover system to promote geochemical stability (i.e. non-polluting).
- Supporting the Post-Mining Land Use of Native Ecosystem **[4].**
- Forming a free-flowing landform that conveys surface waters from the upstream catchment through an outlet structure with no storage within the former TSF.

Overall, the rehabilitation objectives that relate to this Memo include the following:

Non-Polluting

- Surface water runoff quality will be within accepted criteria and will not result in deleterious impact to the receiving environment.

Physically Stable

- Achieves a factor of safety in accordance with Australian National Committee on Large Dams (ANCOLD) Guidelines on Dam Safety Management.

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- Mass stability under static and earthquake conditions.
- Minimises erosion risk within the approved disturbance footprint.
- Surface water drainage system to reduce erosion and runoff velocity and provide sustainable flow into the downstream natural drainage.

Sustains Agreed Post Mining Land Use

- Appropriate for the local climate and estimated climate change.
- Supports a PMLU of native ecosystems.

3 CLOSURE LANDFORM DESIGN

The final Stage 3 tailings surface at the end of deposition is illustrated in **DIAGRAM 1 [2]**. As discussed in **Section 2.1**, the final Stage 3 tailings will require earthworks modification to allow for a self-shedding and stable final TSF landform. This has been modelled as shown in **DIAGRAM 2.**

DIAGRAM 1: STAGE 3 FINAL TAILINGS SURFACE

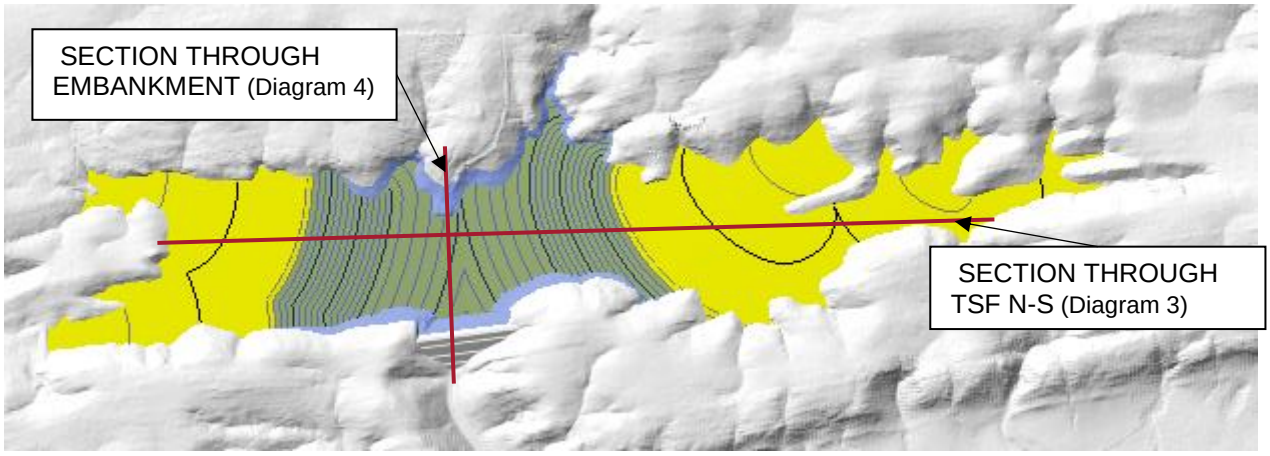

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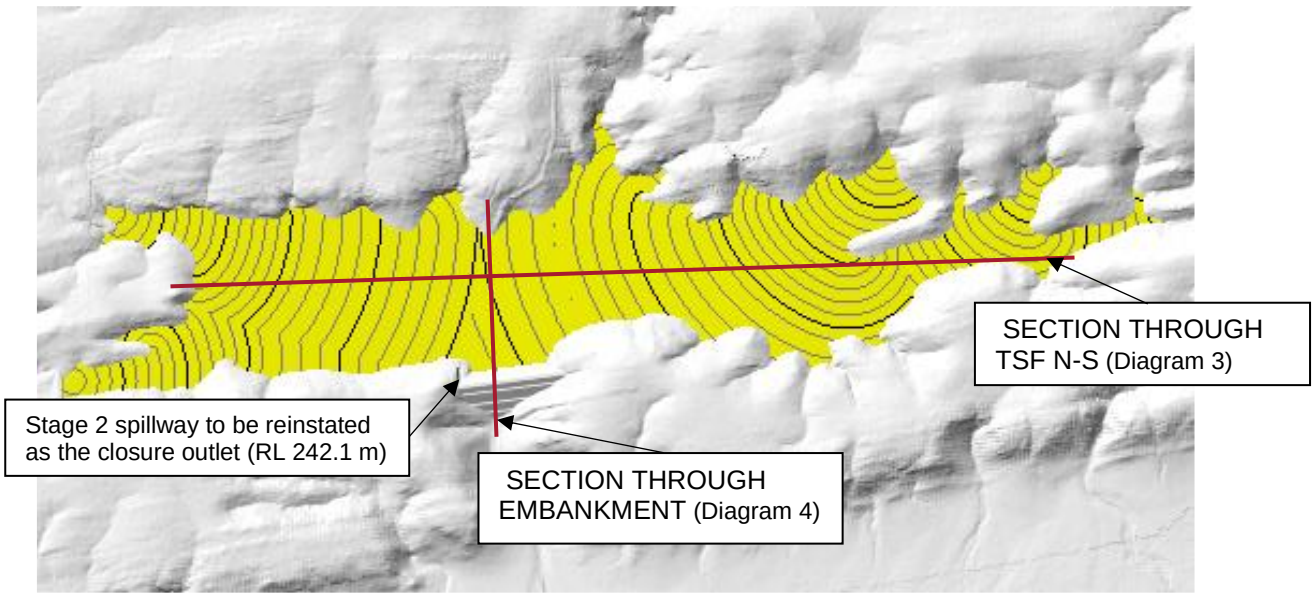
DIAGRAM 2: CONCEPT CLOSURE FINAL TAILINGS SURFACE (RESHAPE)



A comparison between the Stage 3 final tailings surface (also showing the maximum level of operational pond volume of 4,070 ML) against the conceptual final tailings surface is also shown in sections as shown in **DIAGRAM 3** and **DIAGRAM 4**.

DIAGRAM 3: CONCEPT FINAL TAILINGS SURFACE – SECTION THROUGH TSF N-S

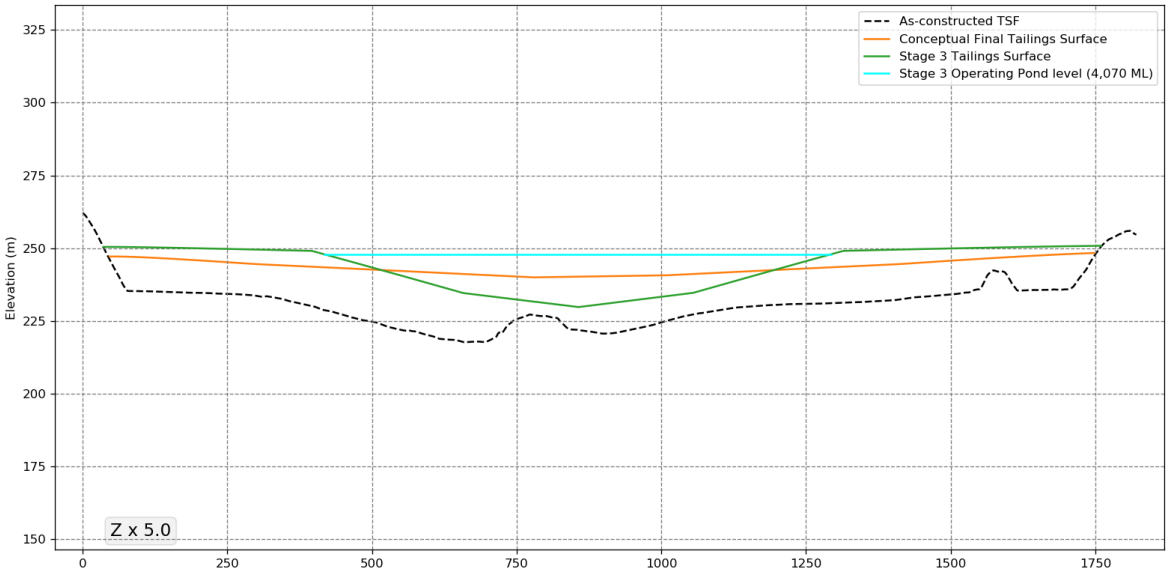


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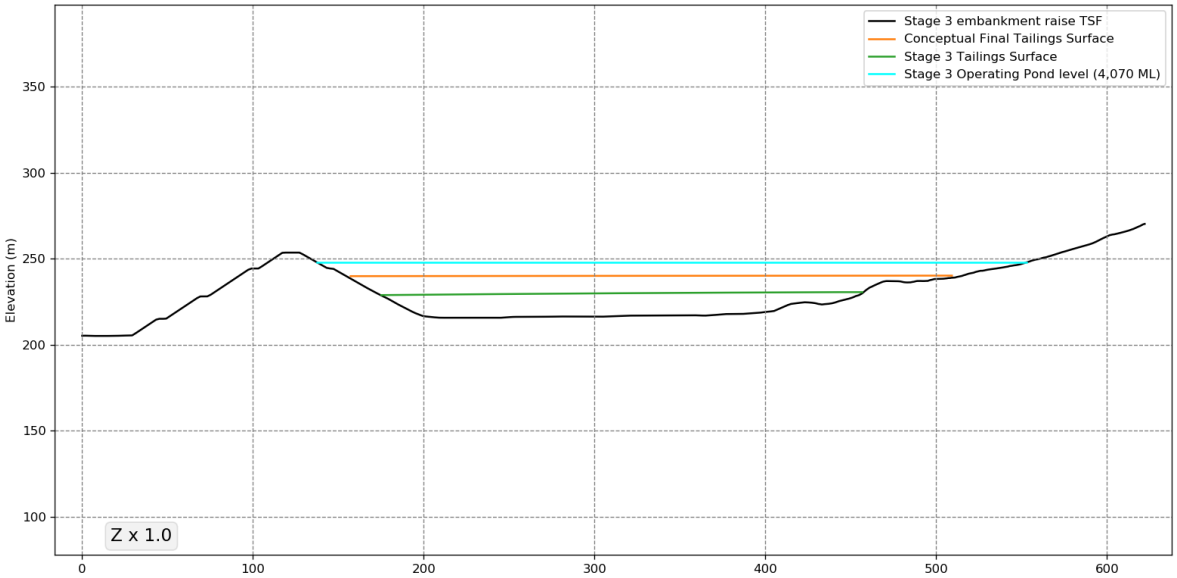
DIAGRAM 4: CONCEPT FINAL TAILINGS SURFACE – SECTION THROUGH EMBANKMENT



Approximately 1.7 Mm^3 of cut and 1.9 Mm^3 of fill will be required to reshape the tailings surface to achieve the conceptual final tailings surface. The additional 200,000 m^3 of final material may be won from the cut embankment or additional NAF material. Optimisation of the final closure landform will be optimised as the design of the Stage 3 raise and operational deposition progresses.

To minimise the work required to reshape the final tailings surface, optioneering of the conceptual final tailings surface is required to consider:

- steeper tailings slopes,
- elevation of closure embankment and outlet structures,
- optimised tailings deposition strategy for the LoM, and
- availability of TSF areas for progressive rehabilitation.

3.1 Water Management at Closure

At the time of closure, the expected operating Pond volume will be at 4,070 ML and with elevation at RL 249.05 m against the Stage 3 embankment **[2]**. The TSF has a catchment size of about 90 ha. At closure, water from the dams will also be emptied into the TSF to allow for rehabilitation of the whole site.

The removal of these water will be required to allow for consolidation and rehabilitation of the tailings. It is expected that the final TSF landform will be self-shedding with an outlet at the embankment for surface water runoff.

At this concept stage, the current Stage 2 spillway of RL 242.1 m will be reinstated to form the outlet. This outlet is sized to pass the peak flood resulting from the Probable Maximum Precipitation (PMP). The sizing details is provided updated Hydraulic Impact Assessment report (ref: *240288.R01*).

3.2 Surface Water Management at Closure

Surface waters from upstream catchments reporting to the TSF will be conveyed through a series of surface channels to the outlet structures located either side of the current embankment. The TSF closure landform is designed to convey surface waters to these outlet structures, avoiding water

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ponding and storage within the footprint of the facility. Further details on surface water management at closure is available in the Hydraulic Impact Assessment report (ref: *240288.R01*).

3.3 Main Embankment at Closure

The downstream face of the TSF main embankment will be flattened to a nominal 1V:6.5H to stabilise the embankment in the long term and eliminate water ponding and storage within the TSF. The landform surface is designed to allow for stormwater to flow in a controlled manner towards the outlet structures and therefore, no water storage capacity has been allowed within the TSF final landform.

The concept plan and section of the flattened embankment (with the nominal tailings cover) is provided **DIAGRAM 5** and **DIAGRAM 6**.

DIAGRAM 5: EMBANKMENT AT CLOSURE

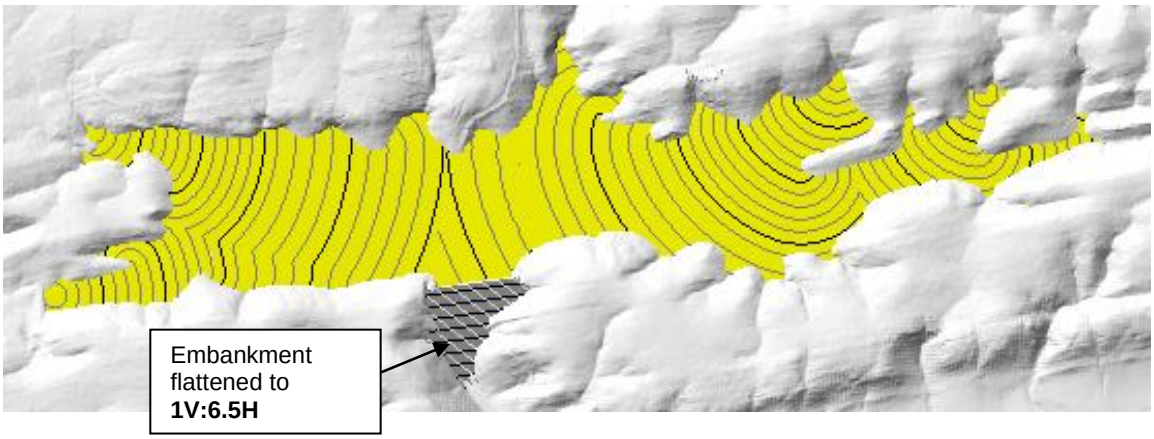
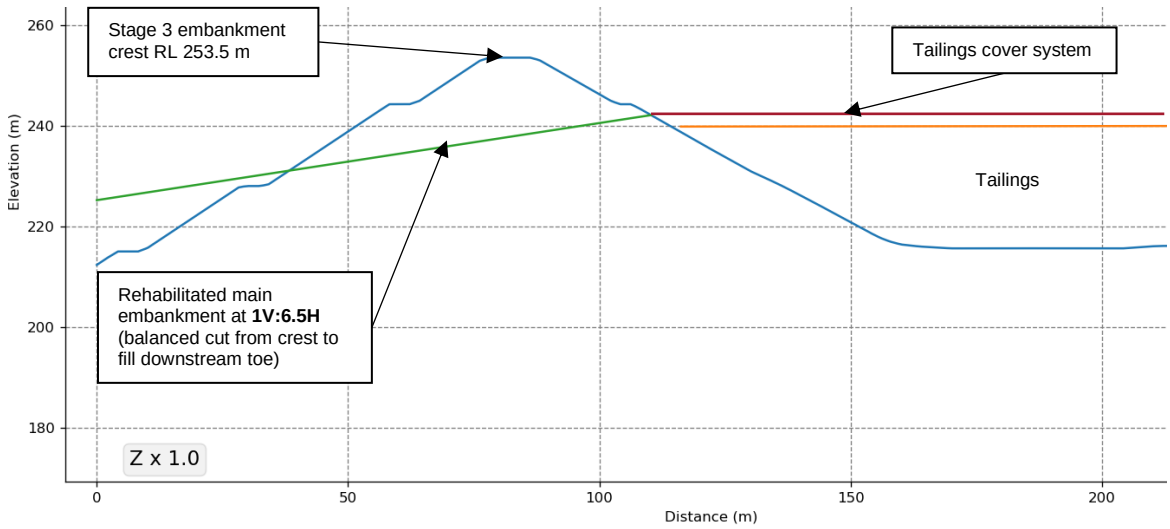


DIAGRAM 6: EMBANKMENT AT CLOSURE - SECTION



The cut/fill volume to achieve the rehabilitated main embankment is approximately 170,000 m^3 (cut) and 110,000 m^3 (fill). The excess cut volume can be diverted towards the tailings cover or reshaping of the tailings surface.

There is also the opportunity to win more material from the embankment through steepening of the rehabilitated main embankment to a 1V:5H slope, resulting in 200,000 m^3 (cut) and only 40,000 m^3 (fill). There is an excess of 160,000 m^3 material that potentially could be used as part of rehabilitation of the TSF. This option can be investigated further if preferred i.e. stability analysis, erosion, surface water runoff.

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4 CONCLUSION AND RECOMMENDATIONS

The conceptual final tailings surface (prior to cover system construction) has been modelled with the key assumptions of a flatter 0.67% to 1.5% grade for the final tailings surface and reinstating the Stage 2 spillway as the surface water outlet at closure. This however results in a significant volume of earthwork of 1.7 Mm^3 in cut volume and 1.9 Mm^3 of fill volume that may take take 3-5 years to complete (alongside 3-4 years to progressively remove the water storage within the TSF). Areas of the TSF will become available for progressive rehabilitation as closure earthworks progress.

To reduce the time, effort and cost prior to commencing cover system construction within the TSF, it is recommended that these options are taken into considerations:

- Optimisation of the tailings deposition strategy such as locations of spigot and frequency of deposition, especially 5-10 years before closure.
- The steepness of the final tailings surface before capping whereby analysis of erosion, surface water flow, stability of rehabilitated embankment are required.
- Progressively rehabilitating the TSF before closure to reduce catchment size and increasing efficiency when capping during closure. Considerations for reducing the operating pond and DSA volume, and a trial plot can also be investigated as part of this work.

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REFERENCES

[1] Department of Environment, Science and Innovation (DESI) – Environmental Authority – EPML00731213. 7 November 2024.

[2] ATC Williams (2024) – Dugald River Mine, Tailings Storage Facility Stage 3 Concept Design (108003.67R01 RevA) September 2024.

[3] ATC Williams (2015) MMG Dugald River – Tailings Storage Facility Revised Concept Design (108003.20-R01).

[4] Wulguru Technical Services (2024) – Progressive Rehabilitation and Closure Plan Dugald River Mine (2024.02002 Version 5.0) October 2024.

[5] ATC Williams (2025) Dugald River Mine – Additional PRCP Studies – Closure dewatering plan (240288-M01).

Appendix M: Conceptual Cover System Modelling Results

MEMORANDUM

TO	Dirk McNicoll, Amy Harburg; Kate Brosnan; Robert James	**COMPANY**	MMG Dugald River Mine
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PROJECT TITLE	Dugald River Mine – TSF Conceptual Closure Design		
SUBJECT	DRM – Landform Conceptual Design – Conceptual Cover System Modelling Results		
DATE	19 March 2025	**OUR REF**	240189.M06.Rev1

1 INTRODUCTION

MMG Dugald River Pty Ltd (MMG) is an underground lead and zinc mining operation, located approximately 60 kilometres (km) northwest of Cloncurry in North West Queensland. It is owned and operated by MMG, a wholly owned subsidiary of MMG Australia Limited.

Dugald River Mine (DRM) is authorised by the Department of Environment, Tourism, Science and Innovation (DETSI) under Environmental Authority (EA) EPML00731213 and resides on 40 Mining Leases (ML) and one Mineral Development Lease (MDL).

MMG proposes to increase the capacity of the tailings storage facility (TSF) at DRM by raising the crest height of the main embankment (the Stage 3 embankment raise design concept) **[1]**. This constitutes a major amendment of the EA, triggering the requirements for updated Progressive Rehabilitation and Closure Plan (PRCP) and PRCP Schedule.

ATC Williams Pty Ltd (ATCW) has been engaged by MMG to develop a conceptual closure design for the TSF to inform the PRCP. The conceptual closure design must be consistent with the approved PRCP **[2]**, and meet the minimum information requirements in the PRCP Guideline **[3]**. The closure design includes landform design, cover system design and erosion modelling. The cover system options considered and background information used to define the cover systems developed were discussed in **[4]**. The memorandum summarises the results from the cover system water balance modelling for each of these options.

2 MATERIAL CHARACTERISATION

The material characterisations are discussed in TSF Cover Soils Geotechnical Investigation memo **[5]** and Conceptual Cover System Options memo **[4]**.

The main outcomes from the characterisations are that:

Tailings:

- have the potential to leach metal and metalloids and are considered Potentially Acid Forming (PAF) and as such the cover system is required to limit rainfall infiltration into the tailings to decrease seepage and mobilisation of oxidation products from the PAF tailings that may impact surface water.

Cover Materials:

- Clay, as a potential low permeability layer would be difficult to source onsite. Therefore, a geosynthetic liner may be required as a component of the cover system to limit infiltration.
- Soil profiles are generally shallow, therefore it would be critical to optimise the thickness of the cover system to limit the extent of the borrow area footprint.
- Limited topsoil is available, some soil amelioration of the subsoil may be required to support vegetation establishment.

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3 COVER SYSTEM OBJECTIVES

3.1 Objectives

The cover system objectives are discussed in the Conceptual Cover System Options memo **[4]**. As discussed in the memo, potential cover system options have been developed based on the significant risk with respect to AMD and NMD exist from the tailings. The cover system is therefore required to:

- Minimise infiltration to the maximum extent, such that seepage from the TSF is minimised.
- Minimise capillary rise from the tailings into the cover system, thereby contaminating the cover soils.
- Be physically stable.
- Be chemically stable.
- Be able to sustain agreed Post-Mining Land Use (PMLU) of native vegetation **[2]**.

3.2 Progressive Rehabilitation and Closure Plan

3.2.1 Closure Objectives and Post Mining Land Use

The *Environmental Protection Act 1994* (EP Act) requires that all areas disturbed within the relevant mining tenure must be rehabilitated to a Post Mining Land Use (PMLU) or managed as a Non-Use Management Area (NUMA). The approved PMLU for the TSF and associated pipelines and seepage collection pond is native ecosystem **[2]**. A PMLU of native ecosystem is consistent with the rehabilitation objective defined in *Schedule I - Table 1* of the EA.

A PMLU must be rehabilitated to stable condition in accordance with the definition given in Section 111A of the EP Act.

> *"Land is in stable condition if:*
>
> *a) the land is safe and structurally stable; and*
> *b) there is no environmental harm being caused by anything on or in the land; and*
> *c) the land can sustain a post-mining land use."*

3.2.2 Completion Criteria

The completion criteria for measuring whether the PMLU has been successfully achieved are outlined in the approved PRCP. The completion criteria for the PMLU will be used as milestone criteria for the final milestone in the PRCP Schedule, which shows achievement of the PMLU to a stable condition at surrender.

4 COVER SYSTEM CONFIGURATIONS

The cover system configurations are discussed in the Conceptual Cover System Options memo **[4]**. A number of potential cover systems have been identified and are proposed to be modelled to assess their relative performance regarding net percolation and determine which option(s) would meet the closure objectives.

As discussed in the Conceptual Cover System Options memo **[4]**, the International Network for Acid Prevention's (INAP's) Global Acid Rock Drainage Guide (GARD Guide) **[6]** suggests that a store and release cover system is the most suitable for the climate.

Recognising the limited availability of site soils (quantity of ISL, lack of RPL), and the environmental risk from the tailings, the potential use of geosynthetic liners as an integral part of the cover system profiles should be evaluated.

Prior to implementation of the cover system following cessation of deposition in the DRM TSF, further site investigation for material availability should be conducted as the use of local soil materials may be a cost effective option.

A description of key cover elements is provided in **TABLE 1.**

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TABLE 1: FUNCTION OF COVER LAYERS

Layer	Abbreviation	Purpose	Source and Description
Topsoil	Topsoil	Support vegetation.	Borrow area, to be located adjacent to the TSF.
Infiltration Storage Layer	ISL	Store moisture to support vegetation growth and limit downward flux into the tailings.	This material would be sourced from a borrow located near the TSF, and comprise the subsoil, being the material immediately beneath the topsoil and above the weathered rock.
Reduced Permeability Layer	RPL	Limit flux through the cover system into the tailings.	Provide a barrier beneath the ISL to reduce percolation into the underlying tailings material and PAF waste rock when the overlying storage capacity is exceeded.
Capillary Break Layer	CB	Disrupt the upward and downward movement of water (and hence salt) through capillary action by providing a change in pore size distribution.	To comprise a clean gravel product. A manufactured material, sourced from a licenced quarry or crushed and screened NAF waste rock.
Geomembrane (GCL/HDPE)	GM	Low permeability barrier, to be used in the absence of an RPL, if required.	Geosynthetic clay liner (GCL) is a sodium-bentonite clay sandwiched between non-woven geotextile and forms a very low permeability barrier to water but is susceptible to structural changes from high calcium content. High density polyethylene (HDPE) or Linear Low Density Polyethylene (LLDPE) are thermoplastic polymer sheets that form an impermeable barrier to water and many contaminants. Purchased from specialised supply companies and installed by qualified installers.

The cover system configurations considered are summarised as follows and the profiles depicted in **TABLE 2**:. The thickness of layers in **TABLE 2** are based on similar project experience as complete laboratory data were not available at the time of this memo. Layer thickness may be refined and optimised at subsequent design stages if material properties differ from those assumed herein.

Cover 1: Store and release cover (SAR) system that comprises topsoil, Infiltration Storage Layer (ISL), and Reduced Permeability Layer (RPL). This option is generally consistent with the cover system recommended by the GARD guide, although as previously noted, no material has been identified on-site which would meet the requirements of a low-permeability layer.

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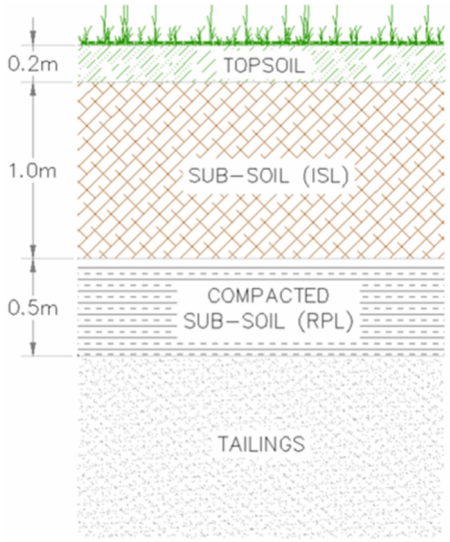
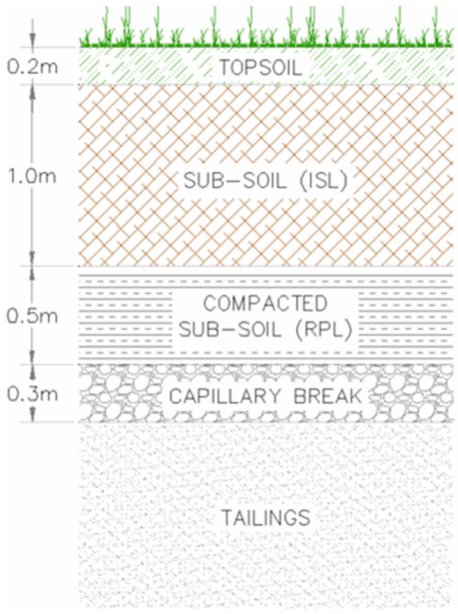
Cover 2: Single capillary break (CAP) cover system (PRCP). Cover 2 adopts a similar profile to Cover 1, however also incorporates a capillary break. Depending on the outcomes of the modelling, a capillary break may be required to prevent capillary rise. Cover 2 also comprises a RPL which will be difficult to source onsite.

Cover 3: Cover 3 adopts a similar profile to Cover 2, with the topsoil and ISL, however includes a Geosynthetic Clay Liner (GCL) as the RPL in replacement for a clay soil. This is in recognition that clay may be difficult to source on site. Cover 3 also includes a capillary break as the GCL does not prevent capillary rise.

Cover 4: Cover 4 includes the same topsoil and ISL layer but incudes an HDPE liner as a replacement for the RPL, which would prevent infiltration and capillary rise. The clay RPL and capillary break have therefore been omitted for option 4.

TABLE 2: COVER SYSTEM CONFIGURATIONS

COVER 1: STORE AND RELEASE (SAR)	COVER 2: CAPILLARY BREAK (CAP) [PRCP]
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL)	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • 0.5 m Reduced Permeability Layer (RPL) • 0.3 m Capillary Break
	

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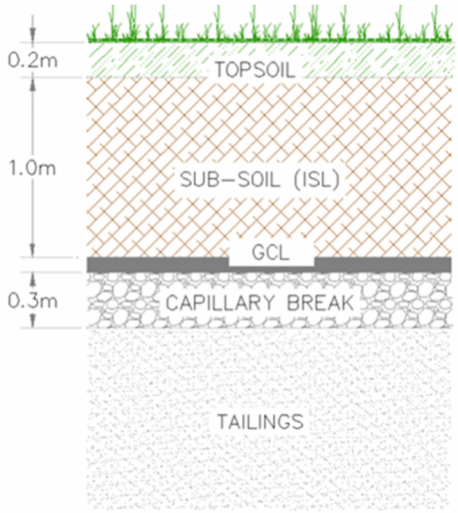
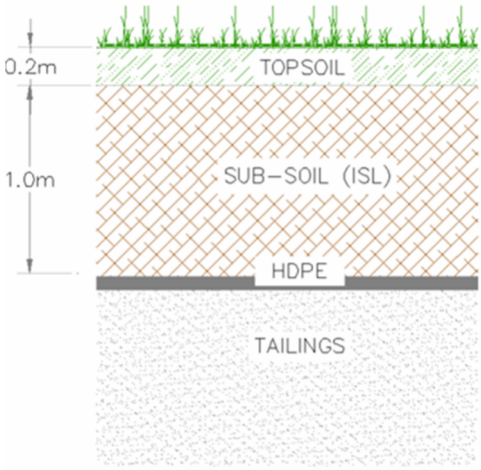
COVER 3: GCL	COVER 4: HDPE
• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • GCL • 0.3 m Capillary Break	• 0.2 m Topsoil • 1 m Infiltration Storage Layer (ISL) • HDPE
	

5 COVER SYSTEM MODELLING

Modelling was undertaken with SEEP/W, a finite element package software used for numerical modelling of saturated and unsaturated flow within soils. Modelling assumed a one-dimensional column through the proposed cover system profile and extending 5 m into the tailings profile.

This memorandum presents the results from the Store and Release and the HDPE cover systems. These two represent the likely extremes in cover system performance and hence provide the potential boundaries of cover system performance. The results for all four cover systems will be presented and discussed in further detail in the detailed modelling report.

5.1 Method

5.1.1 Model Geometry

The SEEP/W model comprises a one-dimensional column, comprised of 5 m of tailings overlain by the cover system. While the depth of tailings exceeds 5 m, climatic forcing is generally limited to the top few metres of the modelled profile. This assumption was checked during modelling to ensure that movement of water was not observed at the tailings depths greater than 5 m. It was noted that negligible movement of water was estimated by the model within the tailings. Therefore, modelling increased tailings depths would have no material impact on the outcome of the model.

5.1.2 Climate Data

Climate data from 1970 until 2024 were sourced from Queensland Government Scientific Information for Land Owners (SILO) for the site location **[7]**. BoM station 29127 MOUNT ISA AERO is the closest recording station, and is located about 85 km south west of the site. The year range selected covers decadal changes including extended periods of hotter, wetter, cooler and drier weather.

The site is within the Hot (Winter Drought) Grassland area based on the Koppen climate classification. Median monthly rainfall and temperature for the period of January 1970 to December 2024 is depicted in **GRAPH 1** below and show the winter drought extends from April to

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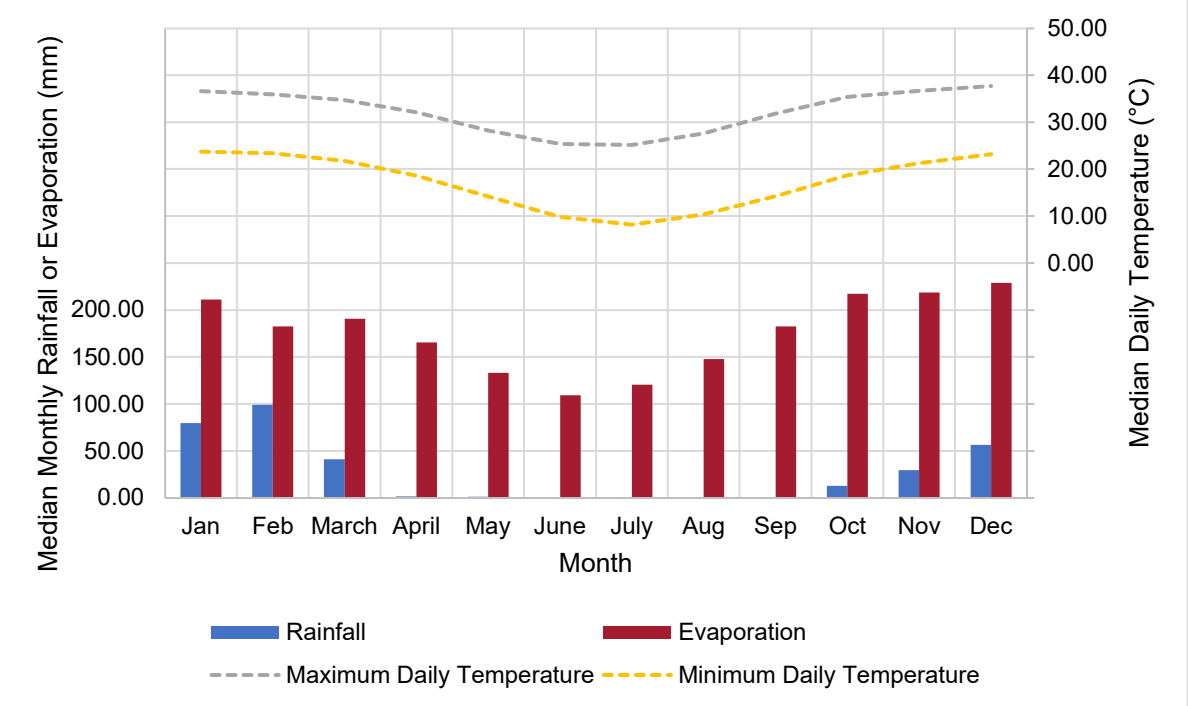
September with effectively 0 mm rainfall received in these months. The average maximum monthly evaporation for the reporting period is 228.9 mm in December, and the average minimum monthly rainfall is 109.2 mm in June with evaporation exceeding rainfall in every month showing a strong moisture deficit in most years. The average maximum daily temperature for the reporting period is 37.7°C in December, and the average minimum daily temperature is 8.2°C in July showing wide extremes of temperature over the year are common.

GRAPH 1: MONTHLY CLIMATE DATA



For water balance, the data are aggregated based on a weather year, i.e. from the start of the wet to the end of the dry. Defining the weather year in this way assists in ensuring the rainfall received is correlated to any percolation which may be delayed, in some cases by months According to the SILO data discussed above, August has the lowest rainfall, where as September can be more variable due to an earlier break in the seasons. Thus, September was chosen as the start month of the Weather Year (WY).

Rainfall for the weather years from September 1974 to August 2024 is depicted in **GRAPH 2** below. The mean rainfall was 471.9 mm, the maximum rainfall of 1092.4 mm occurred in 2011/12 whilst the minimum rainfall of 93.5 mm occurred two years later in 2012/13. Successive wet or dry years can have a major impact on the percolation and the capillary rise from the tailings. The driest five years occurred from 1985/86 to 1989/90 and the wettest period was from 1997/98 to 2001/02 (**Graph 2**).

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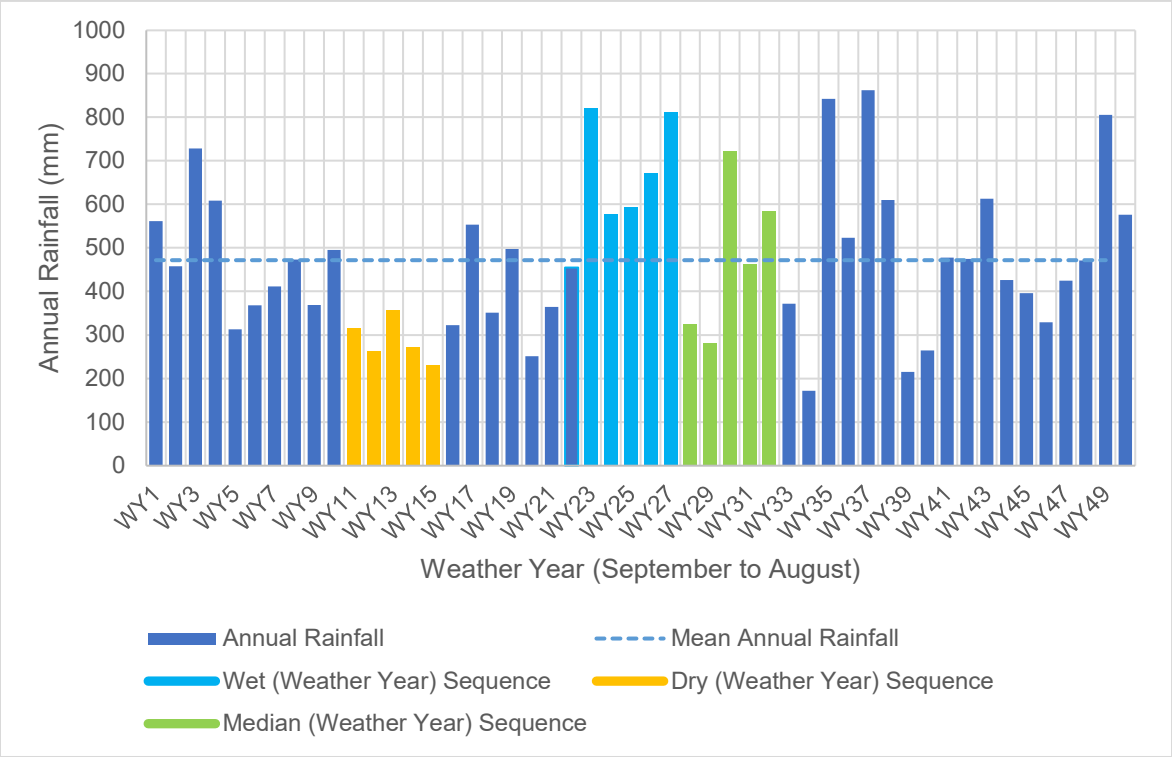
GRAPH 2: ANNUAL RAINFALL BASED ON WEATHER YEAR



5.1.3 Boundary Conditions

The model boundary conditions are outlined as follows:

Climatic Conditions:	Applied to the surface of the cover system as detailed in **SECTION 5.1.2**.
Initial Gradient (Free Drainage):	Applied at the base of the model to allow seepage from the model. Seepage rates are calculated assuming the downward flux is equal to the hydraulic conductivity at that point.
Vegetation:	Applied assuming native vegetation, which is discussed further in **SECTION 5.1.5**.

Initial moisture content and pore water pressures were defined as an initial water head located 1 m below the tailings surface.

5.1.4 Material Properties

The 2025 laboratory SWCC testing results were not available at the time of conducting the SEEP/W modelling. As a result, the default SWCCs were adopted in the SEEP/W, with adjustments made according to previous geotechnical investigations and test pit information. Adopted SWCC's are shown in **GRAPH 3**.

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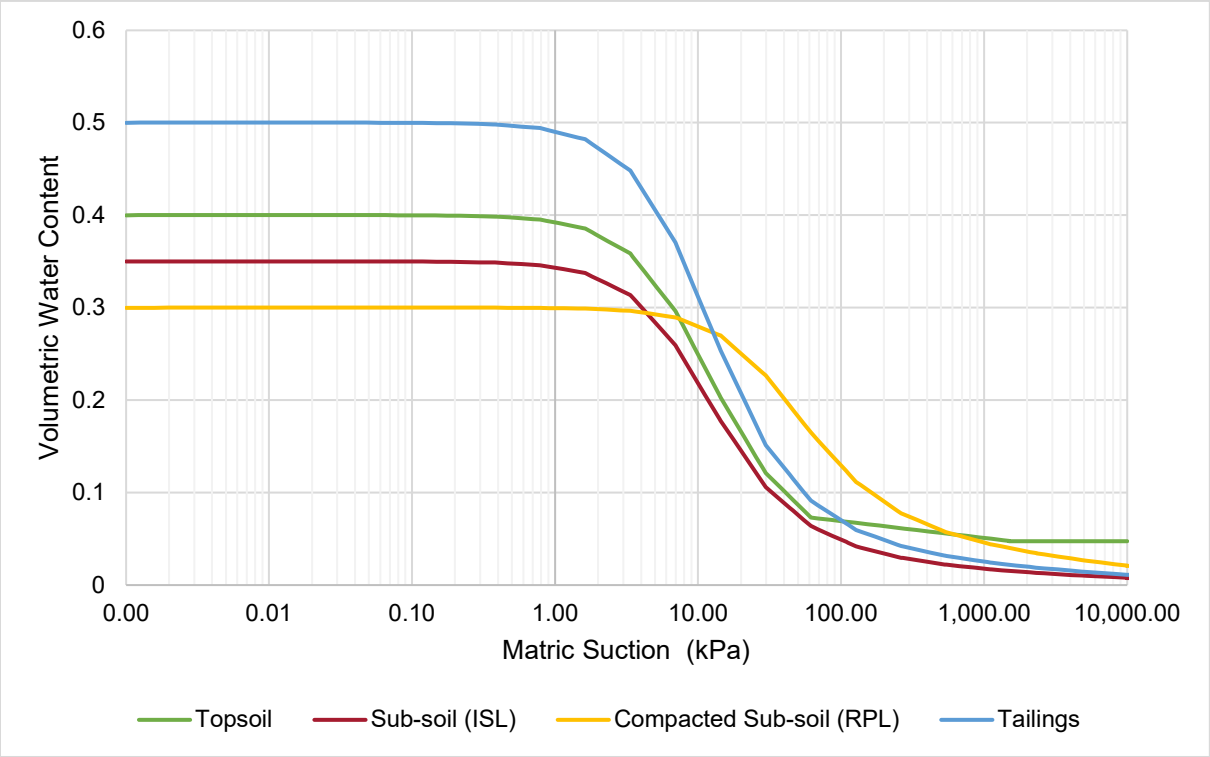
GRAPH 3: SOIL WATER CHARACTERISTIC CURVES



The hydraulic conductivity curves were estimated using SEEP/W's inbuilt Fredlund-Xing-Huang model, as shown in **GRAPH 4**. The model inputs are the SWCCs and saturated hydraulic conductivity, as shown in **TABLE 3**.

TABLE 3: SATURATED HYDRAULIC CONDUCTIVITY

LAYER	SATURATED HYDRAULIC CONDUCTIVITY (m/s)
Topsoil	1×10^{-5}
ISL (sub-soil)	1×10^{-5}
RPL (compacted sub-soil)	1×10^{-9}
HDPE	1×10^{-18}
Tailings	1×10^{-7}

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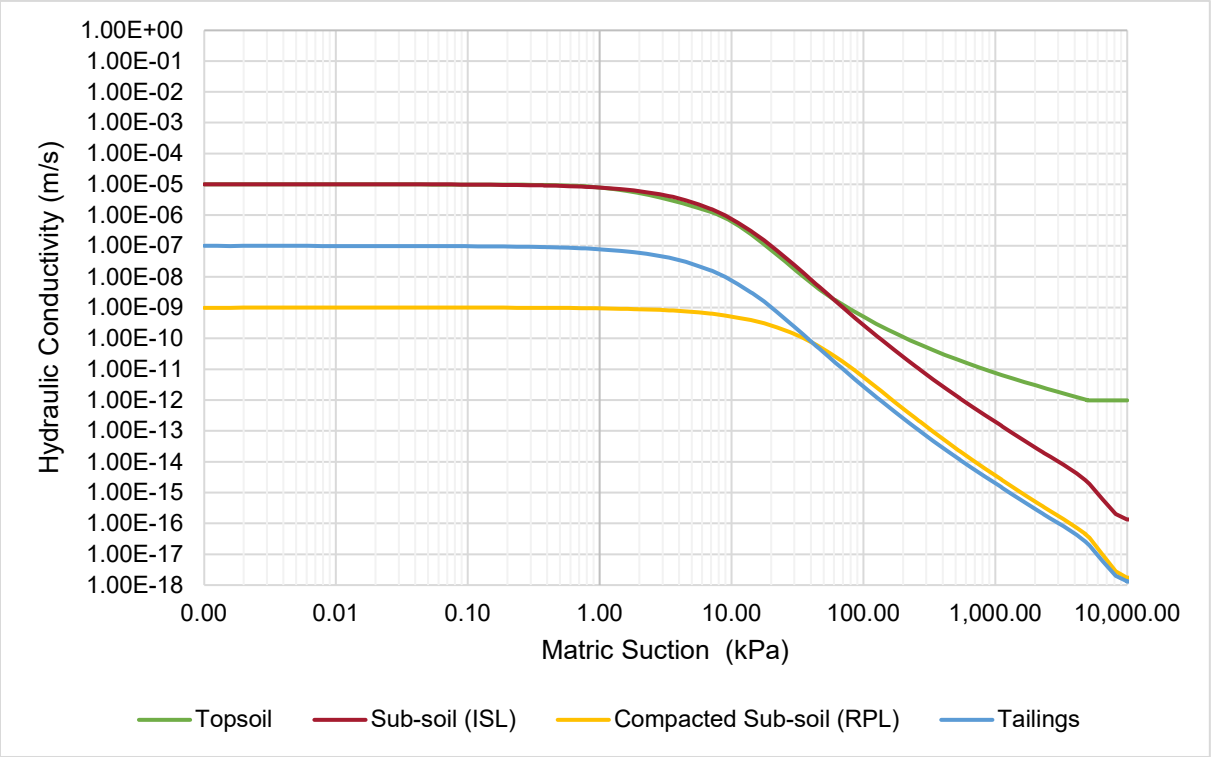
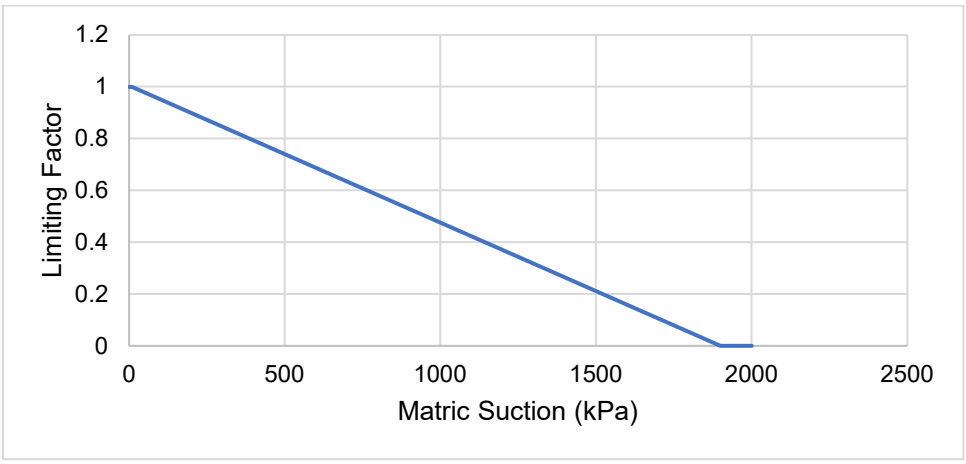
GRAPH 4: HYDRAULIC CONDUCTIVITY FUNCTION



5.1.5 Vegetation Model Scenarios

Vegetation inputs to SEEP/W comprise leaf area index, plant moisture limiting function, normalised root density and cover soil fraction. Vegetation parameters are highly variable depending on species and environmental factors such as rainfall. Vegetation parameters input into the model represent the PMLU of native vegetation in the area, described as low open woodland **[8]** (regional ecosystem code of RE 1.11.2a/1.7.7a and RE 1.11.3a/1.3.13a **[9]**). For the purposes of the model, a constant leaf area index of 1.5 and cover soil fraction of 0.78 were adopted, meaning the vegetation remains constant over the duration of the modelling and does not vary seasonally or annually. Plant moisture limiting function, root density and cover soil fraction functions are shown in **GRAPH 5** to **GRAPH 7**. The LAI and soil cover fraction are low as would be typical in an arid environment such as DRM. Plants would rapidly respond to rainfall and increase leaf area and coverage, so adopting a constant low LAI and coverage presents a conservative estimate of transpiration.

GRAPH 5: PLANT MOISTURE LIMITING FUNCTION



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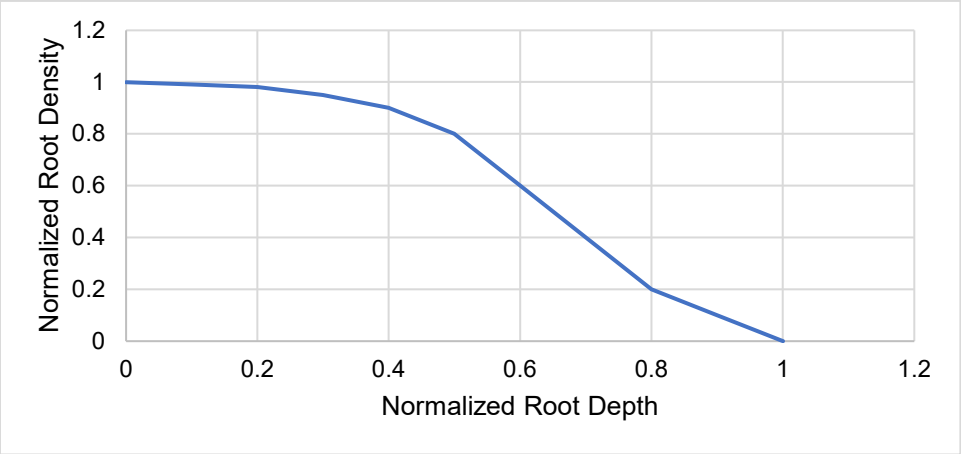
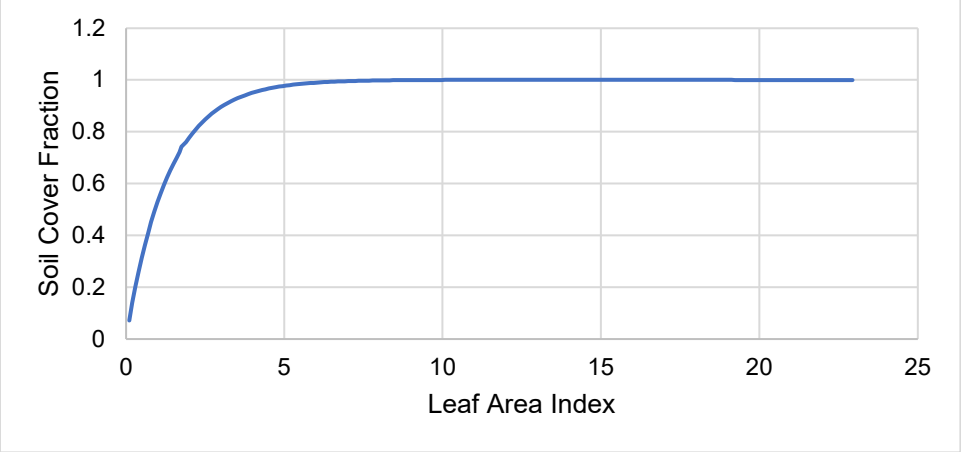
GRAPH 6: NORMALISED ROOT DENSITY



GRAPH 7: SOIL COVER FRACTION



5.1.6 Model Limitations

The cover system model has been developed using empirical formulas and material parameters obtained in laboratory testing, i.e. it has not been calibrated against field data. An uncalibrated model can have an error up to an order of magnitude due to the variability between laboratory and longer-term field obtained values. The primary function of the current, uncalibrated cover system model is to compare cover system options and configurations. It is not intended to accurately predict the performance of each cover system, rather it is precise.

Undertaking a desktop assessment utilising laboratory test results of soils in a model is a standard approach to understand the relative performance of the cover system. Calibration of the model is then undertaken using data collected as part of field trials to improve model prediction over the longer term. This may then result in further optimisation of the cover profile for final rehabilitation.

5.2 Results and Discussion

5.2.1 Overview and Terminology

The performance of each cover system has been assessed against the closure criteria discussed in **SECTION 3**. The terminology used is summarised as follows:

Water Balance

The water balance shows the balance of moisture within the modelled profile. Results which form part of the water balance are:

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Rainfall:	Rainfall depth occurring for the modelled period.
Runoff:	Rainfall runoff that does not infiltrate into the cover system that reports as surface water runoff off the TSF. It is noted that as the model is one-dimensional, no run on is considered, with rainfall reporting as runoff leaving the model domain.
Evaporation:	Moisture lost from the surface of the soil due to climate.
Transpiration	Transpiration is the water that a plant extracts from the soil through it roots and then expels into the air through aerial parts, such as leaves, stems and flowers.
Flux:	Moisture flux indicates the direction and rate of movement of moisture within and through the cover system profile. Negative flux rates indicate downward movement of moisture (e.g. rainfall infiltrating into the soil or percolation out of the soil and into the tailings) whilst positive flux rates are upward (e.g. evaporation or evapotranspiration to the atmosphere or capillary rise).
Net Percolation:	The volume of water moving out of the cover system profile and into the underlying tailings (Noting capillary rise is not deducted from these values).

Volumetric Water Content and Degree of Saturation

The volumetric water content (VWC) is calculated on a daily basis to account for the redistribution of the net infiltration through the soil profile which can then potentially enter the underlying tailings. The plant available water content (PAWC) is typically calculated as the difference between field capacity (nominally 33 kPa) and permanent wilting point (nominally 1,500 kPa). If drier than the wilting point, the matric suction no longer allows for uptake of moisture by plants.

Degree of Saturation provides the same chart to the VWC with the difference of the Y axis displaying the ratio of saturation from the residual moisture content (0.03 to 0.5) to saturated (1) (refer **Graph 10**).

5.2.2 Water Balance

Graphs depicting the cumulative WY water balance for the 50 year modelled duration are provided in **Graph 8** to **GRAPH 9**. A summary of the water balance is provided in **TABLE 4**. Model results indicate runoff accounts for less than 1% of the rainfall volume on an average annual basis, though it is noted that the simplification used by one-dimensional water balance models does not allow for accurate runoff prediction. The remaining rainfall initially infiltrates into upper layers of the cover system and is subsequently lost through evaporation and transpiration, which typically represents more than 17% and 81%, respectively, of the rainfall volume. Importantly, net percolation (NP) met the performance criteria for all model scenarios, limiting the net percolation into the underlying tailings material.

The performance of the cover systems is predicted to achieve the performance objectives described in **SECTION 3**. Objectives achieved include minimising infiltration, minimising capillary rise, and being able to sustain agreed PMLU of native vegetation. The similarity between cover system performance is a result of the constant vegetation parameters and the moisture remaining predominantly in the ISL.

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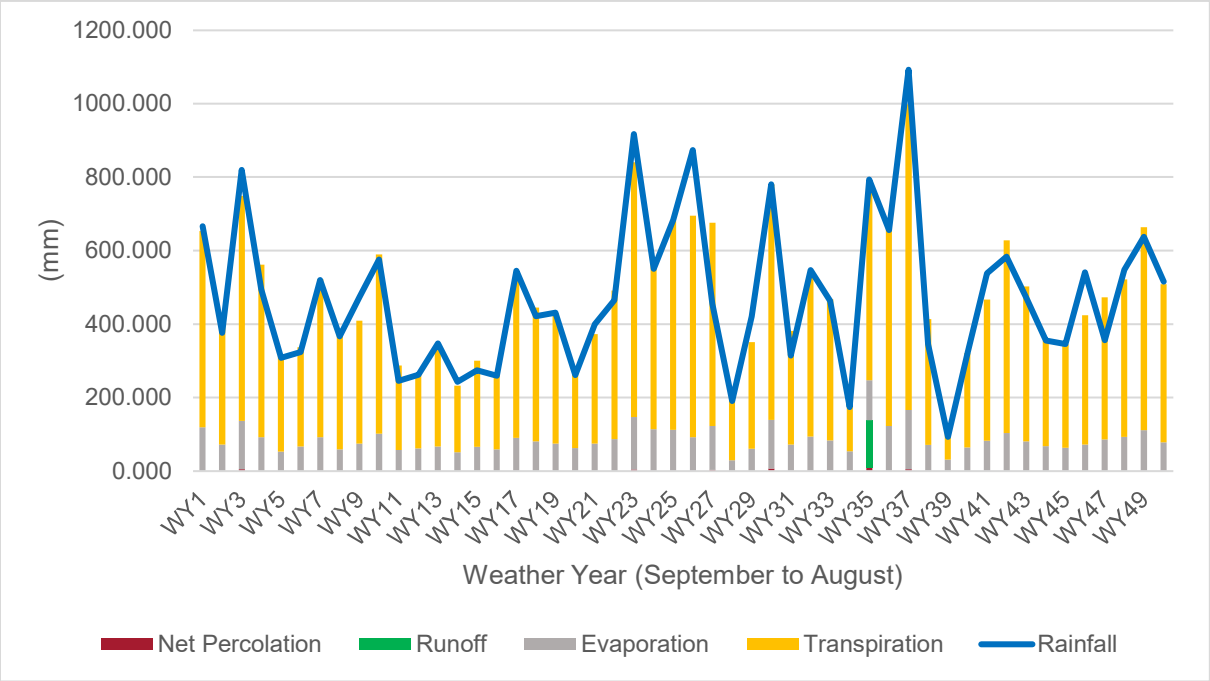
GRAPH 8: SAR COVER WATER BALANCE



GRAPH 9: HDPE COVER WATER BALANCE

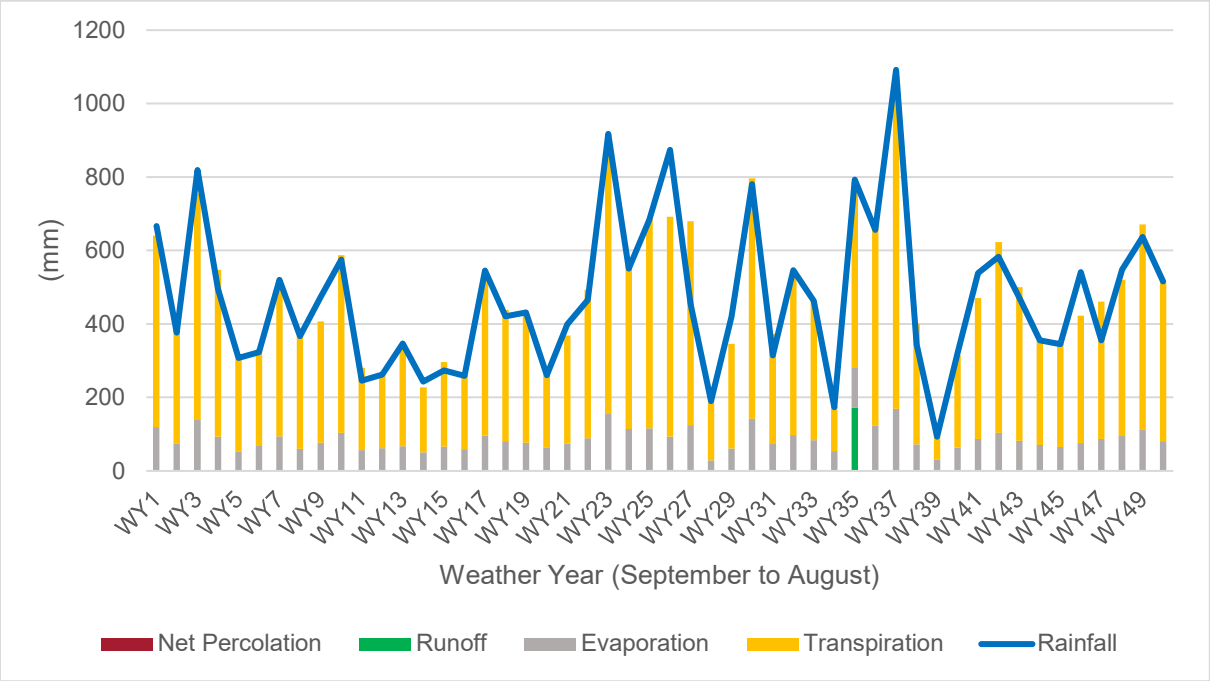


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TABLE 4: AVERAGE ANNUAL WATER BALANCE

Cover	Mean Annual Water Balance				
	Rainfall (mm/yr)	Runoff (mm/yr and % of Rainfall)	Evaporation (mm/yr and % of Rainfall)	Transpiration (mm/yr and % of Rainfall)	NP (mm/yr and % of Rainfall)
SAR	472.7	2.6 (0.5%)	83.8 (17.7%)	386.6 (81.7%)	0.7 (0.2%)
HDPE	472.7	3.5 (0.7%)	85.9 (18.2%)	382.4 (80.9%)	0.0 (0.0%)

Note: Minor errors in the water balance are related to differing initial and final conditions and modelling errors.

5.2.3 Degree of Saturation

Saturation in the topsoil and upper layers of the ISL is highly variable, with increased water saturation after rainfall events, followed by rapid drying due to evapotranspiration. At greater depths within in the ISL, increases in saturation are observed only following large rainfall events, indicating a significant rainfall depth is required for infiltration deep into the cover system profile. The tailings moisture content steadily decreases through the modelling period for all scenarios except the store and release cover where occasional increases in moisture content are observed. As the lower boundary of the model is free-draining, the decrease is for most scenarios is due to downward movement of moisture through the tailings and not upward movement via capillary rise.

Graph 10 to **GRAPH 11** depicts a range of saturation within the cover system as a response to rainfall events, for the 5 wettest weather years (WY23 to WY27).

Some key observations for both cover systems are:

- The degree of saturation increases after rainfall events.
- The ISL varies greatly with rainfall, and loses the moisture slowly over the following months, thus is storing and releasing water and working as intended. The ISL is typically dry at the beginning of the following weather year showing that the soil storage capacity is near its maximum and able to store the following years rainfall.
- The RPL varies less than the ISL due to the higher clay content and low rainfall environment. Very little is transmitted through the RPL and hence it is performing as required.

The degree of saturation in the SAR cover system shows water moves predominantly in the topsoil and ISL but also moves into the RPL and then slowly decreases. During WY23 and in WY27, the moisture moves deeper in the cover system and percolates into the tailings. In the HDPE cover system, the moisture accumulates above the HDPE (i.e. 0.01 m above the tailings) but does not enter the tailings. This accumulated moisture can potential move laterally but is also likely to be used by the plants.

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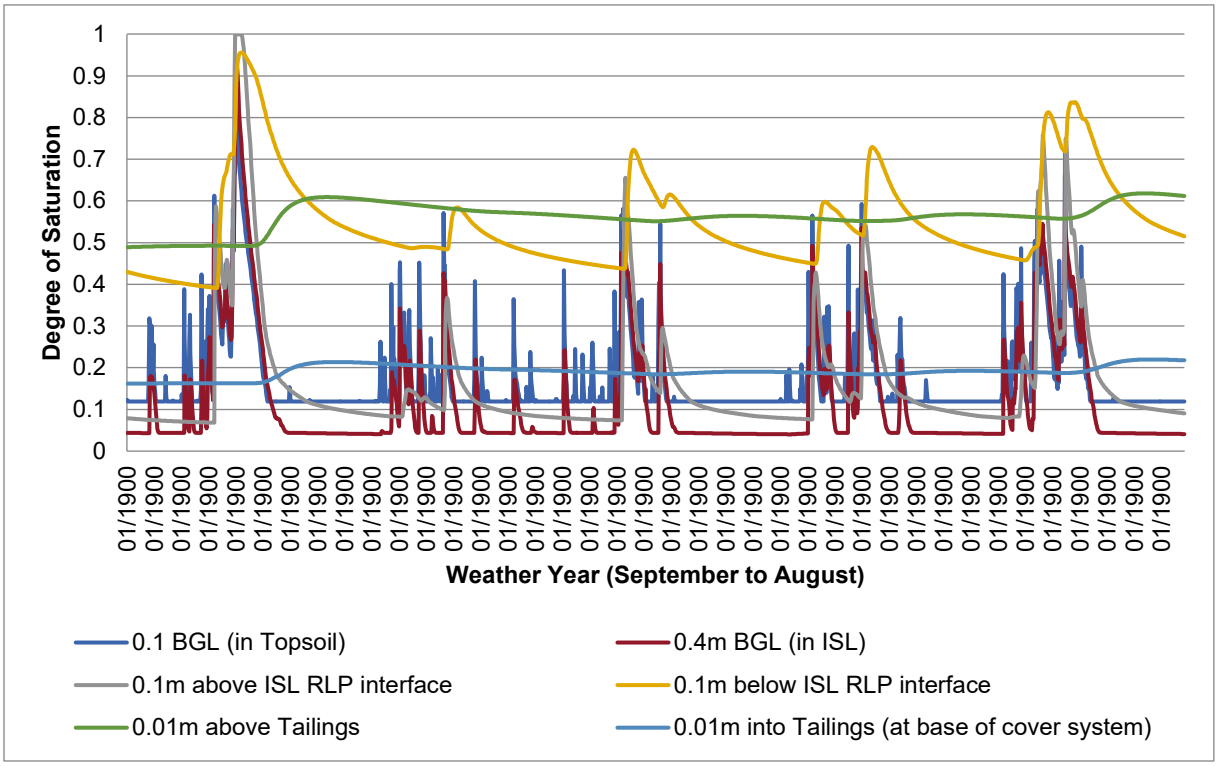
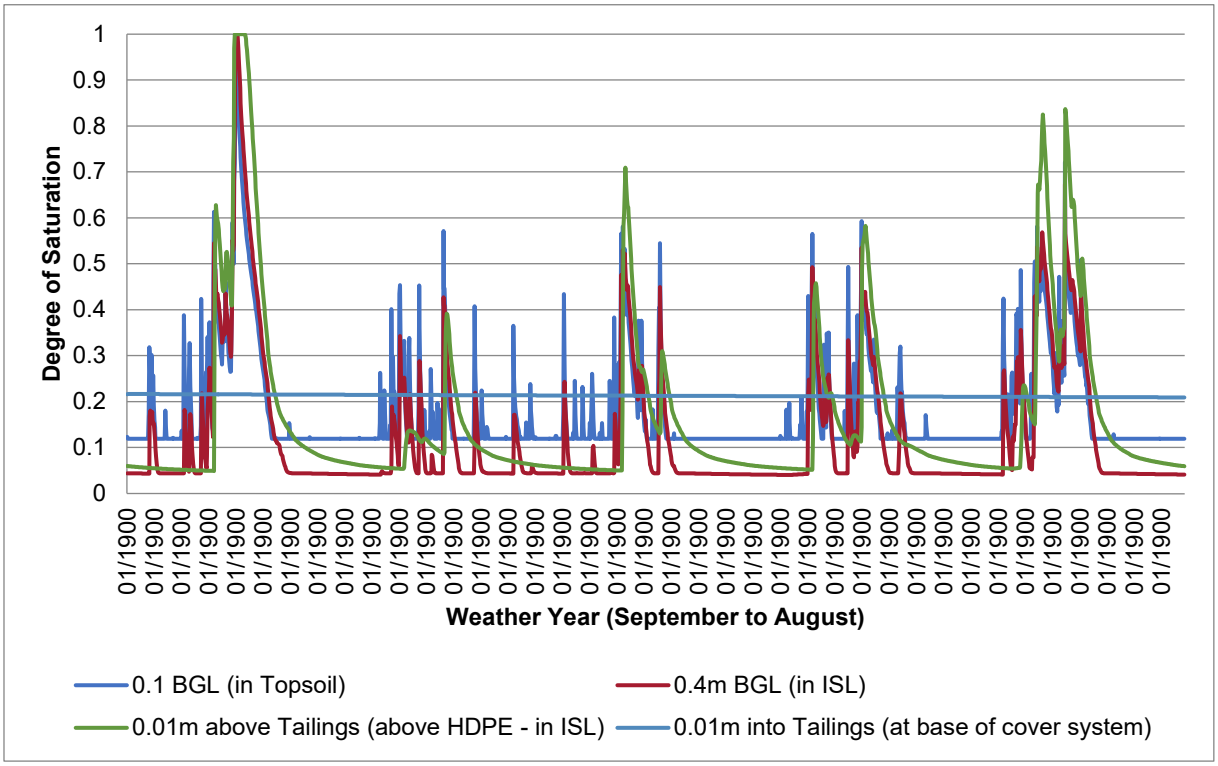
GRAPH 10: SAR COVER – DEGREE OF SATURATION



GRAPH 11: HDPE COVER – DEGREE OF SATURATION



Overall, there is a net deficit of rainfall which will require plants to have drought tolerance to be able to survive during the dry season and lower rainfall years. The use of endemic native species will improve the potential for successful vegetation survival and establishment.

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5.2.4 Net Percolation

Net Percolation (NP) in the tailings, 0.01 m below the interface of the cover system and the tailings, is close to zero (refer to **TABLE 5** and **GRAPH 12**).

The modelling NP results indicate downward percolation is an order of magnitude higher in the SAR cover system, though all are relatively small flux into the tailings (**TABLE 5**), Upward flux is not predicted for any cover design except for the SAR. The upward flux small but is greter than the downward flux which suggests salts may move into the cover soil and are likely to accumulate (**Graph 12**). Field trials would assist in understanding how high in the profile the salts may accumulate.

Overall, the net percolation represents a small proportion of the rainfall received. However, it must be remembered that these results are predicted from an uncalibrated model and the actual percolation in the field may be an order of magnitude lower or higher than predicted by the model. For the very low percolation predicted for the HDPE cover system, this would still result in very small amounts of percolation. For the higher percolation predicted for the SAR cover systems, this range of accuracy may result in more significant percolation into the tailings and/or capillary rise. For the SAR cover, the accuracy of prediction can be improved by monitoring the water balance in field trials and calibrating the water balance model , if required.

TABLE 5: NET PERCOLATION COVER PERFORMANCE

Cover	SAR	HDPE
Maximum downward NP (m/s)	$2.7x10^{-9}$	$1.1x10^{-10}$
Maximum downward NP (mm/year)	8.6	3.6
Cumulative downward NP (mm over 50 year modelling duration)	56.8	1.7
Maximum upward NP (m/s)	$5x10^{-10}$	0
Maximum upward NP (mm/year)	15.8	0
Cumulative upward NP (mm over 50 year modelling duration)	104.9	0

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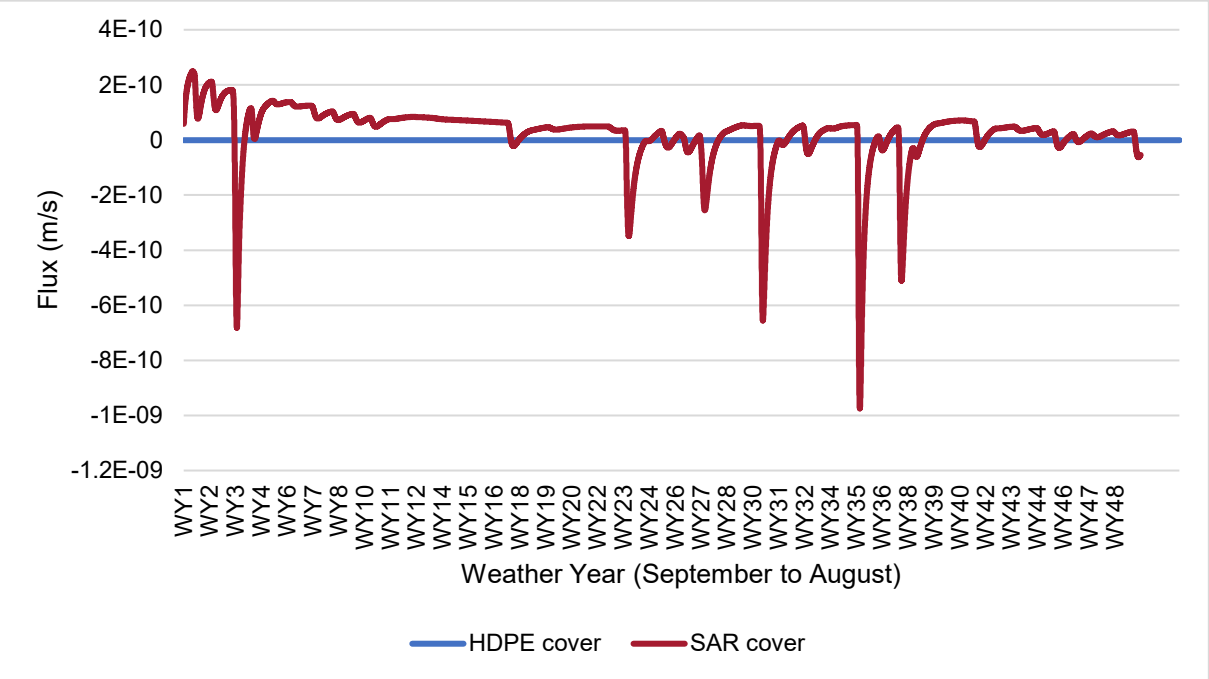
GRAPH 12: NET PERCOLATION AT TOP OF TAILINGS (0.01M BELOW COVER/TAILINGS INTERFACE)



6 CONCLUSION

Numerical modelling of the cover system options provides an indication of the relative performance of each cover profile in meeting the closure objectives for rehabilitation of the TSF.

DRM is in a hot, dry climate with mean annual rainfall < 500 mm and summer temperatures often over 40 °C. However, the climate is highly variable with rainfall over 1000 mm and temperatures dropping to < 5 °C. These extremes require the cover to provide a robust solution to controlling moisture movement into and out of the tailings.

The water balance model for the two different cover scenarios has assumed that the topsoil and ISL are the same for all systems and that the vegetation remains constant. This assumption results in the model predicting similar runoff and transpiration for all cover systems. There are potentially significant differences in the percolation between the cover systems. The HDPE cover is likely to significantly reduce percolation into the tailings to near 0 mm/yr and prevent capillary rise from the tailings into the soil. The SAR cover allowed percolation into the tailings and also allowed capillary rise from the tailings into the soil. Over the longer term, the net percolation was upward suggesting it is likely that the movement of salt into the soil profile in drier years would accumulate in the soil and the percolation in wet years may not be sufficient to leach the salt back into the tailings. Hence there is potential that salts may accumulate and affect the growth of native plant species.

Overall, the cover systems modelled significantly reduce the potential for percolation of rainfall into the tailings. The largest loss of rainfall is via evapotranspiration, with transpiration by plants needed to remove moisture stored in the soil profile during wetter years. The HDPE cover reduced percolation and prevented the upward movement of water and salts from tailings. For the SAR cover, there is increased uncertainty as its performance is more reliant on natural material properties. As such, there is increased potential for higher percolation than predicted and for a net upward movement of salt into the profile. If the SAR cover is the preferred cover, further assessments should be undertaken to more accurately quantify the cover system performance, increase confidence in the chosen approach, and manage these risks. These assessments could include further material sampling and testing campaign and/or cover system trials (laboratory, column or field scale) to improve the knowledge base and refine mitigation strategies. The selection of the cover system will also need to consider the availability of materials, potential impact and rehabilitation of the borrow pit, capital and operating costs and sustainability.

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Appendix N: Landform Conceptual Design – Erosion Modelling

MEMORANDUM

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PROJECT TITLE	Dugald River Mine – TSF Conceptual Closure Design		
SUBJECT	DRM – Landform Conceptual Design – Erosion Modelling		
DATE	27 February 2025	**OUR REF**	240189.M04 Rev0

1 INTRODUCTION

MMG Dugald River Pty Ltd (MMG) is an underground lead and zinc mining operation, located approximately 60 kilometres (km) northwest of Cloncurry in North West Queensland. It is owned and operated by MMG, a wholly owned subsidiary of MMG Australia Limited.

Dugald River Mine (DRM) is authorised by the Department of Environment, Tourism, Science and Innovation (DETSI) under Environmental Authority (EA) EPML00731213 and resides on 40 Mining Leases (ML) and one Mineral Development Lease (MDL).

This memo provides details on the erosion assessment and modelling for the conceptual final landform for the Tailings Storage Facility (TSF).

2 BACKGROUND

MMG proposes to increase the capacity of the TSF by raising the crest height of the main embankment (the Stage 3 embankment raise design concept) **[1]**. This requires a major amendment to the EA, triggering the requirements for updated Progressive Rehabilitation and Closure Plan (PRCP) and PRCP Schedule.

ATC Williams Pty Ltd (ATCW) has been engaged by MMG to develop a conceptual closure design for the TSF. The conceptual closure design must be consistent with the approved PRCP **[2]**, and meet the minimum information requirements in the PRCP Guideline **[3]**. The conceptual closure design includes the landform conceptual design, which involves doing erosion assessment for the closure landform. Development of a Landform Evolution Model (LEM) for the facility has been excluded at this conceptual stage of work.

2.1 Closure Concept

Concept design for the final TSF geometry has been undertaken by ATCW **[4]**. An overview of the closure concept developed is summarised as follows:

Deposition during the operational life of the TSF will be undertaken to optimise the balance between operational requirements and earthworks required to form a suitable surface for closure. Generally, deposition occurs from the north and south extents of the facility, forming the decant area in the centre of the TSF, against the embankment. To form the final surface for closure, reshaping of the tailings beach would be undertaken to form a uniform gradient within the tailings beach, and partially fill the decant area. These reshaping works would be undertaken to form a self-draining landform with shallow slopes on the rehabilitated tailings beach to reduce erosion. The former decant area will be filled and the landform's surface flows report to an outlet structure to the North of the embankment (re-established Stage 2 spillway). The final tailing beach is shown in **DIAGRAM 1** with a section depicting the tailings beach following final deposition and the reshaped tailing beach shown in **DIAGRAM 2**.

Following reshaping of the tailings beach, a cover system will be constructed over the final tailings surface, comprised of site soils won from a borrow area near the TSF and including a reduced-permeability layer (natural materials or synthetic liner).

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The Stage 3 embankment will comprise steep batters (1.5H:1V). For closure, the embankment is proposed to be reprofiled to a 6.5H:1V continuous batter. Reprofiling the embankment will be undertaken by decreasing the embankment height and using excess fill to flatten batters, as shown in **DIAGRAM 3**. The Stage 3 embankment shell will be constructed out of coarse rockfill and would therefore be resistant to erosion.

DIAGRAM 1: CONCEPT CLOSURE FINAL TAILINGS SURFACE (RESHAPE)

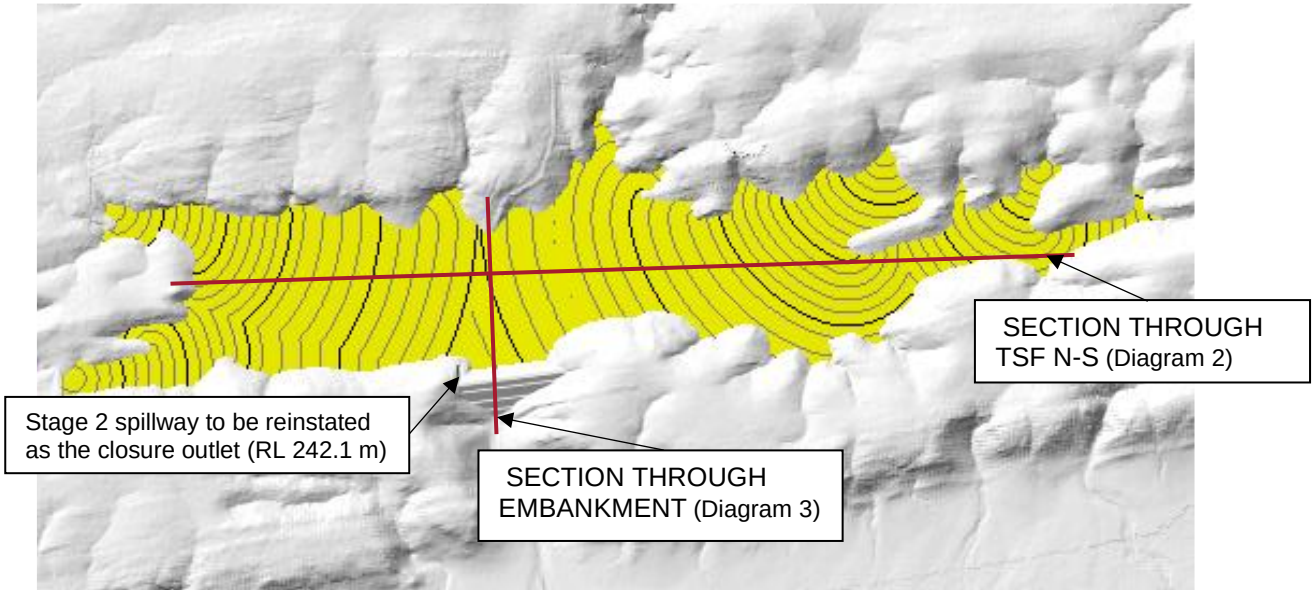

DIAGRAM 2: CONCEPTUAL FINAL TAILINGS SURFACE – SECTION THROUGH TSF N-S

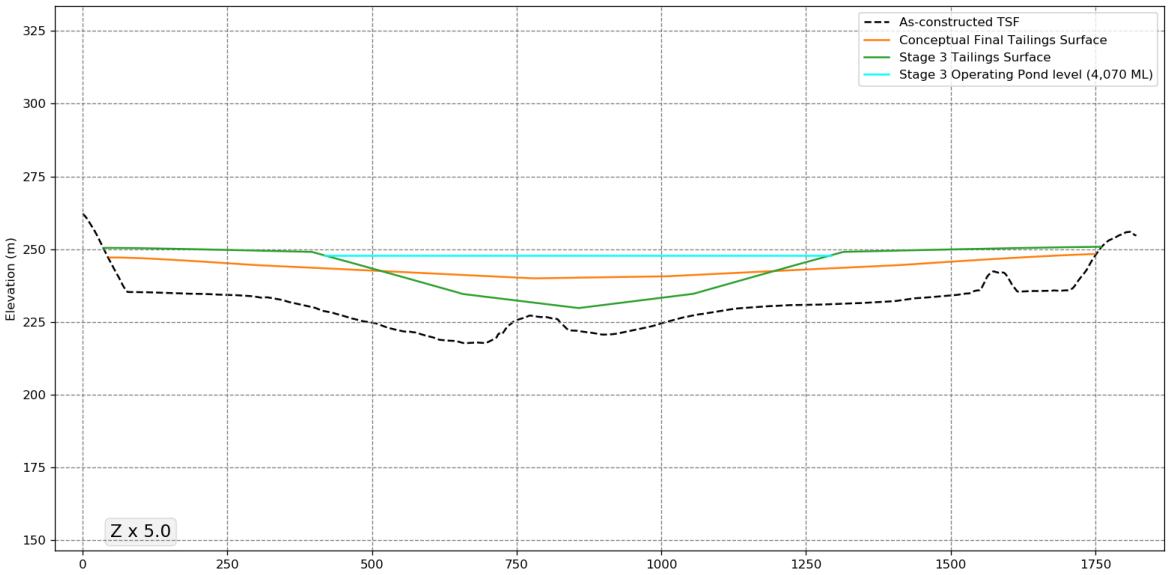

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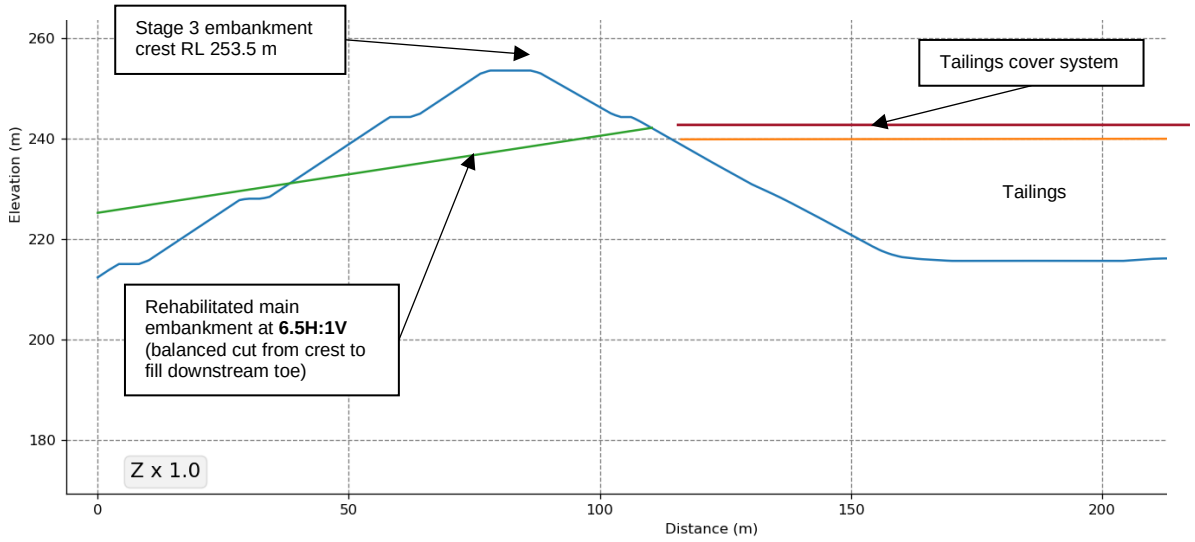
DIAGRAM 3: CONCEPTUAL EMBANKMENT AT CLOSURE – SECTION (FROM DIAGRAM 6 IN [4])



2.2 Closure Performance Objectives - Erosion

The primary objectives for the TSF closure landform with respect to erosion are to:

- Avoid erosion which would impact the performance of the cover system (i.e. through reducing thickness of the cover system and impacting cover system performance).
- Prevent exposure of the underlying tailings.
- Ensure long-term erosional stability of the landform.

The key driver for preventing erosion will be to establish and maintain vegetation over the rehabilitated landform. For the purpose of this assessment, a target soil loss rate of 5 t/ha/yr has been assigned as the maximum average soil loss rate for all years of modelling **[2]**.

2.3 Assessment Methodology

At closure, the surface of tailings beach and the embankment will comprise cover soils and rockfill, respectively. The difference in material at surface warrants different approaches to assess erosion. The methodology adopted to assess erosion for each of these surfaces is summarised as follows:

Tailings beach:	Modelling using Water Erosion Prediction Project (WEPP), as discussed in **Section 3**.
Embankment:	Assessed using flood study results undertaken by ATCW **[10]**, as discussed in **Section 4**.

3 WEPP MODELLING

Average annual erosion rates for the final landform were estimated using the Water Erosion Prediction Project (WEPP) model. The WEPP model is a continuous simulation erosion prediction model developed by the United States Department of Agriculture (USDA). The WEPP model incorporates hydrology, vegetation science, hydraulics, and soil mechanics to simulate the erosion process (both detachment and transport) at a two-dimensional hillslope scale. The purpose of WEPP modelling is to estimate the net soil loss for rehabilitated areas.

3.1 Model Duration

A model duration of 50 years was adopted based on the following:

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- Vegetation is assumed to be established at the beginning of the model start time, as erosion control structures would remain in place until sufficient ground cover is established, nominally to be established by a construction and rehabilitation works completion date. Vegetation coverage is discussed in **Section 3.5**.
- The 50-year period adopted includes years of high and low rainfall, allowing assessment of loss rates for varying climatic conditions.
- A 50-year period allows sufficient time for initial erosional features to develop and to address any required change in erosion management during the post-closure adaptive management period.

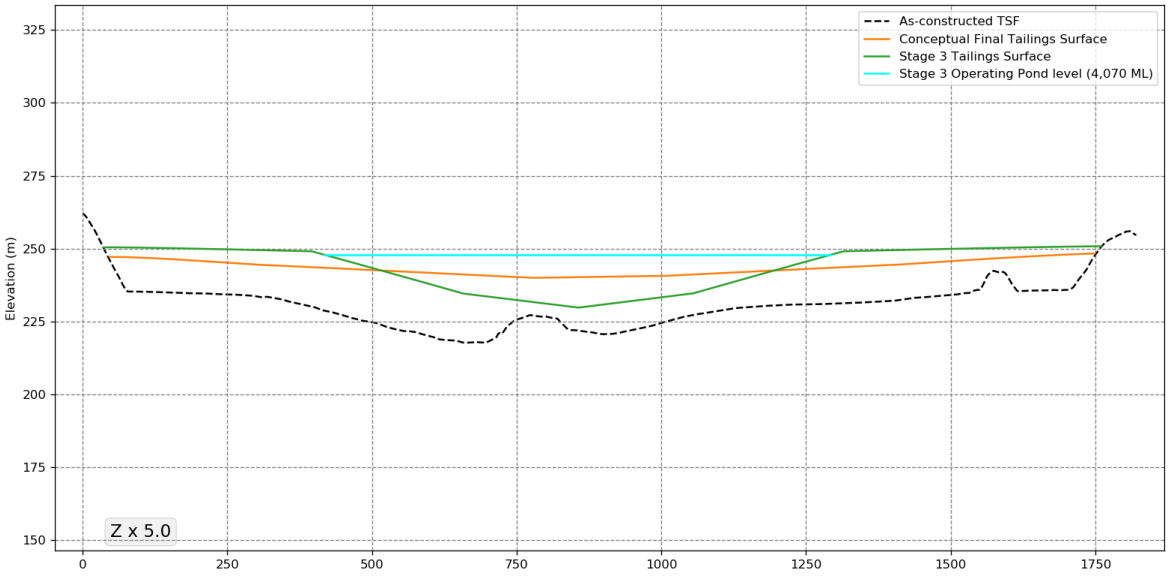
3.2 Geometry

Geometry for the model was adopted from the concept TSF Closure Landform Design **[4],** undertaken by ATCW. As outlined in this report, generally, the final tailings beach slopes are 1.5% for first 500m (top 1/3 of beach), 1% for second 500m (middle 1/3 of beach) and 0.67% for remaining slopes (bottom 1/3 of beach), as shown in **DIAGRAM 4**.

WEPP recommends that flow path lengths do not exceed 100m **[12]**, with potential to overestimate the erosion rates for slope lengths that exceed this distance. For the purpose of the model, a flow path length of 500m at 1.5% was adopted. This flow path is conservative recognising the following:

- WEPP states that erosion is likely to be overestimated for slope lengths greater than 100, therefore results are likely conservative.
- The maximum flow path length is limited to around 500m by surface water drains as discussed in **Section 5**.

DIAGRAM 4: CONCEPT FINAL TAILINGS SURFACE – SECTION (DIAGRAM 6 [4])



3.3 Climate Data

A 50 year synthetic climate file was generated using the CLIGEN stochastic weather generator. Fifty years (1975 to 2024) of patched daily temperature (maximum and minimum) and rainfall data was imported into CLIGEN.

The annual rainfall for the years 1975 to 2024 are shown in **GRAPH 1**. The modelled period includes years of low rainfall (2013, 93.5 mm) and high rainfall (2011, 1,092.4 mm), compared to a mean annual rainfall of 475.6mm.

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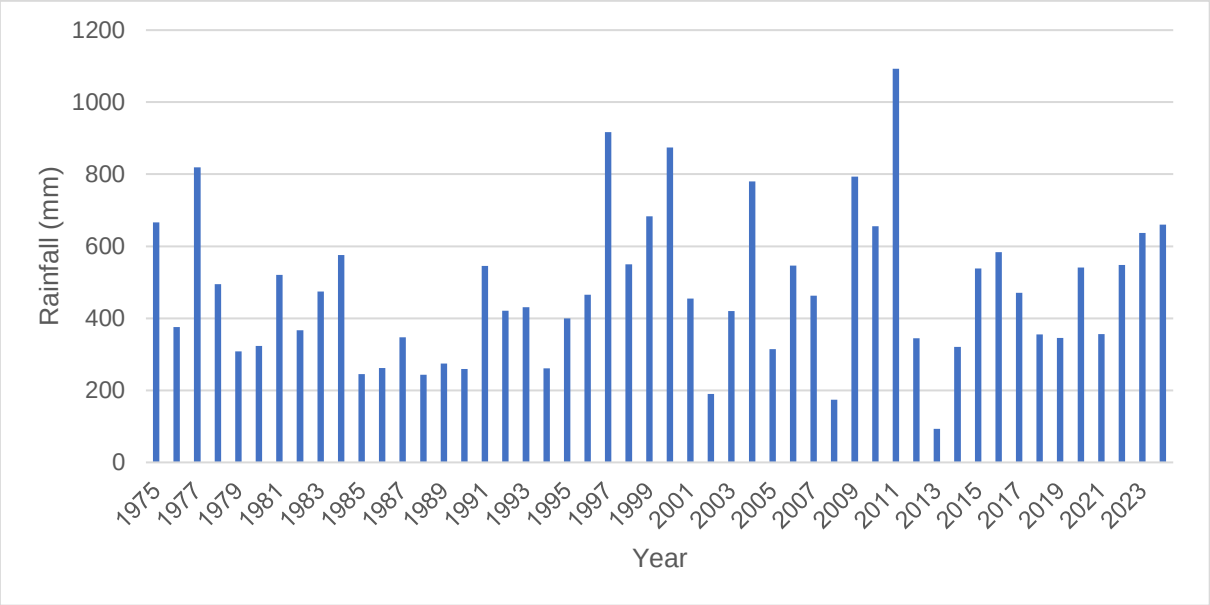
GRAPH 1: ANNUAL RAINFALL



3.4 Soil Input Parameters

WEPP modelling was undertaken prior to receiving the entirety of laboratory results from the 2024 borrow source investigation **[5]**. In the absence of laboratory test data from the borrow source investigation, material parameters were informed by historical investigation for the TSF embankment **[6]** and experience with similar sites. Visually, materials from the previous investigation and the samples obtained from the 2024 **[5]** investigation were similar. Additionally, laboratory results obtained following completion of the modelling, and prior to writing this report further demonstrated consistency, with the permeability results within the same order of magnitude, and PSD results were very similar to the Mix 1 from **[6]** used as the topsoil material.

The Organic Matter and Cation Exchange Capacity has not been previously assessed for site, these were based on known values from materials with similar properties **[12]**.

The soil input parameters adopted in the WEPP model, for the TSF beach slope, are summarised in **TABLE 1**.

TABLE 1: WEPP MODEL SOIL INPUT PARAMETERS

Parameter	Topsoil	Sub-Soil (ISL)
Clay (%)	14	33
Sand (%)	17	18
Rock (%)	69	49
Organic Matter (%)	1.1	0.5
Cation Exchange Capacity (meq/100g)	10	10

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3.5 Vegetation

The Post-Mining Land Use (PMLU) for the site is native ecosystem **[2]**, which will support a range of native grasses and shrubs. The vegetation endemic to the region has a regional ecosystem code of RE 1.11.2a/1.7.7a and RE 1.11.3a/1.3.13a **[7]**. Descriptions of individual regional ecosystems and vegetation communities are shown in **TABLE 2 [8]**.

TABLE 2: REGIONAL ECOSYSTEM CODE DESCRIPTIONS

RE code	Description
1.11.2a	*Eucalpyptus leucophloia* often with *Corymbia spp*., *Terminalia aridicola* and *E. leucophylla* low open woodland
1.7.7a	*Corymbia capricornia* low open woodland on silcrete
1.11.3a	*Eucalyptus leucophylla* low open woodland often with *Corymbia terminalis*, *C. aparrerinja* and *E. leucophloia*
1.3.13a	*Eucalyptus leucophylla* and/or *Corymbia* terminalis woodland on levees and minor drainage lines

The approved PRCP rehabilitation objective for vegetation is to achieve a ground cover 70%. Three vegetation scenarios were used in the WEPP model: no vegetation (0 %) (worst case), 30%, and 70 %. Static vegetation cover was adopted for all scenarios (i.e., vegetation does not grow or die off over the course of the simulation), aligning with the performance criteria. Noting that static vegetation cover may not represent site conditions (e.g., seasonal dieback and extended wet or dry seasons).

It is highlighted that plant parameters are influenced by a wide range of factors including climate conditions, plant species and conditions. No plant specific inputs for the particular species listed in **Table 2** were available, and as such, values were adopted based on similar project experience

3.6 Model Limitations

The following limitations are noted:

- The WEPP model results are based on static (no change in vegetation cover over time), or no vegetation cover as stated in the modelling assumptions. No allowance has been made for seasonal dieback and increased soil loss rates as a result of rainfall after a dry period with reduced vegetation density.
- The WEPP model results are based on a simplified cross section geometry (e.g. 500 m slope at 1.5 %). Localised erosion rates are likely to occur which exceed the average annual soil loss rates presented, which represent the annual average soil loss rates for the entire slope length.
- Some material parameters used are not based on site specific data, as described in Section 3.4. Variation to soil properties would impact the WEPP model outcomes (percentages of clay, sand and rock, organic matter and cation exchange capacity).

3.7 Results and Discussion

The primary output from WEPP is the estimated soil loss rate expressed in tonnes per hectare per year (t/ha/yr). The objective is to achieve an average soil loss rate of less than 5 t/ha/yr. The average annual soil loss rates predicted by the WEPP model are summarised in **TABLE 3**.

Results indicated that for the TSF beach slope, with 70% vegetation cover, the soil loss rates were 1.11 t/ha/yr, which is less than a quarter of the target soil loss rate. At 30% cover, the soil loss rates were 3.89 t/ha/yr, which still achieves the target loss rate. At the worst case scenario of 0% cover, the soil loss rates were 12.7 t/ha/yr, which does not achieve the target soil loss rate.

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Results indicate while acceptable erosion rates can be achieved with proposed final landform, vegetation will be critical to successful rehabilitation

TABLE 3: TSF BEACH SLOPE AVERAGE ANNUAL SOIL LOSS

70 % Vegetation Cover	30 % Vegetation Cover	0 % No Vegetation Cover
1.11	3.89	12.70

4 TSF EMBANKMENT

As outlined in **Section 2.1**, rehabilitation of the embankment will comprise flattening the batter from 1.5H:1V to 6.5H:1V, undertaken by pushing excess fill material from the crest of the embankment to fill the downstream toe of the embankment. **Table 4** summarises the specification for embankment zone 3B fill for the Stage 1 embankment fill.

TABLE 4: ZONE 3B – ACCEPTABLE RANGE OF PARTICLE SIZE DISTRIBUTION (FROM TABLE 8.5 IN [11])

Particle Size (mm)	Zone 3B
800	100
400	100 – 55
150	55 – 10
100	–
26.5	45 – 0
19.0	35 – 0
4.75	15 – 0
0.075	10 – 0

A hydraulic assessment has been undertaken by ATCW **[10]**, which indicates flow velocity on the embankment would range from 1.5m/s at the crest to 2.1m/s at the toe of the embankment. Recommended D50 rock sizing for this range of flow velocities range from 150mm to 300mm. These particle sizes are generally in accordance with the upper and lower bounds of the zone 3B material specification. Notwithstanding, careful consideration during earthworks would be required to preferentially place the larger particles towards the base of the embankment, where flow velocities are higher.

It is highlighted that the ATCW study was primarily focused on the TSF beach and is considered conservative with respect to flow velocities on the embankment. A relatively low manning's value for the embankment surface (0.035) was adopted considering the surface would comprise rockfill with D50 ranging from 150mm to 300mm.

5 WATER MANAGEMENT

Erosion modelling indicated very low erosion rates on the TSF. Notwithstanding, the external catchment to the TSF has multiple, natural gullys reporting to the TSF. Natural gullys would introduce concentrated flows to the rehabilitated tailings surface, likely to cause localised erosion and scour. To reduce the risk of erosion and scour, a network of surface channels is proposed to convey flows from the upstream catchments to the discharge outlet structure.

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The proposed conceptual general arrangement for the final drainage of the TSF is shown in **Diagram 5**. The drainage channels shown are conceptual only, intended to allow for the capture of runoff from upstream external catchment sources, rather than incidental rainfall on the TSF itself. The TSF closure surface was modelled to incorporate the shedding surface to convey runoff from the upstream connected catchments towards the repurposed Stage 2 emergency spillway **[10].** As part of detailed design, the surface will be modelled with the conceptual drainage channels to ensure there is no ponding on the TSF surface post closure to reduce the potential for seepage in channels with low to no longitudinal grade.

The channel dimensions are to maintain low velocity by maximising channel width (compared to depth). The channel is to be rock lined with a geotextile underlay, as shown in **Diagram 6**. The drains will be designed to convey peak flows to a suitable design event.

DIAGRAM 5: CONCEPTUAL SURFACE WATER DRAINAGE

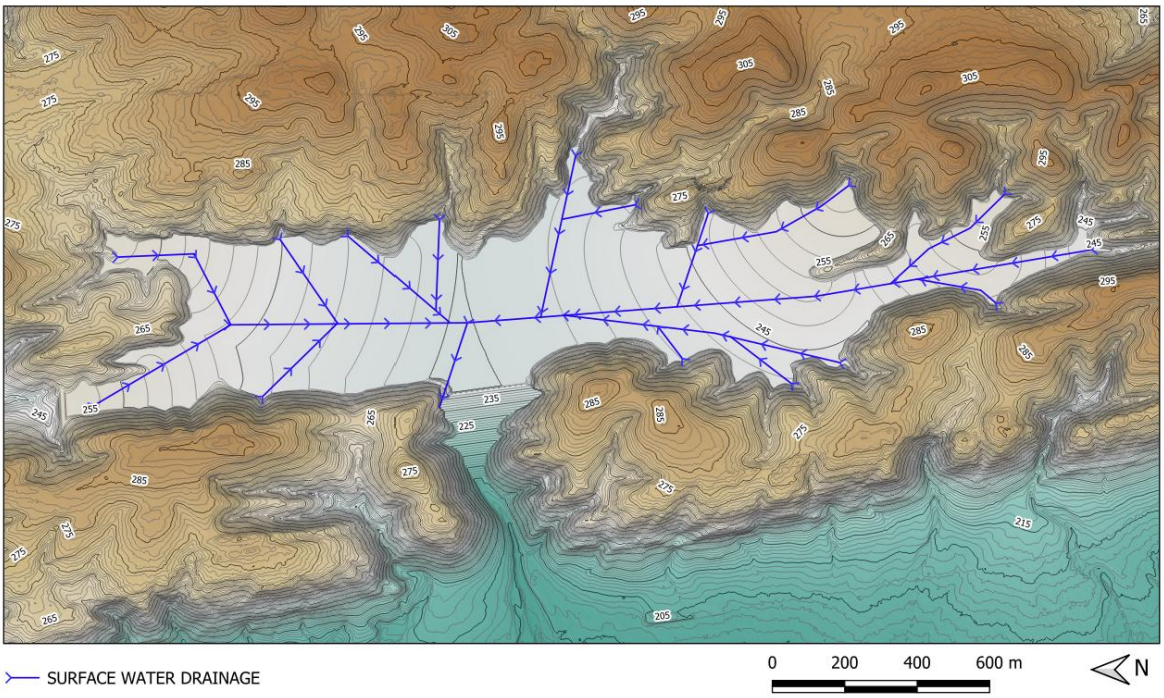
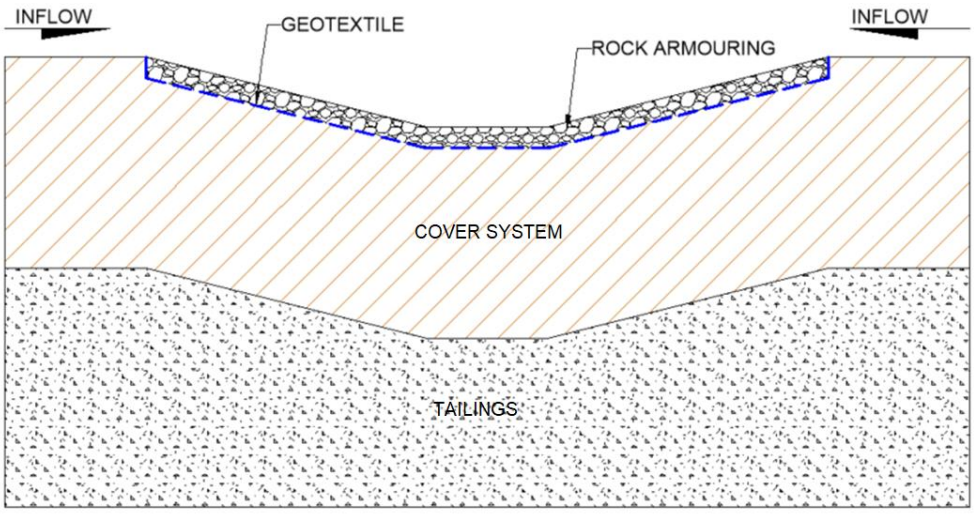


DIAGRAM 6: DRAIN CONCEPT SECTION



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6 CONCLUSION

The WEPP erosion modelling conducted as part of the conceptual closure design for the Tailings Storage Facility (TSF) provides important insights into the long-term stability and sustainability of the final landform. WEPP modelling was conducted for the rehabilitated tailings surface.

The key findings from the WEPP modelling include:

- A 50-year model duration was adopted, which captures high and low rainfall periods and allows sufficient time for initial erosional features to develop.
- The modelling was based on a conservative flow path length of 500 m at a 1.5% slope, recognizing that WEPP tends to overestimate erosion for slope lengths greater than 100 m.
- WEPP modelling indicates that the conceptual closure design can achieve long-term stability, with average annual soil loss rates estimated to be within acceptable limits.
- Identified limitations highlight the need for further detailed design and site-specific data collection to refine the erosion assessment and closure plan.
- Ongoing monitoring and adaptive management will also be critical to ensure the long-term sustainability of the final TSF landform.

Embankment erosion was assessed using flood study results undertaken by ATCW, as discussed in Section 4. This assessment was focused on the embankment surface, which will comprise coarse rockfill that is resistant to erosion. The flood study results were considered conservative with respect to flow velocities on the embankment and resulted in a recommended rockfill surface with a D50 ranging from 150-300 mm.

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[10] ATCW (2025), ‘Dugald River Mine – Final Landform Assessment - TSF and Process Area Hydraulic Impact Assessment’ Ref:240288, 7 February 2025.

[11] Catchments and Creeks, 2023. https://catchmentsandcreeks.com.au/wp-content/uploads/2023/10/Background-To-Rock-Sizing-Equations.pdf

[12] Water Erosion Prediction Project (WEPP) Version 95.7 User Summary

Appendix O: Proposed Changes to PRCP Schedule

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
RA1	RM1	The commencement date for RM1 changed from 2048 to 2044.	Changes to the DRM mine plan have resulted in the life of mine (LoM) being reached by 2043, compared to previous mine planning which nominated 2047. Mine planning remains ongoing and potential future extensions continue to be investigated. RA1 is therefore available for rehabilitation in 2044, immediately after the cessation of the LoM.	N/A	N/A
	RM2	The commencement date for RM2 changed from 2050 to 2046.	RM2 to RM14 have been brought forward, as a result of RM1 commencing earlier.	N/A	N/A
	RM3	The commencement date for RM3 changed from 2050 to 2046.	RM2 to RM14 have been brought forward, as a result of RM1 commencing earlier.	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
	RM9	The commencement date for RM9 changed from 2050 to 2046.	RM2 to RM14 have been brought forward, as a result of RM1 commencing earlier.	Topsoil application depth changed from a minimum of 0.2 m to a range of 0.1 m – 0.2 m.	The previously approved planning part of the PRCP nominated application of topsoil at a depth of 0.1 m – 0.2 m. The previous PRCP and schedule were inconsistent. The application of 0.1 – 0.2 m topsoil is supported by information presented in PRCP Section 3.5.6.5 and the TSF Closure Plan.
	RM10	The commencement date for RM10 changed from 2051 to 2047.	RM2 to RM14 have been brought forward, as a result of RM1 commencing earlier.	N/A	N/A
	RM12	The commencement date for RM12 changed from 2053 to 2049.	RM2 to RM14 have been brought forward, as a result of RM1 commencing earlier.	Sub criteria (b) was amended to be an *"Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y",*	The erosion target was changed to be consistent with industry best practice. The addition to the MC will provide improved environmental outcomes. It does

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
				compared to the previously approved *"Average erosion rate <5 t/ha/yr".* Sub criteria (l), previously approved in the PRCP schedule was removed in the amended PRCP. In this NPM response, the criteria have been reintroduced to RM12.	not change any rehabilitation method previously proposed. The criteria were deemed to be superfluous and a duplication of the other seepage rate criteria. It has been added back into this revised schedule, for completeness.
	RM14	The commencement date for RM14 changed from 2059 to 2055.	RM2 to RM14 have been brought forward, as a result of RM1 commencing earlier. 15 years is allowed for the achievement of the native ecosystem PMLU, from seeding. This is	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
			consistent with the previous schedule.		
RA2	RM1	Area for RA2 has increased from 38.88 to 43.84. This has been carried through to all subsequent RMs.	The area change is in relation to additional borrow pits required for the TSF and PAF waste pad expansion.	N/A	N/A
	RM4	N/A	There has been no change to this commencement date in this application. RA2 is available to commence rehabilitation in 2050. Rehabilitation of the borrow pits (RA2) will commence after material has been exhausted for capping of the TSF.	N/A	N/A
	RM9	N/A	N/A	Topsoil application depth changed from a minimum of 0.2 m to a range of 0.1 m – 0.2 m.	The previously approved planning part nominated application of topsoil at a depth of 0.1 m – 0.2

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
					m. The previous PRCP and schedule were inconsistent. The application of 0.1 – 0.2 m topsoil is supported by information presented in PRCP Section 3.5.6.5 and the TSF Closure Plan.
	RM11	N/A	N/A	N/A	N/A
	RM13	The application proposed the period be changed from 5 years to 4 years. In this NPM response, the period has reverted to 5 years.	The period allowed for RM13 was changed erroneously. These periods have now reverted to the approved periods (5 years) in the previous PRCP schedule.	Sub criteria (c) was amended to be an *"Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y"*, compared to the previously approved *"Average erosion rate <5 t/ha/yr".*	The erosion target was changed to be consistent with industry best practice. The addition to the MC will provide improved environmental outcomes. It does not change any rehabilitation method previously proposed.

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
	RM15	The application proposed the period be changed from 5 years to 6 years. In this NPM response, the period has reverted to 5 years.	The period allowed for RM15 was change erroneously. These periods have now reverted to the approved periods in the previous PRCP schedule. 10 years is allowed for the achievement of the low intensity grazing PMLU, from seeding. This is consistent with the previous schedule.	N/A	N/A
RA3	RM1	The commencement date for RM1 changed from 2048 to 2051.	In the previous schedule, rehabilitation of RA3 and RA4 were scheduled to commence concurrently. For best practice management of contaminants, RA3 (runoff dams and diversions) will be retained until the WRDs (RA4) have stabilised. WRDs are scheduled to be removed by 2050. RA3 will commence rehabilitation immediately	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
		The period for achieving the RM reduced from 2 years to 1 year.	following, in 2051. This change to the schedule is proposed to allow capture of sediments and potential contaminants from the WRDs, leading to better environmental outcomes. Given the area within RA3 has reduced from 41.6 ha to 32.29 ha, less time has been allocated to complete RM1.		
	RM2	The commencement date for RM2 changed from 2048 to 2049.	In the previous schedule, rehabilitation of RA3 and RA4 were scheduled to commence concurrently. For best practice management of contaminants, RA3 (runoff dams and diversions) will be retained until the WRDs (RA4) have stabilised. WRDs are scheduled to be removed by 2050. RA3 will commence rehabilitation immediately	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
		The period to achieve the RM reduced from 2 years to 1 year	following, in 2051. This change to the schedule is proposed to allow capture of sediments and potential contaminants from the WRDs, leading to better environmental outcomes. Given the area within RA3 has reduced from 41.6 ha to 32.29 ha, less time has been allocated to complete RM2.		
	RM5	The commencement date for RM5 changed from 2050 to 2052.	The commencement date of this RM has been delayed, as a result of RM1 commencing earlier.	N/A	N/A
	RM9	The commencement date for RM9 changed from 2050 to 2052.	The commencement date of this RM has been delayed, as a result of RM1 commencing earlier.	Topsoil application depth changed from a minimum of 0.2 m to a range of 0.1 m – 0.2 m.	The previously approved planning part nominated application of topsoil at a depth of 0.1 m – 0.2 m. The previous PRCP and schedule were inconsistent.

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
					The application of 0.1 – 0.2 m topsoil is supported by information presented in PRCP Section 3.5.6.5 and the TSF Closure Plan.
	RM11	The commencement date for RM11 changed from 2055 to 2057. An additional change is proposed in this NPM response. The previously approved period to achieve RM was 3 years. This has been revised to 1 year.	The commencement date of this RM has been delayed, as a result of RM1 commencing earlier. RM11 has been reduced to 1 year as a more practical timeframe. MMG has committed to completing all works for the RM within 1 year. This period is consistent with RM11 being applied for other RA's.	N/A	N/A
	RM13	The commencement date for RM9 changed from 2058 to 2060. Further changes have since been applied,	The commencement date of this RM has been delayed, as a result of RM1 commencing earlier.	Sub criteria (c) was amended to be an *"Average erosion rate of <5 t/ha/y with the maximum erosion rate at*	The erosion target was changed to be consistent with industry best practice. The addition to the MC will provide improved environmental outcomes. It does

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
		taking the commencement date back to 2058.	Changes to the preceding RM11 period have resulted in this now reverting to 2058.	*any point on the landform of <10 t/ha/y"*, compared to the previously approved *"Average erosion rate <5 t/ha/yr".*	not change any rehabilitation method previously proposed.
	RM15	The application originally proposed a changed of the commencement date from 2063 to 2065. Further changes have since been applied, taking the commencement date back to 2063.	The commencement date of this RM has been delayed, as a result of RM1 commencing earlier. Changes to the RM11 period have resulted in this now reverting to 2063.	N/A	N/A
RA4	RM2	The area for RA4 has increased from 22.40 to 22.56. This has been	The area increase is related to a small increased area for the PAF WRD, based on detailed designs.	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
		carried through to subsequent RMs. There is no change to the commencement date for this RA. The period to complete this RM has increased from 1 year to 3 years.	Material within RA4 (NAF waste rock) will be utilised for the capping of the TSF. Modelling completed for the revised TSF closure plan, calculated that the surface of the TSF will complete drying and be trafficable by 2047. Waste rock can then be placed from 2048, allowing commencement of RA4 in 2048. The revised TSF Closure Plan identified that the application of the cover system will require 3 years. This time was not accounted for in the previous schedule. RM2 for RA4 has increased to 3 years to allow material to be removed from the WRDs and applied to the TSF cover system.		

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
	RM6	The commencement date changed from 2049 to 2051. The application proposed a 3-year period for this RM. In this NPM response, the period has reverted to 1 year.	The commencement date was delayed due to the extended period for RM2. The period allowed for RM6 was change erroneously. This period has now reverted to the approved period (1 year) in the previous PRCP schedule.	N/A	N/A
	RM9	The commencement date changed from 2049 to 2051. The application proposed a 3-year period for this RM. In this NPM response, the period has reverted to 1 year.	The commencement date was delayed due to the extended period for RM2. The period allowed for RM9 was change erroneously. This period has now reverted to the approved period in the previous PRCP schedule (1 year).	Topsoil application depth changed from a minimum of 0.2 m to a range of 0.1 m – 0.2 m.	The previously approved planning part nominated application of topsoil at a depth of 0.1 m – 0.2 m. The previous PRCP and schedule were inconsistent. The application of 0.1 – 0.2 m topsoil is supported by information presented in PRCP Section 3.5.6.5 and the TSF Closure Plan.

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
	RM11	The commencement date changed from 2050 to 2052. The period was changed from 3 years to 1 year.	The commencement date changed due to the extended period for RM2 and the change in period for RM6 and RM9. RM11 has been reduced to one year as a more practical timeframe. MMG has committed to completing all works for the RM within 1 year. This is consistent with the period for RM11 applied to other RA's.	N/A	N/A
	RM13	N/A	N/A	Sub criteria (c) was amended to be an *"Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y",* compared to the previously approved	The erosion target was changed to be consistent with industry best practice. The addition to the MC will provide improved environmental outcomes. It does not change any rehabilitation method previously proposed.

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
				"Average erosion rate <5 t/ha/yr".	
	RM15	N/A	N/A	N/A	N/A
RA5	RM1	The area for RA5 has increased from 180.53 to 180.78. This has been carried through to subsequent RMs. The commencement date changed from 2048 to 2044. The split between areas available for commencement of RM1 changed from 134.98 ha	The increase in area relates to a small refinement of roads and tracks due to the PAF WRD and TSF expansion. Changes to the DRM mine plan have resulted in the LoM being reached by 2043, compared to previous mine planning which nominated 2047. Mine planning remains ongoing and potential future extensions continue to be investigated. RA1 is therefore available for rehabilitation in 2044, immediately after the cessation of the LoM. The split between areas available in 2045 and 2047 was reviewed in	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
		and 73.18 ha to 124.2 ha and 86.58 ha, respectively.	consideration of revised disturbance areas proposed in the application. The ROM, ROM haul roads, processing plant and conveyor area and powerlines (86.58 ha), will be retained until 2045 to allow processing of any residual ore after closure. Rehabilitation of these area will commence in 2046.		
	RM2	The commencement date changed from 2048 to 2044.	RM2 to RM15 have been brought forward, as a result of RM1 commencing earlier.	N/A	N/A
	RM6	The commencement date changed from 2048 to 2044.	RM2 to RM15 have been brought forward, as a result of RM1 commencing earlier.	N/A	N/A
	RM9	The commencement date changed from 2049 to 2045.	RM2 to RM15 have been brought forward, as a result of RM1 commencing earlier.	Topsoil application depth changed from a minimum of 0.2 m to a range of 0.1 m – 0.2 m.	The previously approved planning part nominated application of topsoil at a depth of 0.1 m – 0.2

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
					m. The previous PRCP and schedule were inconsistent. The application of 0.1 – 0.2 m topsoil is supported by information presented in PRCP Section 3.5.6.5 and the TSF Closure Plan.
	RM11	The commencement date changed from 2049 to 2045. The period to achieve RM11 was reduced from 3 years to 1 year.	RM2 to RM15 have been brought forward, as a result of RM1 commencing earlier. RM11 has been reduced to one year as a more practical timeframe. MMG has committed to completing all works for the RM within 1 year. This is consistent with RM11 applied to other RA's.	N/A	N/A
	RM13	The commencement date changed from 2050 to 2046.	RM2 to RM15 have been brought forward, as a result of RM1 commencing earlier.	Sub criteria (c) was amended to be an *"Average erosion rate of <5 t/ha/y with the*	The erosion target was changed to be consistent with industry best practice. The addition to the MC will provide improved

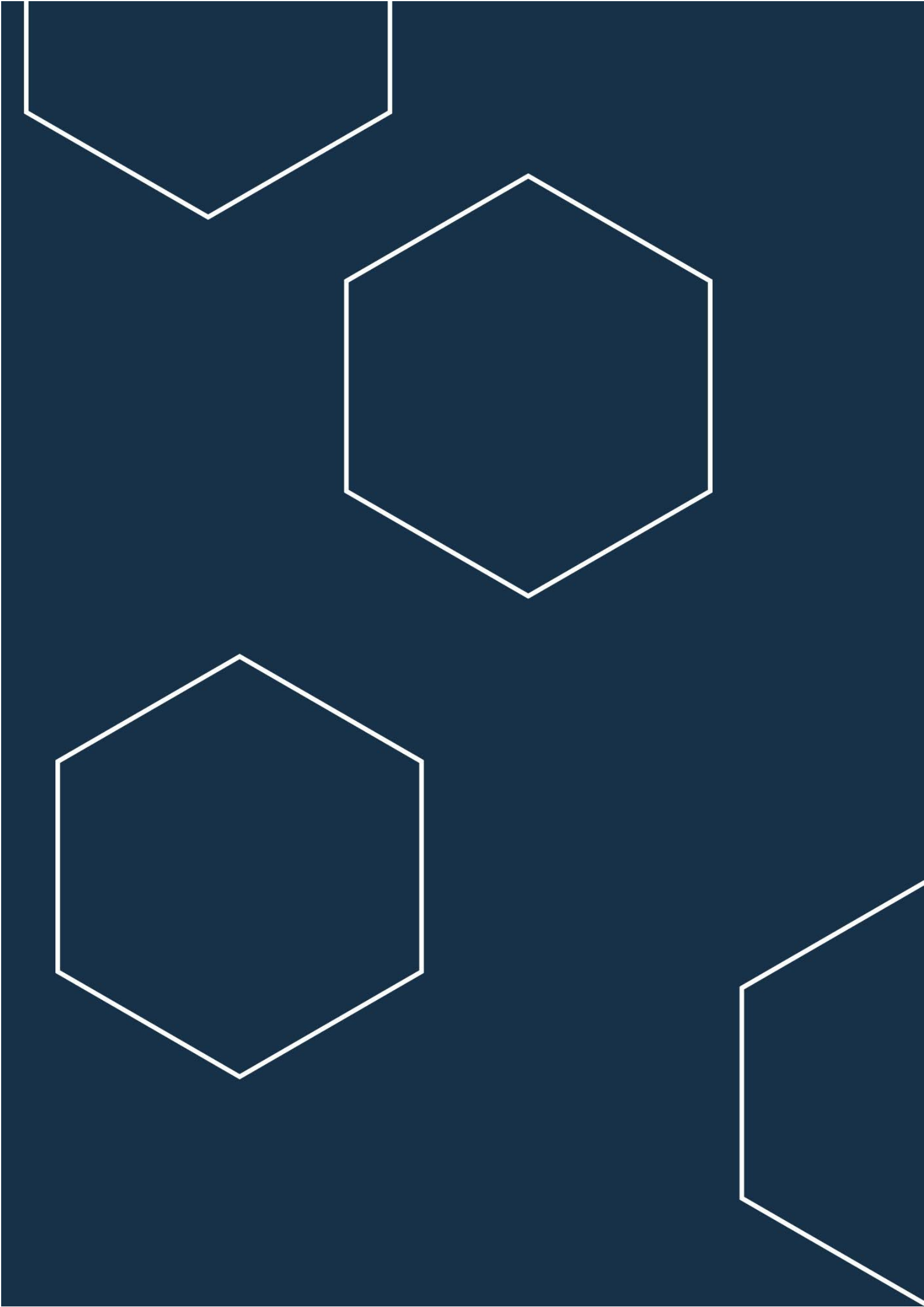
Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
		The period to achieve RM13 changed from 3 years to 5 years.	The period to achieve RM13 changed from 3 years to 5 years to allow one round of major monitoring (every 5 years) to verify achievement of the RM. This is consistent with the period for RM13 applied to other RA's.	*maximum erosion rate at any point on the landform of <10 t/ha/y",* compared to the previously approved *"Average erosion rate <5 t/ha/yr".*	environmental outcomes. It does not change any rehabilitation method previously proposed.
	RM15	The commencement date changed from 2056 to 2051. The application proposed a changed period from 5 years to 10 years. This NPM response reverts the period back to 5 years.	RM2 to RM15 have been brought forward, as a result of RM1 commencing earlier. The period was changed erroneously. This has now been resolved and reverted to 5 years as per the approved schedule. 10 years is allowed for the achievement of the low intensity grazing PMLU, from seeding. This is consistent with the previous schedule.	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
RA6	RM1	The area for RA6 increased from 107.83 ha to 109.88 ha. This was carried through to subsequent RMs. The commencement date changed from 2048 to 2044. The period to complete RM changed from 1 year to 4 years.	The area increase is due to the proposed expansion of the TSF. Changes to the DRM mine plan have resulted in the LoM being reached by 2043, compared to the previous mine planning which nominated 2047. Mine planning remains ongoing and potential future extensions continue to be investigated. RA5 is available for rehabilitation in 2044, immediately after the cessation of the LoM The revised closure landform design for the TSF, modelled that drying of tailings would require four years. This period was not accounted for in the previous schedule. There is no change to the rehabilitation methods.	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
	RM7	The commencement date changed from 2049 to 2048. The period to achieve the RM changed from 1 year to 3 years.	RM2 has been brought forward, as a result of RM1 commencing earlier and the change in period for RM1. The closure plan determined that application of the TSF cover system would require 3 years. This period was not accounted for in the previous schedule. There is no change to the rehabilitation methods.	Sub criteria (i) changed from slopes with a grade of 1% to slopes with a grade of <1.5%. The spillway criteria in sub criteria (k) changed from defining slope and length details to defining a RL for placement. The slope and length details have been reinstated in this revised submission. Sub criteria (o) changed erroneously. This has reverted to the previously approved criteria in the PRCP schedule. Sub criteria (p) was amended to *"Average erosion rate of <5 t/ha/y*	A revised closure design was developed for the TSF regarding the proposed TSF lift in the application. Detailed work has been completed to determine the most appropriate surface slope and spillway for closure regarding surface water management and erosion risk. This is explained in extensive detail in Appendix E of the PRCP.

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
				with the maximum erosion rate at any point on the landform of <10 t/ha/y", compared to the previously approved *"Average erosion rate <5 t/ha/yr".*	The erosion target was changed to be consistent with industry best practice. It provide another milestone to achieve, but does not limit the current target.
	RM9	The commencement date changed from 2050 to 2051. The application proposed a change in period from 2 years to 1 years. This NPM response has reverted this period back to 2 years.	The commencement date of this RM changed as a result of the previous changed to preceding RMs. The period allowed for RM9 was change erroneously. This period has now reverted to the approved period in the previous PRCP schedule.	Topsoil application depth changed from a minimum of 0.2 m to a range of 0.1 m – 0.2 m.	The previously approved planning part nominated application of topsoil at a depth of 0.1 m – 0.2 m. The previous PRCP and schedule were inconsistent. The application of 0.1 – 0.2 m topsoil is supported by information presented in PRCP Section 3.5.6.5 and the TSF Closure Plan.

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
	RM10	Commencement date changed from 2050 to 2051. The application proposed a change in period from 2 years to 1 years. This NPM response has reverted this period back to 2 years.	The commencement date of this RM changed as a result of the previous changed to preceding RMs. The period allowed for RM9 was change erroneously. This period has now reverted to the approved period in the previous PRCP schedule.	N/A	N/A
	RM12	N/A	N/A	Sub criteria (b) was amended to be an *"Average erosion rate of <5 t/ha/y with the maximum erosion rate at any point on the landform of <10 t/ha/y"*, compared to the previously approved	The erosion target was changed to be consistent with industry best practice. The addition to the MC will provide improved environmental outcomes. It does not change any rehabilitation method previously proposed.

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
				"Average erosion rate <5 t/ha/yr". Sub criteria (l), previously approved in the PRCP schedule was removed in the amended PRCP. In this NPM response, the criteria has been reintroduced to RM12.	The criteria was deemed to be superfluous and a duplication of the other seepage rate criteria. It has been added back into this revised schedule, for completeness.
	RM14	N/A	N/A	N/A	N/A
RA7	RM1	The area for RA7 decreased from 67.1 to 67.07. This was carried through to subsequent RMs.	The change was a result of a refinement of roads and tracks on the Knapdale Range, as a result of the TSF expansion.	N/A	N/A
	RM2	N/A	N/A	N/A	N/A
	RM8	N/A	N/A	N/A	N/A
	RM9	N/A	N/A	N/A	N/A

Rehabilitation Area (RA)	Rehabilitation Milestone (RM)	Proposed change to schedule	Justification	Proposed change to milestone criteria	Justification
	RM10	N/A	N/A	N/A	N/A
	RM12	N/A	N/A	N/A	N/A
	RM14	N/A	N/A	N/A	N/A