The geotextile shall be covered within 1 month of being deployed in the Works to prevent ultraviolet (UV) damage to the geotextile.

The geotextile shall have minimum property values specified in the **Table 5.3**, unless otherwise approved by the Design Engineer. It shall be noted that these minimum values have been adopted from Geofabrics Australasia Pty Ltd Bidim A64G-M non-woven geotextile range. Appropriate roll width shall be ordered to minimise cutting of the Geotextile.

TABLE 5.3: NAF ROCK ARMOUR PARTICLE SIZE REQUIREMENTS

Property	Units	Minimum Average Roll Value (MARV)	Test
CBR Burst Strength	N	6,400	AS 3706.4
Wide Strip Tensile Strength (MD/XD)	kN/m	37.5	AS 3706.2
Grab Tensile Strength (MD/XD)	N	2,620	AS 3706.2
Pore size O_{95}	micron	75	AS 3706.7
Flow rate (100 mm head)	$L/m^2/s$	90	AS 3706.9

6 BORROW AND STOCKPILE MANAGEMENT

6.1 Borrow Area Development

Stage 4 Works will require borrow area development and management to excavate Type 2 materials to form the required PAF Pad, perimeter drains, to the lines and levels shown in the Drawings. The designated borrow sources for Type 2 materials required for the PAF Pad construction are located South and Southeast of the NAF WRD. The Contractor shall liaise with the Principal to prepare and submit a brief Borrow Management Plan in accordance with the requirements and to the satisfaction of the Principal.

Borrow activities exclude any material sourced from temporary stockpiles or areas excavated at the Contractor's discretion for purposes such as work area access or disposal of excess material.

Type 2 materials won from excavation deemed suitable for use in the Works shall be used in appropriate region per the construction drawings. Where these materials are deemed not suitable for use in the Works, they shall be classified as "Spoil" and disposed of in accordance with **Clause 3.3** of this Specification. No material won from the excavation shall be used in the Works without the approval of the Superintendent.

Appropriate measures shall be implemented to maintain the integrity of the underlying material within the borrow area. The area shall remain free of standing or flowing water, mud, debris, or other contaminants that could compromise material quality. At all times borrow area development within the borrow area shall be to the satisfaction of the Superintendent.

Upon completion of material extraction for the current stage of Works, the borrow area shall be remediated in line with any MMG's borrow management and rehabilitation requirements.

6.2 Stockpile Management

The Contractor shall be responsible for the efficient management of all stockpiles available and prepared for use within the Works. Stockpile areas shall be stripped of vegetation and graded so that they are generally free draining, uniform and planar.

Any stockpiled Type 2 capping materials which becomes contaminated with rockfill or other materials shall be excluded from uses in construction unless approved by the Superintendent or Site Engineer.

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Type 2 capping material stockpiles shall be moisture conditioned and cured at least 24 hours prior to use in construction activities in accordance with **Clause 8.1.5** of this Specification.

All stockpiles shall be used in such a way as to prevent suitable material being rendered unsuitable due to flooding, construction traffic, or contamination with organic or other deleterious material.

6.3 Source of Materials

The anticipated sources of earthwork construction materials are presented in **Table 6.1**.

TABLE 6.1: ANTICIPATED SOURCES OF CONSTRUCTION MATERIALS

Material	Anticipated Source
Type 2 Capping	Excavation from approved borrow area(s) located South of NAF WRD.
PAF Rockfill	PAF WRD Approved mine waste rock stockpiles as directed by the Superintendent (when required).
NAF Rockfill / NAF Rock Armour	NAF WRD Approved mine waste rock stockpiles as directed by the Superintendent (when required).
Crushed NAF Rockfill	NAF WRD Crushed to produce materials with maximum particle size of 50 mm.

7 CONSTRUCTION REQUIREMENTS

7.1 General Requirements

The PAF Pad shall be constructed such that appropriate safety bunds are maintained at all times during construction. The Contractor should allow for over-placement and compaction of the fill materials, with subsequent trimming back to the specified lines and levels, to ensure the specified compacted dimensions, as detailed on the Drawings, are achieved.

7.2 Construction Tolerances

The PAF Pad fill, excavation, perimeter drains and other associated works shall be constructed to the lines, grades, dimensions and details shown on the Drawings. Finished work shall comply with the tolerances set out in **Table 7.1.**

Tolerances specified are for the purpose only of determining acceptability or otherwise of the finished work. They shall mean that if a dimension is checked at a particular location, the work is acceptable provided that the dimension departs from that shown on the Drawings by no more than the amount specified. They shall not be read to imply any basis for payment other than the design dimensions or levels shown on the Drawings. The average dimension of all measurements of individual items shall be not less than that shown on the Drawings.

Tolerances on slopes are assumed that slopes are specified in the format 1 vertical to X horizontal. The tolerance shall be applicable to X.

TABLE 7.1: CONSTRUCTION TOLERANCES

Structure	Item	Tolerance
Excavations	Existing Drainage Excavation	+ 50 mm, - 0 mm
	Excavation Slopes	+ or – 5% of specified

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Structure	Item	Tolerance
PAF Pad Fill	Final Type 2 Material Surface Levels	+ 100 mm, - 0 mm
	Batter Slopes	+ or – 5% of specified
Materials	Type 2 Material Thickness	+ 100 mm, - 0 mm
	PAF/NAF Rockfill Thickness	+ 100 mm, - 100 mm
	Crushed NAF Rockfill Thickness	+ or – 50 mm
	Rock Armour NAF Rockfill Thickness	+ 100 mm, - 50 mm
Drainage	Base Width	+ 100 mm, - 50 mm
	Vertical Alignment	+ 50 mm, - 50 mm
	Batter Slopes	+ or – 5% of specified

8 PLACEMENT OF FILL MATERIALS

8.1 Type 2 Capping Materials

8.1.1 Placement

Type 2 capping materials shall be placed such that:

1. Placement in horizontal layers which are longitudinally and transversely continuous. Layers shall be of a uniform thickness, as specified in **Table 8.1**, and shall be compacted in a continuous direction. Where Type 2 capping material is placed within the drains, the layer shall follow the slope of the drain profile.
2. Before placing fill, the surface of the previously compacted layer (including existing Type 2 materials) shall be lightly scarified to a depth of 50 mm. If the surface has dried out and/or cracked, it shall be tyned to 50 mm below the depth of drying or cracking, then moisture conditioned and reworked. Fill shall not be placed on a surface on which free water has ponded.
3. At the completion of each day's work, or if adverse weather conditions are imminent, and the Contractor intends to suspend operations, the surface shall be graded to a self-shedding profile and sealed with a smooth drum roller. The smoothed surface should be tyned and moisture conditioned, if necessary, prior to the placement of material once operations resume.

Where Type 2 capping material intersects with the NAF rock armour, the drain invert shall be graded appropriately to ensure it remains free-draining and prevents water ponding. Any low points resulting from NAF rock armour placement shall be regarded as necessary to eliminate localised ponding and maintain positive drainage towards PAF Dam 2. The regraded Type 2 surface shall maintain a continuous downslope profile consistent with the overall drain gradient.

If the above procedures are not carried out, the Superintendent may direct tyning to a depth of 100 mm, working, re-compaction and retesting in accordance with **Clause 10**.

8.1.2 Compaction Requirements

Type 2 capping material shall be placed and compacted in accordance with the specified performance requirements summarised in **Table 8.1.**

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TABLE 8.1: TYPE 2 CAPPING MATERIAL PLACEMENT AND COMPACTION REQUIREMENTS

Material	Maximum Layer Thickness	Reported Moisture Variation (1)	Minimum Compaction Requirements (2)
Type 2 Capping Material	250 mm (compacted)	-2.0% (dry) to +2.0% (wet) of Optimum Moisture Content	98% Standard Maximum Dry Density (SMDD)

Note (1) Reported moisture variation is to the nearest 0.5%, as defined by AS 1289, Methods of Testing Soils for Engineering Purposes, Test 5.7.1 -Compaction Control Test, Hilf Density ratio, Rapid Method.

Note (2) The required standard of compaction shall be a function of the moisture variation of the tested material The minimum compaction is in terms of Hilf Density Ratio (RHD), as defined by AS 1289, Methods of Testing Soils for Engineering Purposes, Test 5.7.1 -Compaction Control Test, Hilf Density ratio, Rapid Method.

The Contractor shall determine suitable vibratory compaction equipment and establish the minimum number of passes required to achieve the specified level of compaction, in accordance with the requirements outlined in **Table 8.1**.

8.1.3 Acceptance Testing

Testing for the requirements of **Clause 8.1.2** shall satisfy the criteria and frequencies outlined in **Clause 10.4**. Each testing location shall be identified by the Superintendent and/or Site Engineer. The test location and result will be deemed to be representative of the section or volume of work being tested.

The Contractor shall provide the coordinates of each test location (X, Y, Z) with a tolerance of ± 1 m to the horizontal and ± 50 mm to the vertical.

8.1.4 Remedial Action

Should a test fail to meet the specified density or moisture content, then remedial action shall be carried out as described in **Table 8.2**.

TABLE 8.2: REMEDIAL ACTION FOR COMPACTED TYPE 2 CAPPING MATERIAL

Category	Density Ratio Result	Moisture Content Result	Remedial Action
A	Fail by less than 1.0%	Pass	Re-roll (No. of passes to be specified by the Superintendent, max. 3).
B	Fail by 1.0% or more	Pass, but not more than 1.5% wet of OMC	Rip, re-water, re-compact and re-test.
C	Fail by 1.0% or more	Pass, but 1.5% or more wet of OMC	Rip, re-compact and re-test.
D	Pass	Fail, more than 2.0% dry of OMC	Remove fill and re-condition off-site, replace and re-test
E	Fail	Fail	Remove fill, replace and re-test

Should the Superintendent and/or Site Engineer consider the depth of insufficiently compacted material to be greater than can be effectively compacted from the surface, material shall be removed to a depth at which compaction is satisfactory, and replaced and compacted in layers.

8.1.5 Moisture Conditioning

Type 2 capping materials shall be moisture conditioned in the borrow or stockpile area and allowed to cure, prior to it being used in any part of the Works. Watering shall be carried out not less than 24 hours in advance of construction operations to ensure uniformity of moisture content.

The Contractor's attention is drawn to the fact the meeting the specified moisture condition for Type 2 material is equally as important as the compaction requirement at the specified density.

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It is likely that the in-situ moisture content of fill materials may be drier than the range specified in **Table 8.1** of this Specification. The maximum increase in moisture content by water addition at the location of placement shall be 1%. Water addition that may be required in excess of this shall be carried out in the borrow or stockpile area.

Where test results show the Type 2 materials to vary by more than 1 % from the specified moisture range (i.e. is excessively wet or dry), the layer shall be removed to a temporary conditioning area and treated. On treatment, the material shall be stockpiled and left to cure for not less than 24 hours.

The cost of multiple handling as may be required in this context to ensure uniform moisture distribution within the specified range shall be included in the relevant unit rate for compacted Type 2 capping material.

8.2 Crushed NAF/ NAF / PAF Rockfill

8.2.1 Placement

PAF / NAF Rockfill and Crushed NAF Rockfill shall be placed and compacted in accordance with the following requirements:

1. Placement shall be conducted such that rockfill segregation is minimised, and the subsequent materials are maintained within the limits presented in **Clause 7** of this Specification.
2. 1 longitudinal pass shall constitute complete coverage of the layer being compacted by the roller with the vibration on. Each coverage of the roller shall overlap the previous coverage by at least 0.5 m.
3. The materials laid such that when compacted they form a substantially homogenous mass free of lenses, pockets, or layers of material differing substantially in texture or gradation from the surrounding material within the zone.

The thickness of existing PAF material within Pad 1 varies. Therefore, existing PAF material in the northern area (~ 1-1.5 m thick PAF rock) is to be pushed toward the southern portion (existing ~ 0-0.5 m thick PAF rock) of Pad 1 and compacted per the above requirements.

8.2.2 Compaction

PAF / NAF Rockfill and Crushed NAF Rockfill shall be placed and compacted in accordance with the requirements of **Table 8.3**.

TABLE 8.3: PAF / NAF ROCKFILL AND CRUSHED NAF ROCKFILL PLACEMENT AND COMPACTION REQUIREMENTS

Material	Maximum Layer Thickness	Watering Requirements	Compaction Requirements
Crushed NAF / NAF / PAF	300 mm	As required during placement to assist in compaction and achieve a homogeneous fill mass	6 passes of a 10 tonne (drum mass) vibrating smooth drum or pad foot roller.

8.2.3 Acceptance Testing

Routine compaction testing will not be carried out for PAF / NAF Rockfill and Crushed NAF Rockfill materials. The Superintendent and/or Site Engineer reserves the right to reject incoming material based upon a visual inspection of contamination, particle size or other requirements of **Clause 5.3** of this Specification. The Superintendent and/or Site Engineer may also request further compaction or other remedial action. Reasons for such remedial action may include, but shall not be confined to the failure to achieve a homogeneous fill mass or excessively weathered material or fines.

The PSD of PAF / NAF Rockfill and Crushed NAF Rockfill materials will be qualitatively assessed on an ongoing basis by the Superintendent and/or Site Engineer, who shall reserve the right to conduct

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quantitative testing if it is felt that the material does not comply with the requirements of this Specification.

8.3 NAF Rock Armour

NAF Rock Armour shall be placed within the Type 2 lined PAF Pad perimeter drains using an excavator, as shown on the Drawings.

NAF Rock Armour for Stage 4 Works shall be placed to a thickness and maximum particle size of 225 mm. NAF Rock Armour shall be gently placed and tamped in a single lift within the drains and shaped to match the lines and levels specified in the Drawings. To prevent from causing localised low spots within the perimeter drain invert, the underlying type 2 material shall be graded appropriately to provide positive drainage towards PAF Dam.

NAF Rock Armour shall be slightly over placed along the edges to ensure complete coverage of the underlying geofabric and prevent exposure.

No compaction requirements (hence, no acceptance testing requirements) are specified for NAF Rock Armour.

9 INSTALLATION OF GEOTEXTILE

9.1 General

Application of a non-woven geotextile is required to aid in minimising erosion as an underlay for region where rock armour installation is required. The Contractor shall be responsible for the supply and installation of the geotextile. The geotextile shall be a Bidim A64 non-woven geotextile in accordance with the requirements of **Clause 5.5 of** this Specification.

No specialised lining techniques are required for the installation of the geotextile, and the Contractor may elect to install this material themselves.

9.2 Quality Control

The Geotextile shall be supplied in rolls wrapped in protective waterproof covers, and shall be clearly labelled to include, as a minimum, the following information:

- Manufacturers Name,
- Product identification name or grade,
- Roll number,
- Lot Number,
- Roll Dimensions,
- Reference numbers to raw material batch and laboratory certified reports, and
- The manufacturer’s approved QA stamp and the technician’s signature.

The Contractor shall review the manufacturers quality data sheets to ensure that the materials supplied for the Works meets the requirements of the Specifications and the MQC shall not be older than 12 months from the time of supply.

9.3 Geotextile Installation

Geotextile Installation methodology shall align with the requirements of the Manufacturers Installation Guidelines. No Geotextile installation works shall commence until written approval for the underlying drain Type 2 capping material is provided by the Superintendent.

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The Contractor shall handle the geotextile in such a manner as to ensure it is not damaged in any way, and shall comply with the following:

- Geotextile rolls shall only be removed from protective wrapping immediately prior to installation.
- The Contractor shall employ installation methods that will prevent folds, wrinkles, bridging or tensioning. The Contractor shall take care as to not entrap loose stones, excessive dust or moisture in the geotextile during placement.
- The geotextile shall be placed longitudinally along the length of the channel, following the direction of flow.
- Geotextile panels shall have a minimum overlap of 0.3 m.
- During installation the Contractor shall install sandbags over the panel's free edges to prevent wind uplift. Sandbags shall remain in place until such a time that the geotextile can be sufficiently covered or weighted down.
- The geotextile shall be continuously examined during placement to ensure that the geotextile is not damaged, displaced or torn.

The Contractor shall place overlying NAF Rock Armour material such that the following conditions are satisfied:

- No damage to the geotextile occurs.
- No slippage of the geotextile occurs.
- The geotextile is not tensioned by the installation procedure.
- The geotextile does not wrinkle and that there is intimate contact between the foundation and the geotextile.

At the completion of placement of geotextile, the entire geotextile surface shall be inspected after installation to ensure that no potentially harmful foreign objects are present. The Contractor shall remove any such objects and shall repair or replace any damaged geotextile.

9.4 Transportation, Labelling, Handling and Storage

Geotextile delivered to site shall be marked with product identification and supplied with data sheet and information according to the requirements of *AS 3705 - Geotextiles - Identification, Marking and General Data*.

Once the Geotextile is delivered to site, the Contractor shall be responsible for the handling, storage and care of the Geotextile from the time of delivery to site until final acceptance of the completed work by the Superintendent and Site Engineer. The Contractor shall be liable for all damages to the materials during such time. Any damage done to the geotextile due to poor handling and storage practices shall be repaired by the Contractor at their expense

The Geotextile shall be handled with care and in a controlled manner during unloading to avoid causing damage. The onsite Geotextile materials shall be protected from UV light exposure, precipitation or other inundation, spills of hydrocarbons, mud, dirt, dust, puncture, cutting or other damaging deleterious conditions.

10 INSPECTION, TESTING AND VERIFICATION

10.1 Inspections and Hold Points

Clause 1.7.2 outlines the requirements for an ITP as part of the Contractor's Quality Plan for the Works.

Routine visual inspections are required for ongoing approval of the various aspects of the Works. Verification of routine visual inspections will be formalised by the relevant parties (Superintendent, Site

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Engineer and/or Contractor) signature to confirm visual inspections has been conducted at a suitable frequency.

Routine visual inspections will comprise of (but are not limited to) the following. Further inspection points may be introduced during development of the ITPs:

- Ongoing excavation of materials.
- PAF Pad fill materials (Type 2, PAF/NAF/Crushed NAF and Rock Armour) at borrow/stockpiles prior to hauling to the worksite.
- Ongoing material handling, conditioning, placement and compaction.
- Placement of Geotextile

In addition to the above, particular stages of the Works shall be hold points beyond which the Works shall not proceed without review and release by the Superintendent or Site Engineer/Design Engineer. The release will be formalised by the Superintendent signing the relevant ITP prepared by the Contractor for the relevant part of the Works.

The hold points will comprise of (but are not limited to) the following. Further hold points may be introduced during development of the ITPs:-

- Set-out of the works, including provision of Construction models
- Completion of stripping borrow area **(S)**.
- Completion of Type A foundation preparation over natural surface **(S).**
- Completion of Type B foundation preparation and excavation of existing surfaces / PAF perimeter drains **(S).**
- Completion of placement and compaction of NAF Rockfill material to raise natural / existing surface levels **(S).**
- Completion of placement and compaction of Crushed NAF Rockfill material to place Type 2 capping materials over **(S).**
- Completion of placement and compaction of PAF Rockfill material to raise existing surface levels **(S).**
- Completion of placement and compaction of Type 2 capping materials for the PAF Pad and Pad 1 encapsulation impermeable layer (hold point once per layer) **(S).**
- Visual inspection of the delivered Geotextile product.
- Completion of PAF Perimeter drains ready for Geotextile and NAF Rock Armour placement **(S)**.
- Completion of placement of geotextile underlay for the rock lined drains (hold point once per drain/area).
- Completion of PAF Perimeter drains (including placement of Geotextile and NAF Rock Armour) **(S).**
- Completion of the Works.

At one or more of these stages, survey may be required for submission to the Superintendent and/or Site Engineer for validation of constructed dimensions and/or set-out, in accordance with **Clause 1.9.2** and **1.9.3.** Items where survey will be required are denote with **(S)** in the list above.

10.2 Testing Authority & Methods

Sampling and laboratory compliance testing of fill material shall be performed by the Contractor. The Contractor shall appoint a NATA accredited testing authority to conduct all such sampling and testing.

The Contractor shall submit with their tender the details of their nominated testing authority, including documentation demonstrating NATA accreditation for the testing specified in this Specification.

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Notwithstanding this, sampling and laboratory testing shall only be conducted by a testing authority approved by the Superintendent.

The cost of sampling and testing of fill materials, and any resulting delays shall be deemed to be included in the tendered unit rates.

10.3 Quality Control Criteria

The Contractor shall note that quality control of PAF Pad fill materials shall be conducted using both performance and method Specifications, as follows:

- Method Specification:
  - Foundation preparations.
  - PAF/ NAF Rockfill (including Crushed and Rock Armour NAF) Placement.
- Performance Specification:
  - Type 2 Capping Materials.

Compliance with Type 2 capping Performance Specification will be assessed using the methods presented in **Clause 5.2**, **8.1** and **10.4** of this Specification**.**

Compliance with Method Specifications will generally be assessed through visual inspections by the Superintendent and/or Site Engineer.

With respect to visual assessment of compliance, the Superintendent reserves the right to the following:

1. Reject incoming earthworks fill material on the basis of particle size, weathering classification or excessive organics content.
2. Instruct the Contractor to conduct compliance tests on earthworks fill materials which, in their opinion, do not meet the specified criteria.

10.4 Performance Specification Testing

10.4.1 Overview

Type 2 capping material performance specification testing shall be in accordance with **Table 10.1**. Notwithstanding, the Superintendent and/or Site Engineer may request the Contractor to perform testing at a higher frequency than those stated if they are not satisfied that compaction or material is adequate.

TABLE 10.1: TYPE 2 MATERIAL TESTING REQUIREMENTS

Material	Test Type	Testing Frequency
Type 2 Capping Material	Compaction Control - Insitu Density / Moisture Content	1 per 500 m^3, or 1 per day (if less than 500 m^3 is placed in any given day)
	Material Compliance – Particle Size Distribution + Atterberg Limits	1 per 2,000 m^3

10.4.2 Insitu Density Testing

10.4.2.1 General Requirements

The following general requirements shall apply with regards to Insitu Density Testing:

1. Tests shall be as specified in **Clause 10.4.2.2** of this Specification.

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2. Testing shall occur not later than 24 hours after compaction has been completed.
3. The Contractor shall be responsible for giving notice to the Superintendent and/or Site Engineer that areas are ready for in-situ density testing.
4. Actual in-situ density test locations shall be nominated by the Superintendent and/or Site Engineer, based on their assessment of the particular area or layer being tested.
5. Test results shall be made available to the Superintendent without delay.
6. No additional filling or compaction shall be carried out in an area that has been tested before the Contractor is advised by the Superintendent that the test results in this area are satisfactory. If construction work continues over areas or with materials not yet approved by the Superintendent, the risk and associated expenses of removal and replacement shall be borne by the Contractor.
7. The Contractor shall allow for reasonable delays whilst tasks are being performed and shall accept the interpretation of the results by the Superintendent and the resulting directions.

10.4.2.2 Testing Methods

For the purposes of this Specification, “In-Situ Density Testing” shall constitute the following:

1. Determination of field density and field moisture content using Nuclear Surface Moisture-Density Gauge in accordance with AS 1289 Method 5.8.1
2. Compaction control testing using the Hilf (Rapid) Method in accordance with AS 1289 Method 5.7.1.
3. The ratio of field density and compaction control testing shall be 1:1.

10.4.3 Material Compliance Testing

Sampling and compliance testing of Type 2 material shall be performed by the Contractor to demonstrate compliance with the Specification. The samples to be tested shall be selected by the Superintendent and/or Site Engineer after the material has been prepared for testing by the Contractor.

Testing of materials for PSD and Atterberg limits compliance shall be carried out and approval granted by the Superintendent before material from any particular borrow location is used in construction.

For the purposes of this Specification, “Material Compliance Testing” shall constitute the following:

1. Determination of Atterberg Limits (Liquid Limit and Plasticity Index) in accordance with AS 1289 Method 3.1.2, 3.2.1, 3.3.1 and 3.3.2.
2. Determination of PSD in accordance with AS 1289 Method 3.6.1.

The results of all testing shall be issued directly to the Superintendent and the Contractor by the testing authority as soon as the results are available. Alternatively, the Contractor shall forward the test results to the Superintendent within two hours of them being received.

The Contractor shall allow for reasonable delays resulting from the taking of tests and shall accept the interpretation of the results by the Superintendent and the resulting directions.

REFERENCES

[1] ATC Williams (2025), MMG Dugald River Mine, “Dugald River Stage 3 and 4 PAF Pad Detailed Design – Borrow Investigation”, Reference 240261.02-L01, February 2025.

[2] ATC Williams (2025), MMG Dugald River Mine, “Dugald River Mine PAF Pad Expansion- Stage 4 Expansion Design Report”, Reference 240261.04-R01 Rev A, October 2025.

DRAWINGS

APPENDICES

APPENDIX A – GEOTECHNICAL INVESTIGATION

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Our Ref: 240261.02-L01

14 February 2025

MMG Dugald River

Burke Development Road

CLONCURRY QLD 4824

ATTENTION: JACK HOLLINGSWORTH

Dear Jack,

DUGALD RIVER STAGE 3 AND 4 PAF PAD DETAILED DESIGN – BORROW INVESTIGATION

1 INTRODUCTION

ATC Williams (ATCW) has been engaged by MMG Limited (MMG) to produce a detailed design for the Stage 3 and Stage 4 Potentially Acid Forming (PAF) Pads at the Dugald River Mine.

This letter report presents the results of a test pitting site investigation to identify suitable borrow areas for Stage 3 and Stage 4 PAF Pad construction material, which are proposed to be used as low permeability earth fill (Type 2 material) according to the budget proposal **[2].**

2 BACKGROUND

For Stages 3 and 4 of the PAF Pads, the Type 2 material (Refer to **Section 4**) is planned to be sourced from borrow areas. ATCW conducted a geotechnical investigation comprising 19 test pits within these borrow areas to identify suitable materials. Additionally, three test pits were excavated near the PAF Dam 1 area to assess the foundation conditions for the Stage 4 PAF Pad works.

3 INVESTIGATION OVERVIEW

The borrow investigation was undertaken on the 29th and 31st of October 2024. The weather on both days was sunny and approximately 37 degrees Celsius, and no significant rainfall occurred during the period preceding the work.

Locations of the 19 test pits in the borrow area on the south side of PAF PAD 2 are shown in **DIAGRAM 1**. The three test pits near the PAF dam 1 area for Stage 4 PAD expansion are shown in **DIAGRAM 2**. Test pit locations are also presented in **Attachment 1** and **Attachment 2**.

Test pitting was performed using a Caterpillar 20 tonne excavator supplied by MMG. The investigation was supervised by Muhammad Abu Bakar (ATCW Experienced Engineer). A photo of an excavator used is presented in **PHOTO 1**.

From the 22 test pits excavated, six soil samples were taken for subsequent laboratory testing. Field dry strength and toughness tests were conducted to identify possible Type 2 materials (historically used within PAD 1 & 2 construction) **[3]**.

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The investigation generally encountered two main types of materials, and further testing was conducted to determine their eligibility as Type 2 materials.

Test pits were generally excavated to refusal or terminated at the engineer's request due to unsuitable material being found.

DIAGRAM 1: PAF PAD BORROW INVESTIGATION TEST PIT LOCATIONS

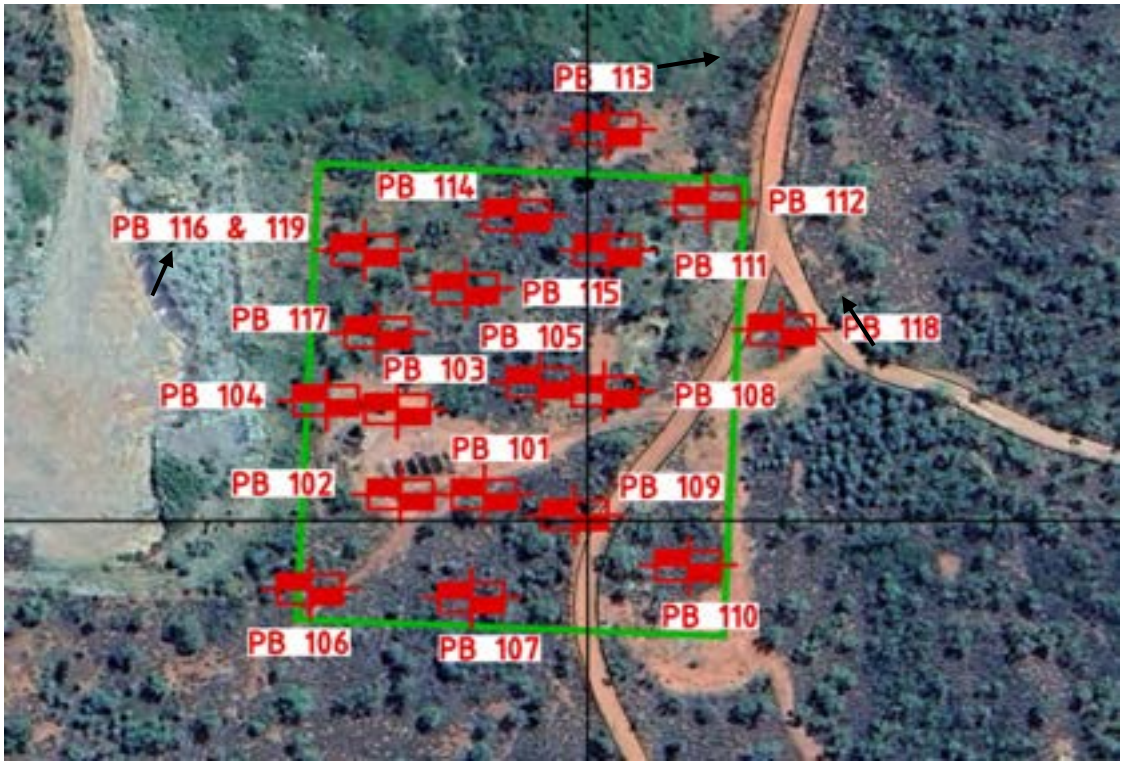


DIAGRAM 2: PAF PAD FOUNDATION TEST PIT LOCATIONS



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PHOTO 1: CAT 20T EXCAVATOR



4 TYPE 2 MATERIAL

Type 2 material is proposed to form the low permeability cover liner over the surface of the PAF Pads to avoid contaminating the groundwater with PAF runoff. Type 2 material is generally expected to consist of low plasticity cohesive soils.

Type 2 materials were previously produced (in the PAF PAD 1 and 2 works) by stripping and the cohesive soil materials from the PAF Pad Dam excavations.

The Type 2 material will have a nominal target saturated permeability of $1x10^{-9}$ m/s **[1]**.

The plasticity of the fine-grained fraction of the Type 2 material (i.e. the portion of the material with particle size finer than 0.075 mm) shall exhibit Atterberg Limits, which plot above the 'A' Line to consist with low plasticity clay content.

5 RESULTS OF INVESTIGATION

5.1 Foundation Area

Three test pits were excavated in the foundation area, as shown in **DIAGRAM 2**, to assess the condition of the foundation around the proposed test PADs. The stratigraphy encountered consisted of stiff clay and dense gravel, with refusal depths ranging from 0.1m to 3.8m, as summarised in **Table 1**. Geotechnical logs and photos of each test pit are provided in **Attachment 3**.

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TABLE 1: TEST PITTING SUMMARY

Location	Test Pit	Eastings	Northings	Depth to Refusal (m)	Findings
FOUNDATION	PAD101	411565	7760768	2.0	0m-2m Stiff CLAY
	PAD102	411538	7760834	0.1	0m-0.1m Dense GRAVEL
	PAD103	411397	7760781	3.8	0m-0.2m Stiff CLAY 0.2m-3.8m Dense GRAVEL

The suitability of the foundation material and required preparation, such as stripping or excavation, will be addressed in the stages 3 and 4 detailed design reports.

5.2 Borrow Area

A summary of the test pitting locations is provided in **Table 2**. Geotechnical logs and photos of each test pit are provided in **Attachment 3**. The majority of these test pits were generally deemed as suitable for type 2 material (as described in **section 4**) after being confirmed with lab tests (as described in **section 6**).

TABLE 2: TEST PITTING SUMMARY

Location	Test Pit	Eastings	Northings	Depth to Refusal (m)	Findings and Suitability
BORROW AREA	PB 101[1]	411468	7759509	0.8	0m-0.1m Clayey GRAVEL 0.1m-0.8m Sandy CLAY
	PB 102	411442	7759509	1.4	0m-1.0m Sandy CLAY 1m-1.4m Silty GRAVEL
	PB 103[1]	411441	7759538	1.5	0m-1.5m Sandy CLAY
	PB 104	411419	7759541	2.4	0m-1.2m Sandy CLAY 1.2m-2.4m Silty GRAVEL
	PB 105	411485	7759547	1.5	0m-1.2m Sandy CLAY 1.2m-1.5m Gravelly SILT
	PB 106	411414	7759477	1.1	0m-0.2m Clayey GRAVEL 0.2m-0.8m Gravelly CLAY 0.8m-1.1m Clayey GRAVEL
	PB 107	411464	7759474	1.9	0m-1.2m Sandy CLAY 1.0m-1.9m Silty GRAVEL
	PB 108[1]	411505	7759544	1.2	0m-0.1m Clayey GRAVEL 0.1m-1.2m Sandy CLAY
	PB 109[1]	411496	7759502	0.9	0m-0.1m Clayey GRAVEL 0.1m-0.9m Sandy CLAY
	PB 110[1]	411435	7759564	0.5	0m-0.1m Clayey GRAVEL 0.1m-0.5m Sandy CLAY

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Location	Test Pit	Eastings	Northings	Depth to Refusal (m)	Findings and Suitability
	PB 111[1]	411431	7759592	0.7	0m-0.1m GRAVEL 0.1m-0.7m Sandy CLAY
	PB 112	411506	7759592	1.6	0m-0.1m Clayey GRAVEL 0.1m-1.1m Sandy CLAY 1.1m-1.6m Gravelly CLAY
	PB 113[1]	411506	7759633	1.1	0m-0.1m Clayey GRAVEL 0.1m-1.1m Sandy CLAY
	PB 114[1]	411478	7759604	0.7	0m-0.2m Clayey GRAVEL 0.2m-0.7m Sandy CLAY
	PB 115[1]	411560	7759565	0.6	0m-0.1m Clayey GRAVEL 0.1m-0.6m Sandy Clay
	PB 116[1]	411462	7759579	0.8	0m-0.1m Clayey GRAVEL 0.1m-0.8m Sandy CLAY
	PB 117[1]	411531	7759485	0.6	0m-0.1m Gravelly CLAY 0.1m-0.6m Sandy CLAY
	PB 118	411537	7759608	1.5	0m-0.7m Sandy CLAY 0.7m-1.5m Silty GRAVEL
	PB 119	411431	7759592	0.9	0m-0.1m Gravelly CLAY 0.1m-0.5m Sandy CLAY 0.5m-0.9m Silty Gravelly CLAY

Sandy CLAY- Suitable for type 2 material
[1]Refused at suitable type 2 material, potentially more type 2 material availability

6 LAB TESTINGS AND RESULTS

Following the evaluation of materials encountered during the geotechnical investigation, two primary types were identified by the Site Engineer, distinguished by their colour and particle characteristics. The test pit numbers and depths associated with these materials are shown in **Table 3**.

TABLE 3: SAMPLE LOG

Sample 1 (89524) – Red Brown	Sample 2 (89624) – Grey/Pale Brown
PB101 – 0.1m-0.8m	PB104 – 1.2m - 2.4m
PB102 – 0m-1m	PB 107 – 1m-1.9m
PB103 – 0m-1.5m	-
PB 116 – 0.1m-0.8m	-

Laboratory characterisation tests were conducted to identify potentially suitable Type 2 borrow materials. Additional testing was then conducted on these materials to confirm their properties and suitability for PAF PAD construction.

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6.1 Particle Size Distribution

Sieve analysis passing 19 mm and hydrometer tests were performed to determine the grain size distribution of the soil. This analysis is crucial for understanding the soil's texture and gradation and assessing its suitability as a Type 2 material. A well-graded soil with a mix of different particle sizes can provide superior compaction and reduced permeability. Test results are shown in **Table 4**.

TABLE 4: PARTICLE SIZE DISTRIBUTION

	Sample 1 (89524)	Sample 2 (89624)
Clay	24.0 %	10.0 %
Silt	25.4%	15.4%
Sand	35.9%	35.5%
Gravel	14.7%	39.1%

Based on the test results, the soil samples are classified according to AS1726 as follows:

- Sample 1 (89524): Sandy CLAY
- Sample 2 (89624): Silty GRAVEL

These classifications provide a clear understanding of the soil composition, which is essential for evaluating their suitability for use in the PAF PAD construction.

6.2 Particle Density (Specific Gravity)

The test was conducted to measure the density of soil particles. Knowing the specific gravity is vital for calculating the soil's porosity and void ratio, which are important for evaluating its compaction characteristics and overall stability.

The test results for the soil samples are as follows:

- Sample 89524: 2.71 g/cm³
- Sample 89624: 2.75 g/cm³

6.3 Atterberg Limits

The tests were carried out to determine the plasticity characteristics of the fines component of the soil. The Liquid Limit, Plastic Limit, and Plasticity Index provide insights into the soil's behaviour under varying moisture conditions. This information is crucial for predicting how the soil will perform as a cohesive, low, permeable material, particularly in terms of its workability and compaction. Test results are shown in **Table 5**.

TABLE 5: ATTERBERG LIMITS

	Sample 1 (89524)	Sample 2 (89624)
Liquid Limit (%)	34	32
Plastic Limit (%)	13	17
Plasticity index (%)	21	15

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Based on the test results:

- Sample 1 (89524) is classified as CL – Inorganic Low Plasticity Clay
- Sample 2 (89624) is classified as CL – Inorganic Low Plasticity Clay

These classifications are according to AS1726.

6.4 Emerson Class

The Emerson Class test was conducted to assess the soil's dispersibility, i.e., the tendency to disperse in water. Dispersion can significantly impact the soil's stability and resistance to erosion. Low dispersion is desirable for Stage 3 and Stage 4 PAF PAD construction materials to ensure they remain intact and effective in preventing seepage.

To accurately replicate the site conditions at the PAF PAD, the test was conducted on Sample 1 (89524) using pH 5.0 acidic water, which is approximately similar to the PAF runoff water present at the site. The test results indicated that the soil sample has an Emerson class number of 5, which classifies it as non-dispersive. This suggests that the soil is stable and suitable for use as a type 2 material.

6.5 Permeability Test

A permeability test, using the Constant Head Method, was conducted to measure the soil's permeability. This test determines how easily water can flow through the soil, which is crucial for the PAF PAD to minimise the risk of contaminants leaching into the environment. A remoulded sample was used to simulate conditions after compaction, providing a realistic assessment of the soil's performance.

The test was conducted on Sample 1 (89524) using Melbourne tap water adjusted to pH 5.0 to replicate site conditions. Sample 2 (89624) was not tested due to its higher silt and gravel content. The results were as follows:

- Permeability at 20°C (m/s): 3.44×10^{-10}
- Final Moisture Content (%): 16.3

These results indicate that the soil has low permeability, making it suitable for use in the construction of the PAF PAD.

6.6 Triaxial - Multistage Test

As a part of the testing programme, isotropically consolidated undrained monotonic triaxial tests were performed on Sample 1 (89524). A summary of triaxial test results is presented in **Table 6**.

This test was performed to evaluate the soil's shear strength under different stress conditions. This test provides valuable data on the soil's strength and deformation characteristics, which is critical for the stability and integrity of the PAF PAD, especially under varying loads and environmental conditions.

These tests provide a better understanding of the soil's physical and mechanical properties, which will be adopted in the Stage 4 stability assessment of the PAF PAD. The test results certificates are attached in **Attachment 4**: Lab Test Certificates.

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TABLE 6: SUMMARY OF TRIAXIAL TEST RESULTS

Parameter		Unit	Test 1	Test 2	Test 3
Sample preparation method			Static compaction		
Register Number / Test Number			89524	89524	89524
Test pit / Sample Depth			PB101,102,103 and PB116 (Depth 0.8,1,1.5,0.8m respectively)		
Effective Confining Pressures prior to Shearing, σ'_3		kPa	51	98	198
Effective Vertical Stress prior to Shearing, σ'_1		kPa	51	98	198
Prior to Shearing	Void Ratio, e	-	0.46	0.43	0.40
	Dry Density, ρ_d	t/m^3	1.86	1.89	1.93
Shear Rate		mm/min	0.05		
Deviatoric Stress at Failure [(1)], q		kPa	39	72	149
Mean Effective Stress at Failure, p′		kPa	27	52	115
Undrained Shear Strength Ratio, Su/σ'1:		-	0.38	0.37	0.38
Internal Friction Angle, φ':		degrees	36		

(1) Membrane correction has been applied.

7 PROPOSED BORROW AREA

ATCW has previously produced a conceptual design for Stages 3 & 4, from which high-level quantities were estimated. The estimated required quantities for Stage 3 and Stage 4 PAD are provided in **Table 7**.

TABLE 7: REQUIRED TYPE 2 MATERIAL QUANTITIES FOR STAGE 3 & 4

Zone	Required Quantity (Type 2 Material)
Stage 3	5,400 m^3
Stage 4	15,900 m^3
Total	21,300 m^3

Based on the investigation findings, the investigated borrow area (20,460 m²) is proposed for sourcing the total quantity of type 2 materials.

The proposed Stage 3 and 4 PAF PAD areas are shown in the PAF PAD Expansion Conceptual Options Study **[1]**.

8 CONCLUSION AND RECOMMENDATIONS

The following conclusions and recommendations have been drawn from the investigation, laboratory tests, and subsequent assessment:

- **Sandy CLAY (red brown):** This material has low permeability and is suitable for use as a type 2 material (as described in **section 4**). Refer to **Table 2** for test Pit numbers and layer thicknesses.
- **Silty GRAVEL (grey)**: This material is not suitable for use as a type 2 material in its current state due to a high silt content and the presence of granular material.

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These recommendations adopt the appropriate sourcing and utilisation of materials for the project, maintaining quality and consistency in the construction process of Stage 3 and 4 PAF PAD construction.

9 CLOSURE

This letter has provided a summary of test pitting investigation results primarily to identify a Type 2 material borrow area for the proposed PAF PAD 3 & 4 area construction, as well as the foundation conditions for the Stage 4 PAF PAD works.

Please contact the undersigned for any further queries.

Yours sincerely,

ASANKA DON PEERISLAGE

Experienced Engineer

AsankaP@atcwilliams.com.au

ATC Williams Pty Ltd

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ATTACHMENTS

Attachment 1: FIGURE 1 - PAF PAD Borrow Investigation Test Pit Locations

Attachment 2: FIGURE 2 - PAF PAD Foundation Test Pit Locations

Attachment 3: Test Pitting Logs & Photographs

Attachment 4: Lab Test certificates

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REFERENCES

[1] ATCW (2024), "Dugald River Mine – PAF PAD Expansion Conceptual Options Study", ATCW Ref: 108003.64-R01, Rev A, dated June 2024.

[2] ATCW (2024), "MMG Dugald River Mine PAF PAD Expansion Detailed Design Budget Proposal", ATCW Ref: 240261-P01, Rev A, dated October 2024.

[3] ATC Williams. "MMG Dugald River Mine – Pond B Facility Construction Report", Ref 108003.08-R01, dated June 2012.

ATTACHMENTS

ATTACHMENT 1 – FIGURE 1 - PAF PAD BORROW INVESTIGATION TEST PIT LOCATIONS

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SURVEY NOTES:

1.- GRID COORDINATE SYSTEM IN USE WGS84 Z54S.
HEIGHT DATUM: AHD

LEGEND:

PB DRILLED TEST PITS

TESTPIT COORDINATES

ID #	EASTING (m)	NORTHING (m)
PB 101	411,468	7,759,509
PB 102	411,442	7,759,509
PB 103	411,441	7,759,538
PB 104	411,419	7,759,541
PB 105	411,485	7,759,547
PB 106	411,414	7,759,477
PB 107	411,464	7,759,474
PB 108	411,505	7,759,544
PB 109	411,496	7,759,502
PB 110	411,531	7,759,485
PB 111	411,506	7,759,592
PB 112	411,537	7,759,608
PB 113	411,506	7,759,633
PB 114	411,478	7,759,604
PB 115	411,462	7,759,579
PB 116	411,431	7,759,592
PB 117	411,435	7,759,564
PB 118	411,560	7,759,565
PB 119	411,431	7,759,592

LEASE BOUNDARY

POTENTIAL BORROW AREA
FOR ADDITIONAL REQUIRED
GEOTECH INVESTIGATION

No.	DESCRIPTION	DATE	DRAWN	CHECKD	APPRD

SCALE:	1:5,000
JOB No.	240261.02
DATE	23.10.24
DESIGN	MAB
DRAWN	SP
CHECKED	DR
APPROVED	CN

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MMG DUGALD RIVER
TAILINGS STORAGE FACILITY

PAF PAD BORROW INVESTIGATION
TEST PITTING LOCATIONS

DWG. No.
FIGURE 1

SHEET SIZE | Rev. A

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SHEET 1 OF 1

ATTACHMENT 2 – FIGURE 2 - PAF PAD FOUNDATION TEST PIT LOCATIONS

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SURVEY NOTES:

1.- GRID COORDINATE SYSTEM IN USE WGS84 Z54S.
HEIGHT DATUM: AHD

LEGEND:

PAD PROPOSED TEST PITS



TESTPIT COORDINATES		
ID #	EASTING (m)	NORTHING (m)
PAD101	411,565	7,760,768
PAD102	411,538	7,760,834
PAD103	411,397	7,760,781

No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D

SCALE:	1:1,000
JOB No.	240261.02
DATE	23.10.24
DESIGN	MAB
DRAWN	SP
CHECKED	DR
APPROVED	CN

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PAF PAD FOUNDATION TEST PITTING TEST PITTING LOCATIONS

DWG. No. FIGURE 2

SHEET SIZE | Rev. A

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SHEET 1 OF 1

S:\Dugald\240261 - PAF PAD Detailed Design\CADD\CAD\01. Geotechnical Investigation\FIGURE 2 - PAF PAD Foundation Test Pit Locations.dwg

Printed on: Thursday, 19 December 2024 09:15:19 AM

ATTACHMENT 3 – TEST PITTING LOGS & PHOTOGRAPHS

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REPORT OF TESTPIT: PAD101

Job No	: 240261	Easting	: 411565.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7760768.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 5 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 06/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.2		CL-CI	TOPSOIL, Sandy CLAY (CL-CI); low to medium plasticity, red brown, fine to medium grained sand.	w < PL	St		
							1		CI-CH	RESIDUAL, Gravelly CLAY (CI-CH); medium to high plasticity, red brown mottled grey, medium to coarse sized gravel.	w < PL			
										PAD101 refusal at 2m				

REPORT OF TESTPIT: PAD102

Job No	: 240261	Easting	: 411538.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7760834.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 5 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 06/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A							GM	TOPSOIL, Silty GRAVEL (GM); fine to medium sized, trace fine to coarse grained sand, brown.	D	D		
		Not Observed								**PAD102 refusal at 0.1m**				

REPORT OF TESTPIT: PAD103

Job No	: 240261	Easting	: 411397.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7760781.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 5 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 06/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.2		CL-CI	TOPSOIL, Silty CLAY (CL-CI); low to medium plasticity, red brown, trace fine to coarse grained sand.	w < PL	St		
							1		GM	RESIDUAL, Sandy to silty GRAVEL (GM); medium to coarse sized, fine to coarse grained sand, sub-angular to angular, pale brown mottled white.	D	D		
							1.8		GM	RESIDUAL, Sandy to silty GRAVEL (GM); medium to coarse sized, sub-angular to angular.	D			
							2							
							3							
										PAD103 refusal at 3.8m				

REPORT OF TESTPIT: PB 101

Job No	: 240261	Easting	: 411468.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759509.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 13/01/2025

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A		Bulk Bag			0.1		GC	RESIDUAL, Clayey GRAVEL (GC); fine to medium sized, sub-angular to angular, red brown, medium to high plasticity clay.	D	VD		
									CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, medium grained sand, trace medium sized gravel.		St		
										PB 101 refusal at 0.8m				

REPORT OF TESTPIT: PB 102

Job No	: 240261	Easting	: 411442.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759509.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A							CI-CH	RESIDUAL, Sandy CLAY (CI-CH); medium to high plasticity, red brown, fine to coarse grained sand.	w < PL	VSt		
				Bulk Bag			1		GM	RESIDUAL, Silty GRAVEL (GM); fine to coarse sized, with low plasticity clay, grey.	D	D		
										PB 102 refusal at 1.4m				

REPORT OF TESTPIT: PB 103

Job No	: 240261	Easting	: 411441.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759538.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A		Bulk Bag			1		CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, trace medium sized gravel.		VSt		
										PB 103 refusal at 1.5m				

REPORT OF TESTPIT: PB 104

Job No	: 240261	Easting	: 411419.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759541.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 13/02/2025

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0		CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, fine to coarse grained sand, trace fine to coarse sized gravel.		VSt		
							1							
							1.2							
				Bulk Bag					GM	RESIDUAL, Silty GRAVEL (GM); fine to coarse sized, with low plasticity clay, pale red brown.	D	D		
							2							
										PB 104 refusal at 2.4m				

REPORT OF TESTPIT: PB 105

Job No	: 240261	Easting	: 411485.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759547.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 30/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					1		CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, trace fine sized gravel.	w < PL	VSt		
							1.2		GM	RESIDUAL, Gravelly SILT (GM); low plasticity, light brown grey, medium to coarse sized gravel.	w < PL	St		
										PB 105 refusal at 1.5m				

REPORT OF TESTPIT: PB 106

Job No	: 240261	Easting	: 411414.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759477.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.2		GC	TOPSOIL, Clayey GRAVEL (GC); medium to coarse sized, sub-angular to angular, red brown, low plasticity clay.	D	D		
							0.8		CI-CH	RESIDUAL, Gravelly CLAY (CI-CH); medium to high plasticity, red brown, fine to medium sized gravel.	w < PL	VSt		
							1		GC	RESIDUAL, Clayey GRAVEL (GC); fine to coarse sized, sub-angular to angular, red brown grey, low to medium plasticity clay.	D	VD		
										PB 106 refusal at 1.1m				

REPORT OF TESTPIT: PB 107

Job No	: 240261	Easting	: 411464.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759474.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 21/01/2025

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0		CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, fine to coarse grained sand.	D	VSt		
				Bulk Bag			1		GM	RESIDUAL, Silty GRAVEL (GM); fine to coarse sized, with low plasticity clay, pale brown.	D			
										PB 107 refusal at 1.9m				

REPORT OF TESTPIT: PB 108

Job No	: 240261	Easting	: 411505.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759544.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 02/12/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GC	TOPSOIL, Clayey GRAVEL (GC); medium to coarse sized, sub-angular to angular, red brown, medium to high plasticity clay.	D	VD		
							1		CL-CI	RESIDUAL, Sandy CLAY (CL-CI); low to medium plasticity, dark red brown, fine to coarse grained sand.	D	VSt		
										PB 108 refusal at 1.2m				

REPORT OF TESTPIT: PB 109

Job No	: 240261	Easting	: 411496.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759502.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 02/12/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GC	TOPSOIL, Clayey GRAVEL (GC); medium to coarse sized, sub-angular to angular, red brown, medium plasticity clay.	D	D		
									CI-CH	RESIDUAL, Sandy CLAY (CI-CH); medium to high plasticity, red brown, trace fine to coarse sized gravel.	D	VSt		
										PB 109 refusal at 0.9m				

REPORT OF TESTPIT: PB 110

Job No	: 240261	Easting	: 411531.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759485.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GC	TOPSOIL, Clayey GRAVEL (GC); medium to coarse sized, rounded to angular, red brown, medium plasticity clay.	D	D		
									CI-CH	RESIDUAL, Sandy CLAY (CI-CH); medium to high plasticity, dark red brown, fine to coarse grained sand.	D	VSt		
										PB 110 refusal at 0.5m				

REPORT OF TESTPIT: PB 111

Job No	: 240261	Easting	: 411506.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759592.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GP	TOPSOIL, GRAVEL (GP); medium to coarse sized, sub-angular to angular, brown.	D	D		
									CI-CH	RESIDUAL, Silty CLAY (CI-CH); medium to high plasticity, red brown, with fine to medium sized gravel, trace sand.	D	VSt		
										PB 111 refusal at 0.7m				

REPORT OF TESTPIT: PB 112

Job No	: 240261	Easting	: 411537.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759608.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GC	TOPSOIL, Clayey GRAVEL (GC); medium to coarse sized, sub-angular to angular, red brown, low to medium plasticity clay.	D	D		
									CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, fine to coarse grained sand, trace fine to coarse sized gravel.	D	VSt		
							1							
							1.1		CI-CH	RESIDUAL, Gravelly CLAY (CI-CH); medium to high plasticity, grey, medium to coarse sized gravel.	D	St		
										PB 112 refusal at 1.6m				

REPORT OF TESTPIT: PB 113

Job No	: 240261	Easting	: 411506.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759633.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 14/02/2025

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GC	TOPSOIL, Clayey GRAVEL (GC); medium to coarse sized, sub-rounded to angular, red brown, medium plasticity clay.	D	D		
									CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, fine to coarse grained sand, trace fine to coarse sized gravel.	D	VSt		
							1							
										PB 113 refusal at 1.1m				

REPORT OF TESTPIT: PB 114

Job No	: 240261	Easting	: 411478.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759604.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 14/02/2025

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GC	RESIDUAL, Clayey GRAVEL (GC); fine to coarse sized, trace fine to coarse grained sand, sub-rounded to angular, grey, low plasticity clay.		D		
									CI-CH	RESIDUAL, Sandy CLAY (CI-CH); medium to high plasticity, red brown, fine to coarse grained sand, trace fine to coarse sized gravel.	D	VSt		
										PB 114 refusal at 0.7m				

REPORT OF TESTPIT: PB 115

Job No	: 240261	Easting	: 411462.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759579.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		GC	TOPSOIL, Clayey GRAVEL (GC); medium to coarse sized.		MD		
									CI-CH	RESIDUAL, Sandy CLAY (CI-CH); medium to high plasticity, red brown, fine to coarse grained sand, trace fine to coarse sized gravel.	D	VSt		
										PB 115 refusal at 0.6m				

REPORT OF TESTPIT: PB 116

Job No	: 240261	Easting	: 411431.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759592.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A							GC	RESIDUAL, Clayey GRAVEL (GC); medium to coarse sized, sub-rounded to sub-angular, red brown, low to medium plasticity clay.		D		
				Bulk Bag					CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, medium grained sand, trace fine to coarse sized gravel.	D	VSt		
										PB 116 refusal at 0.8m				

REPORT OF TESTPIT: PB 117

Job No	: 240261	Easting	: 411435.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759564.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600 / Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		CL-CI	TOPSOIL, Gravelly CLAY (CL-CI); low to medium plasticity, red brown, medium to coarse sized gravel.	w < PL	St	
									CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, fine to coarse grained sand, with fine to medium sized gravel.	D	VSt	
										PB 117 refusal at 0.6m			

REPORT OF TESTPIT: PB 118

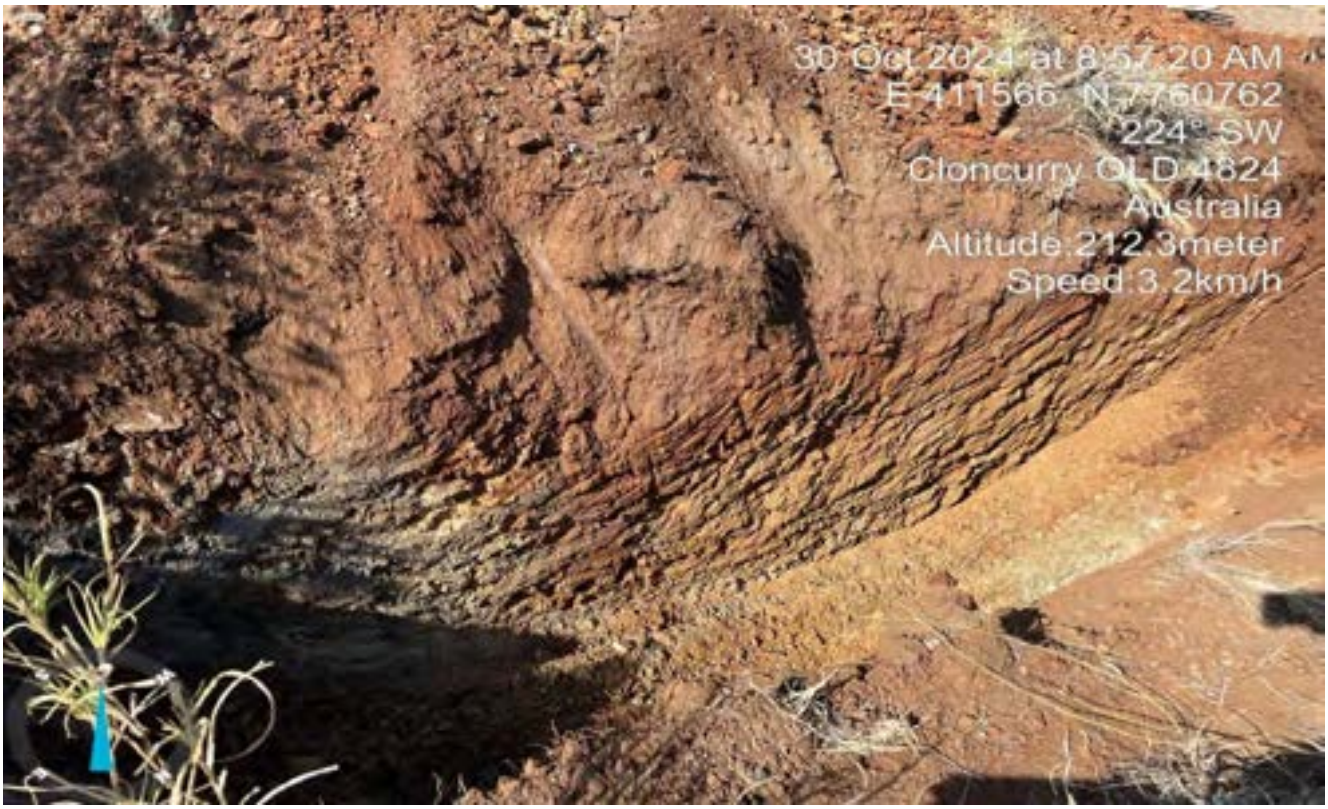
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Client	: MMG Dugald River	Northing	: 7759565.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 31/10/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

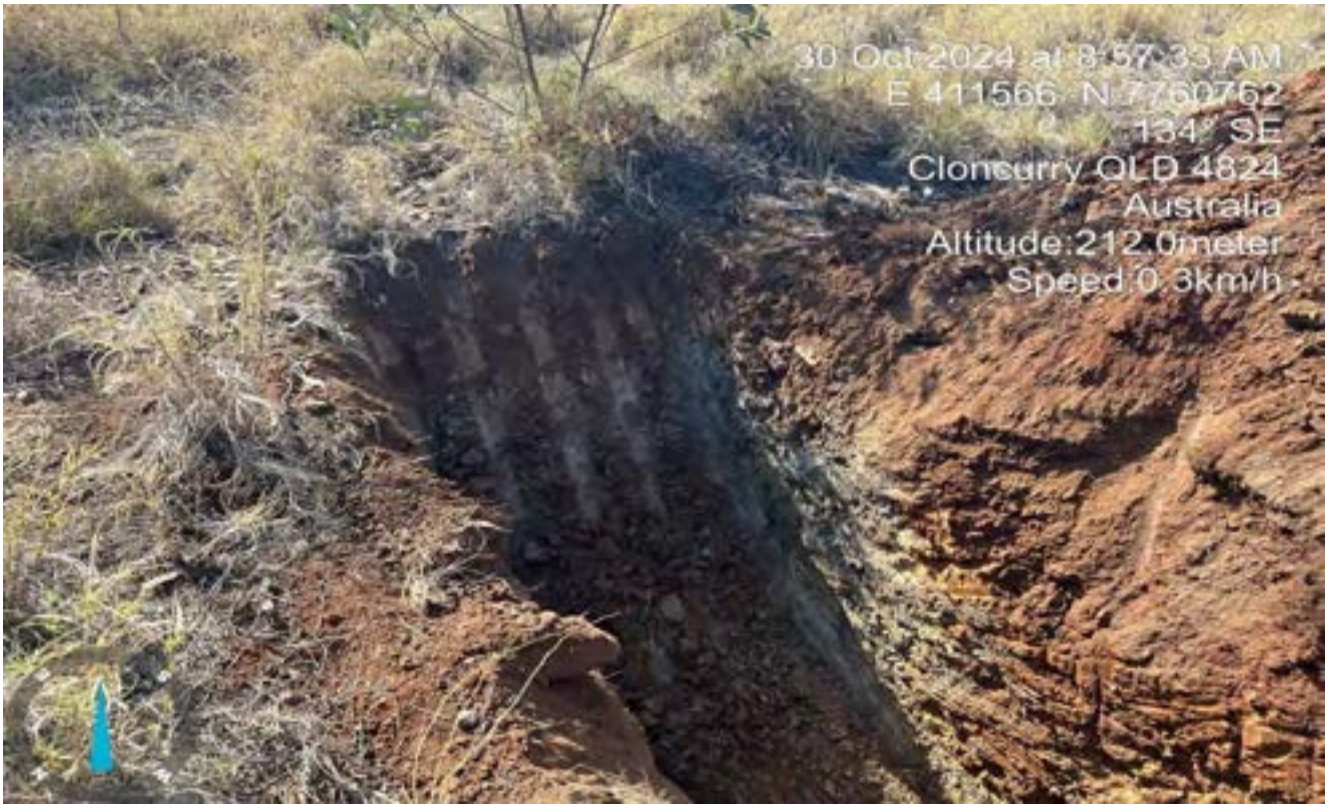
Excavation								Soil Description					Observations
Method	Support	Water	Field Tests	Samples	Recovery	RL (m)	Depth (m)	Graphic Log	Group Symbol	MATERIAL: Origin, Soil Type, Plasticity or Particle Characteristics, Colour, Secondary and Minor Components	Moisture Condition	Consistency / Density	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		CL	RESIDUAL, Sandy CLAY (CL); low plasticity, red brown, fine to coarse grained sand, trace fine to coarse sized gravel.	D	St-V St		
									CL-CI	RESIDUAL, Gravelly to silty CLAY (CL-CI); low to medium plasticity, brown, medium to coarse sized gravel, with sand.	D	D		
							1			**PB 118 refusal at 1.5m**				

REPORT OF TESTPIT: PB 119

Job No	: 240261	Easting	: 411431.00	Sheet	: 1 OF 1
Client	: MMG Dugald River	Northing	: 7759592.00	Logged	: Muhammad Abu Bakar
Project	: PAF PAD Detailed Design	UTM	: 54K	Logged Date	: 03/12/2024
Location	: Dugald River, Cloncurry QLD	Excavator	: CAT 20 Tonne Excavator	Checked	: Asanka Don Peerislage
Contractor	: MMG	Inclination	: -90 deg	Checked Date	: 05/12/2024

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	Pocket Penetrometer UCS (kPa) 0 200 400 600	Structure and Additional Observations
GP Bucket	No Support	N/A					0.1		CL-CI	TOPSOIL, Gravelly CLAY (CL-CI); low to medium plasticity, red brown, medium to coarse sized gravel.	w < PL	St		
							0.5		CI-CH	RESIDUAL, Sandy CLAY (CI-CH); medium to high plasticity, red brown, fine to coarse grained sand, with fine to medium sized gravel.	D	VSt		
									CI-CH	RESIDUAL, Gravelly to silty CLAY (CI-CH); medium to high plasticity, pale brown, fine sized gravel.	w < PL			
										PB 119 refusal at 0.9m				





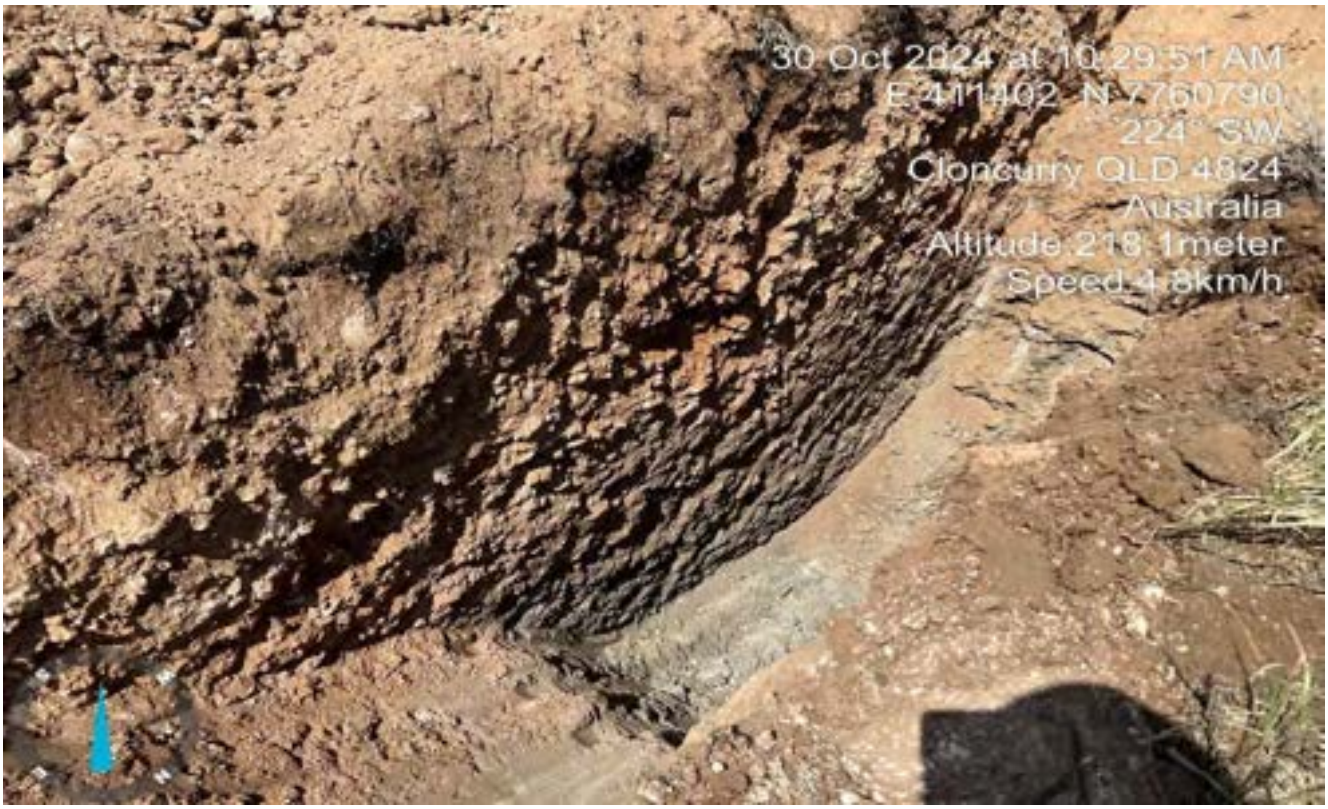
ATC WILLIAMS

Photo description	PAD101		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PAD101	**TP Depth**	2m





Photo description	PAD102		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PAD102	**TP Depth**	0.1m





ATC WILLIAMS

Photo description	PAD103		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PAD103	**TP Depth**	3.8m





ATC WILLIAMS

Photo description	PB101		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 101	**TP Depth**	0.8m





ATC WILLIAMS

Photo description	PB102		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 102	**TP Depth**	1.4m





Photo description	PB103		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 103	**TP Depth**	1.5m





ATC WILLIAMS

Photo description	PB104		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 104	**TP Depth**	2.4m





ATC WILLIAMS

Photo description	PB105		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 105	**TP Depth**	1.5m





Photo description	PB106		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 106	**TP Depth**	1.1m





Photo description	PB107		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 107	**TP Depth**	1.4m





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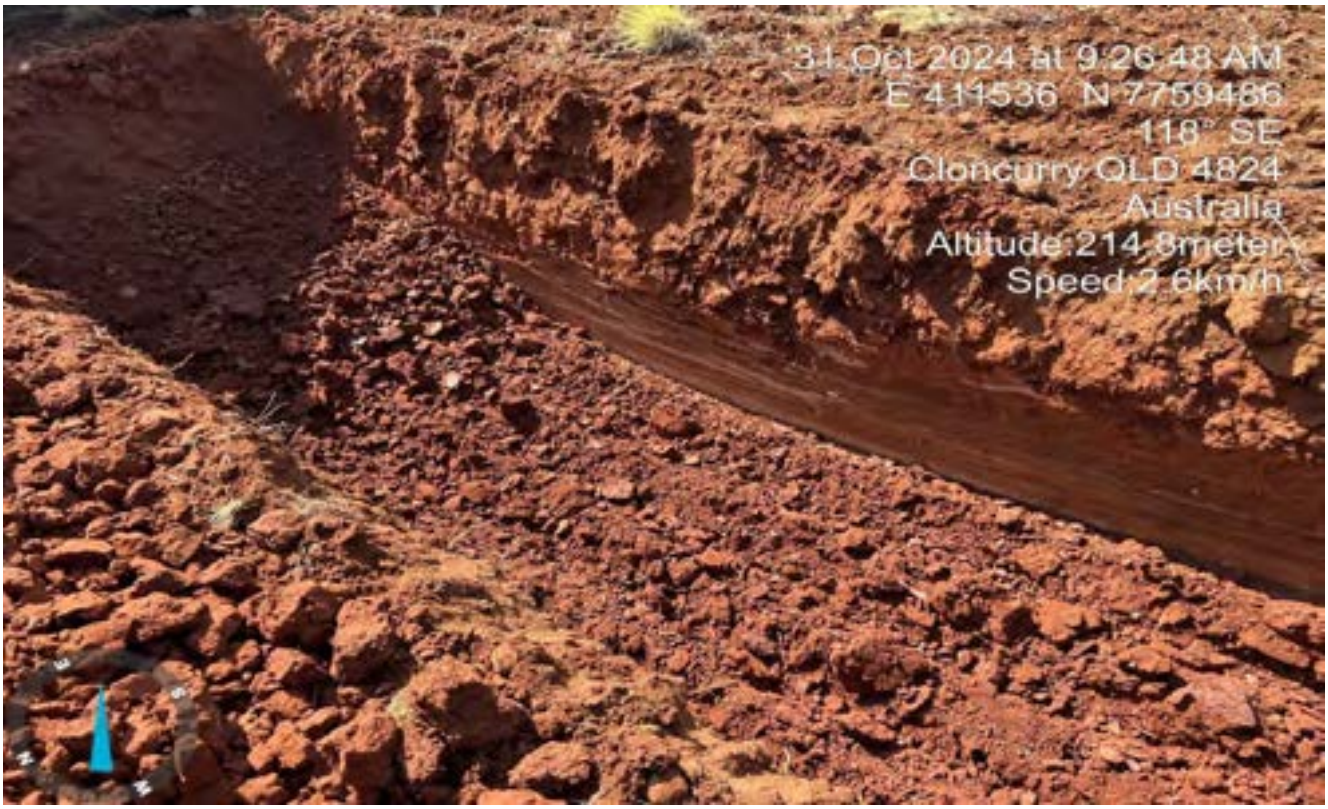
Photo description	PB108		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 108	**TP Depth**	1.2m





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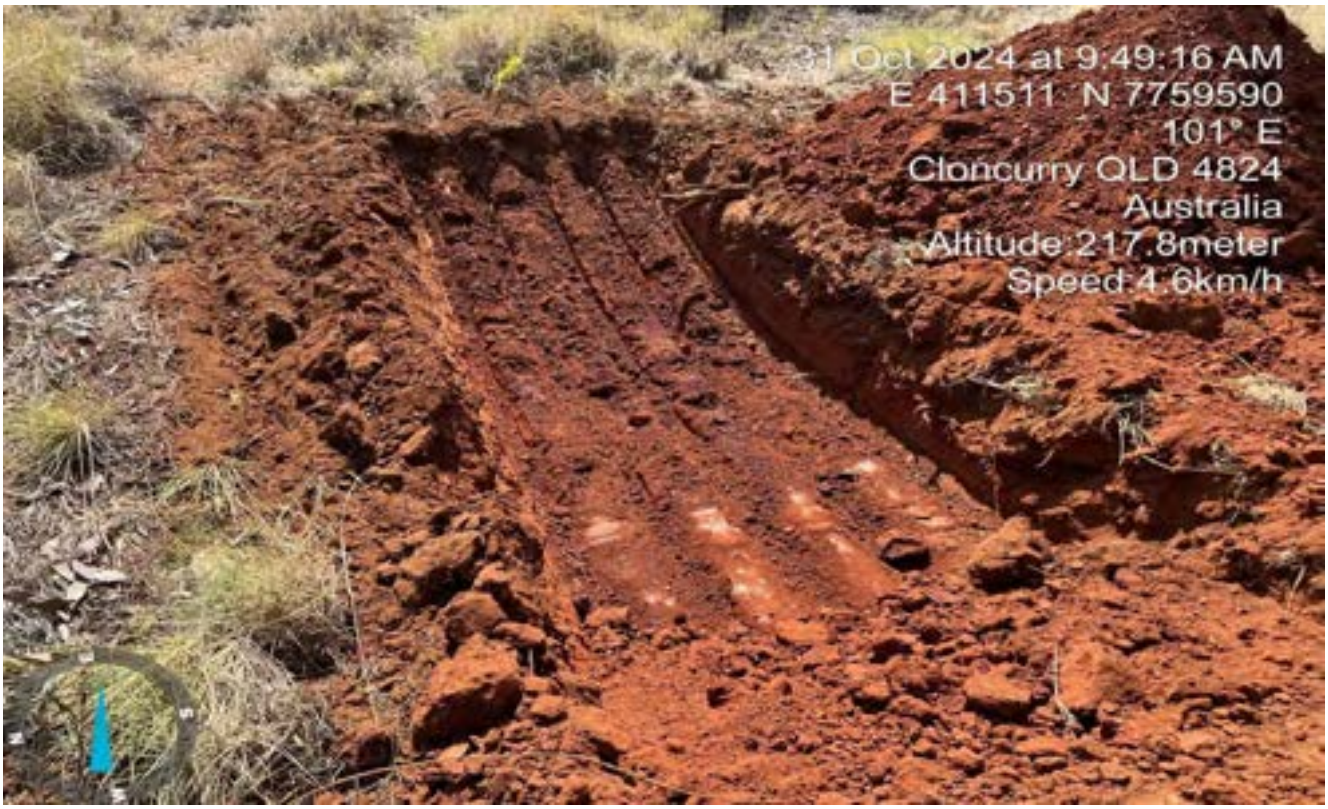
Photo description	PB109		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 109	**TP Depth**	0.9m





ATC WILLIAMS

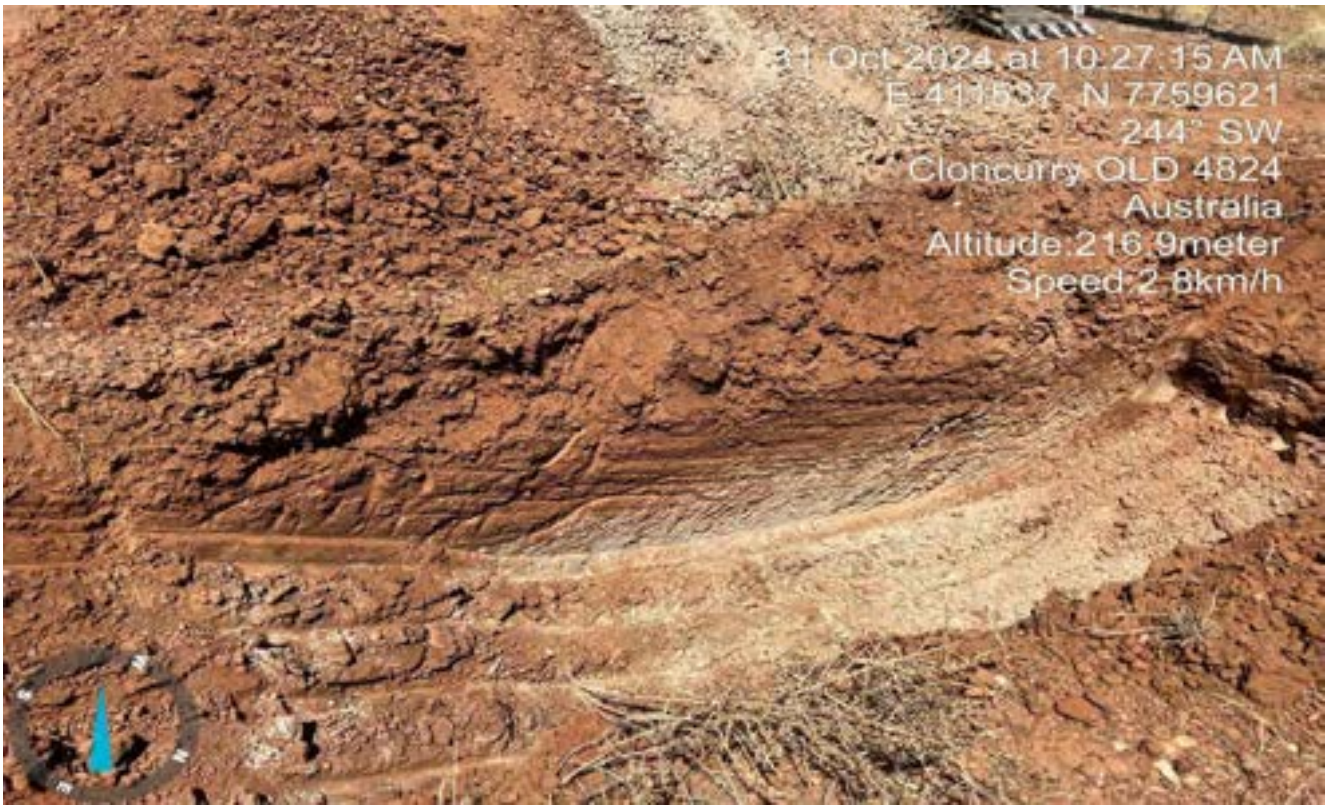
Photo description	PB110		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 110	**TP Depth**	0.5m





ATC WILLIAMS

Photo description	PB111		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 111	**TP Depth**	0.7m





ATC WILLIAMS

Photo description	PB112		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 112	**TP Depth**	1.6m





ATC WILLIAMS

Photo description	PB113		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 113	**TP Depth**	1.1m





ATC WILLIAMS

Photo description	PB114		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 114	**TP Depth**	0.7



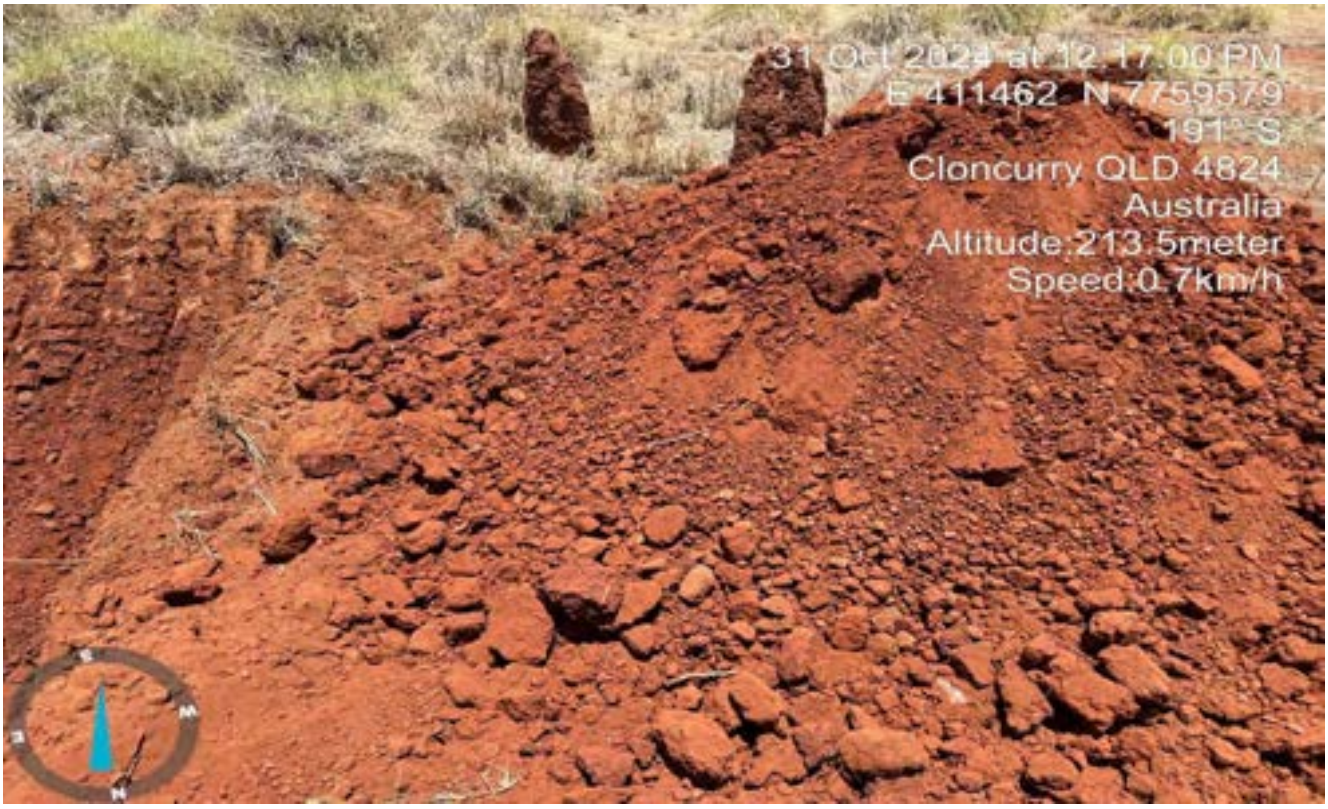


Photo description	PB115		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 115	**TP Depth**	0.6m





ATC WILLIAMS

Photo description	PB116		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 116	**TP Depth**	0.8m





ATC WILLIAMS

Photo description	PB117		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 117	**TP Depth**	0.6m





ATC WILLIAMS

Photo description	PB118		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 118	**TP Depth**	1.5m





ATC WILLIAMS

Photo description	PB119		
Client	MMG Dugald River		
Location	Dugald River, Cloncurry QLD		
Project name	PAF PAD Detailed Design		
Project No	240261	**Scale**	Not to Scale
TP No	PB 119	**TP Depth**	0.9m

ATTACHMENT 4 – LAB TEST CERTIFICATES

TAILINGS.WATER.WASTE.

Particle Size Distribution Results

TEST IN ACCORDANCE WITH AS 1289

☑ Method 3.6.1 ☑ Method 3.6.3

☑ Oven Drying Method 2.1.1

Client: MMG Dugald River Mine

Address: Dugald River Mine Cloncurry QLD 4824

Project: PAF PAD Detailed Design

NATA Report No.: R108424

Job No.: 240261.02

Register No.: 89524

Location: QLD

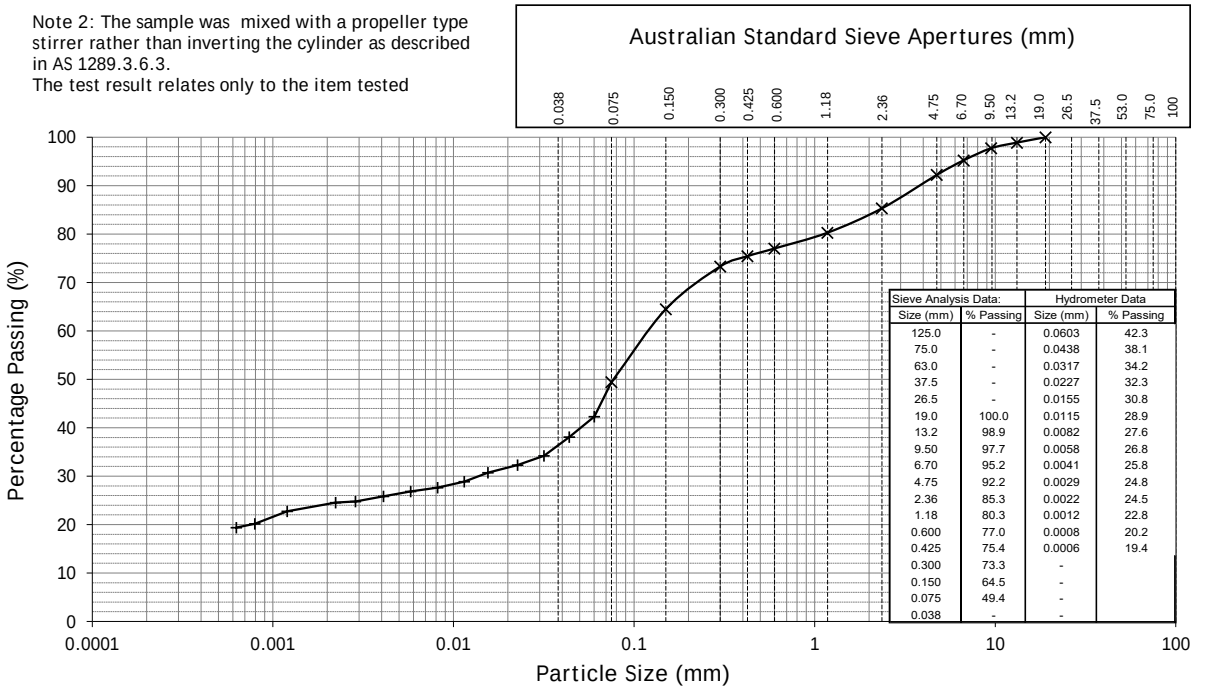
Sample Description: PB103 Clay-Dark Red	Borehole No: ☐	Test Pit Depth: ☐

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	-	0.0603	42.3
75.0	-	0.0438	38.1
63.0	-	0.0317	34.2
37.5	-	0.0227	32.3
26.5	-	0.0155	30.8
19.0	100.0	0.0115	28.9
13.2	98.9	0.0082	27.6
9.50	97.7	0.0058	26.8
6.70	95.2	0.0041	25.8
4.75	92.2	0.0029	24.8
2.36	85.3	0.0022	24.5
1.18	80.3	0.0012	22.8
0.600	77.0	0.0008	20.2
0.425	75.4	0.0006	19.4
0.300	73.3	-	
0.150	64.5	-	
0.075	49.4	-	
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:5-9/12/2024

Name of Signatory: Luke Renkin Date Reported:12/12/2024

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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 Mine

Address: Dugald River Mine Cloncurry QLD 4824

Project: PAF PAD Detailed Design

NATA Report No.: R108524

Job No.: 240261.02

Register No.: 89624

Location: QLD

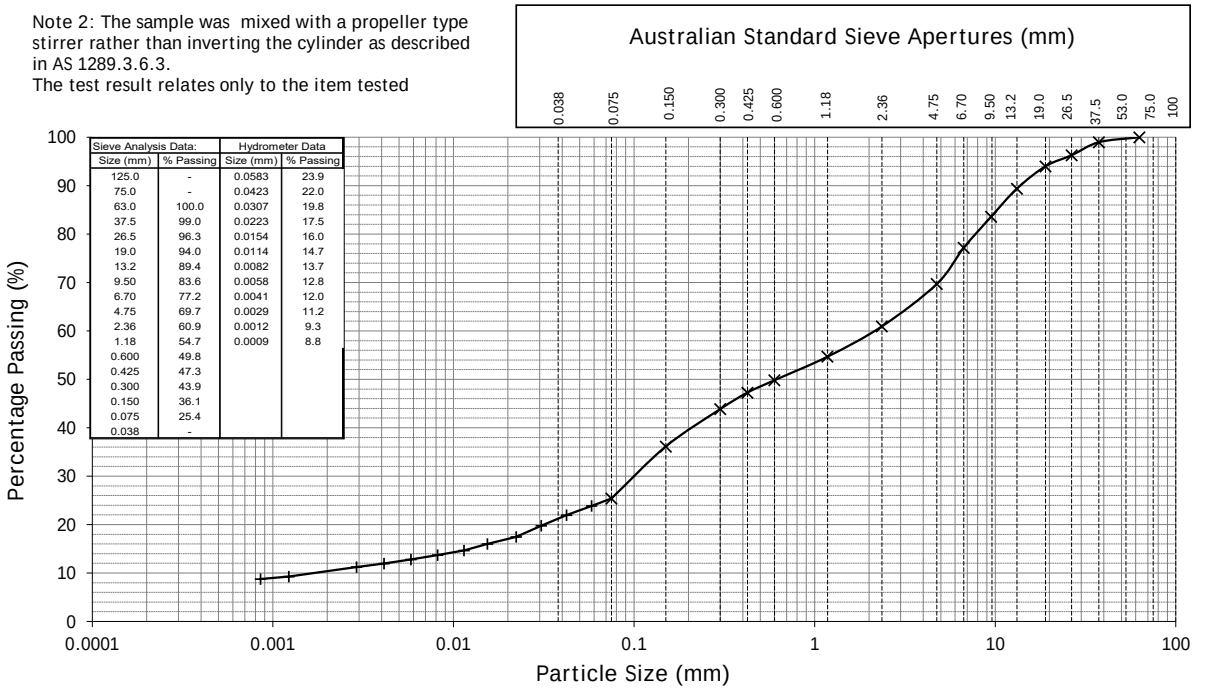
Sample Description: PB104 Clay - Grey	Borehole No: ☐	Test Pit Depth: ☐

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	-	0.0583	23.9
75.0	-	0.0423	22.0
63.0	100.0	0.0307	19.8
37.5	99.0	0.0223	17.5
26.5	96.3	0.0154	16.0
19.0	94.0	0.0114	14.7
13.2	89.4	0.0082	13.7
9.50	83.6	0.0058	12.8
6.70	77.2	0.0041	12.0
4.75	69.7	0.0029	11.2
2.36	60.9	0.0012	9.3
1.18	54.7	0.0009	8.8
0.600	49.8		
0.425	47.3		
0.300	43.9		
0.150	36.1		
0.075	25.4		
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:4-6/12/2024

Name of Signatory: Luke Renkin Date Reported:12/12/2024

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Determination of the Soil Particle Density of a Soil

TEST IN ACCORDANCE WITH AS 1289.3.5.1

Client: MMG Dugald River ..... **Lab Report No.: R108324**

Address: Dugald River Mine Cloncurry QLD 4824..... **Job No.:** 240261.02.....

.....

Project: PAF PAD Detailed Design..... **Location:** QLD.....

Register Number	Sample Description	Test Temperature (°C)	% of Sample >2.36 mm	Particle Density (g/cm^3)
89524	PB103 Clay- Dark Red	26.3	14.7	2.71 *
89624	PB104 Clay-Grey	24.7	39.1	2.75 *

Notes:

☒ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1 Clause 6.5.4

☐ 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: 05-06/12/2024

Name of Signatory: Luke Renkin Date Reported: 12/12/2024

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Form RSN 003.7
Date of Issue: June 2024

Classification (Atterberg Limits)

TEST IN ACCORDANCE WITH AS 1289 – CONE PENETROMETER

Client: MMG Dugald River ..... **Lab Report No.: R108224**

Address: Dugald River Mine Cloncurry QLD 4824..... **Job No.:** 240261.02.....

.....

Project: PAF PAD Detailed Design..... **Location:** QLD.....

Register Number	Sample Description	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Group Classification Symbol
89524	PB103 Clay- Dark Red	34	13	21	-	-
89624	PB104 Clay-Grey	32	17	15	-	-

☒ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1, Clause 6.5.4

☐ 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: 05-06/12/2024

Name of Signatory: Luke Renkin Date Reported: 12/12/2024

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Emerson Class Number

TEST IN ACCORDANCE WITH AS 1289.3.8.1

Client: MMG Dugald River ..... **Lab Report No.: R113124**

Address: Dugald River Mine Cloncurry QLD 4824 ..... **Job No.:** 240261.02 .....

.....

Project: PAF PAD Detailed Design ..... **Location:** QLD .....

Register Number	Sample Description	Date of Sampling	Water				Emerson Class Number
			Origin of Water	Temp °C	Conductivity (µS/cm)	pH	
89524	PB103 Clay	25/11/2024	Distilled	22.9	1.5	5.6	5

Notes:

☒ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1, Clause *6.5.4*

☐ Sample provided by the client

The determination of conductivity was performed according to "in house" test method **IHM 11.0**
The determination of pH was performed according to **AS1289.4.3.1**

The test results relate only to the items tested.

Each procedure of this test was performed for a minimum of 12 hours (overnight) with the exception of the procedure in Clause 6 (f) which was run for the designated 10 minutes.

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory .... Date Tested: 18-19/12/2024

Name of Signatory Luke Renkin Date Reported: 24/12/2024

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Form RSN 0014.10
Date of Issue: June 2024

Permeability – Constant Head Method

TEST IN ACCORDANCE WITH IN-HOUSE PROCEDURE 7.1.1

SAMPLE PREPARATION IN ACCORDANCE WITH

☒ **AS 1289.5.1.1** ☐ **AS 1289.5.2.1**

Client: MMG Dugald River ..... **Lab Report No.: R108724**

Address: Dugald River Mine Cloncurry QLD 4824..... **Job No.:** 240261.02 .....

.....

Project: PAF PAD Detailed Design..... **Location:** QLD .....

Sample Register No.	89524	
Sample	PB 103 Clay -Dark Red	

Sample as prepared

Initial Dry Density (t/m^3)	1.85	
Moisture Content (%)	12.6	
Oversize (>19mm) Discarded (%)	None	

Test Conditions

Surcharge (kPa)	25.7	
Sample Swell During Saturation (mm)	None	
Test Dry Density (t/m^3)	1.85	
Water Used	Melbourne Tap Adjusted to pH 5	
Conductivity of Water (µS/cm)	70	
Hydraulic Gradient	28.7	

Test Results

Permeability @ 20°C (m/s)	3.44 x10^{-10}	
Final Moisture Content (%)	16.3	

Test Notes:

☒ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1, Clause 6.5.4 (Machine Excavated Test Pit)

The test results relate only to the items tested.

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory

Name of Signatory Luke Renkin

Date Tested: 06-09/12/2024

Date Reported: 12/12/2024

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Form RS 013.7
Date of Issue: June 2024

Triaxial Testing - CIU (Multi-stage)

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "STDv2" apparatus

Client:	MMG Dugald River		
Address:	Dugald River Mine	Job No.:	240261.02
	Cloncurry, 4824 QLD	Register No.:	89524
Project:	PAF Pad Detailed Design	Location:	QLD

Report Details:

Report Author:	LR	Report Issued:	14/01/2025
Checked By:	MN	Report Last Updated:	14/01/2025 12:09

Test Details:

Test Start Date:	2/01/2025	Operator:	LR	
Test End Date:	8/01/2025	Membrane Thick.:	1000	µm
Test Type:	CIU (Multi-stage)	Accessible Drainage:	Double	

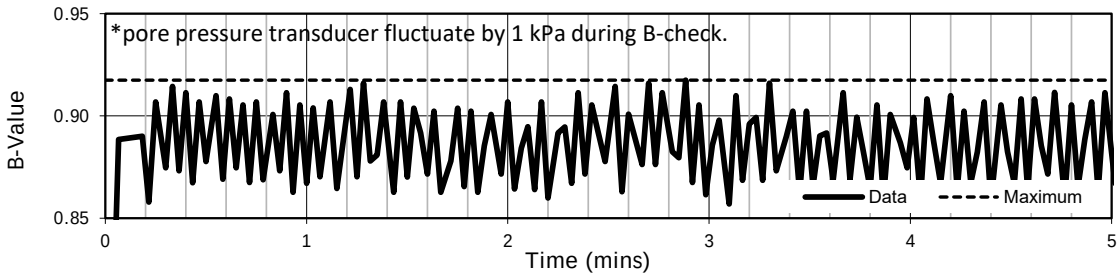
Sample Details:

Register Number:	89524	Date Sampled:	25/11/2024	
Test Number:	1 of 1	Sampled By:	MAB	
Description:	PB 103 Clay-Dark Red	Sample Type:	Remoulded	
Borehole Number:	n/a	Percent Compaction:	95	% SMDD
Depth:	n/a	Particle Density[1], ρ_{st}:	2.71	t/m^3

Specimen Details:

Initial Height:	152.50	mm	Dry Mass, M_d:	1248.07	g
Initial Diameter:	75.00	mm	Initial Area:	44.18	cm^2

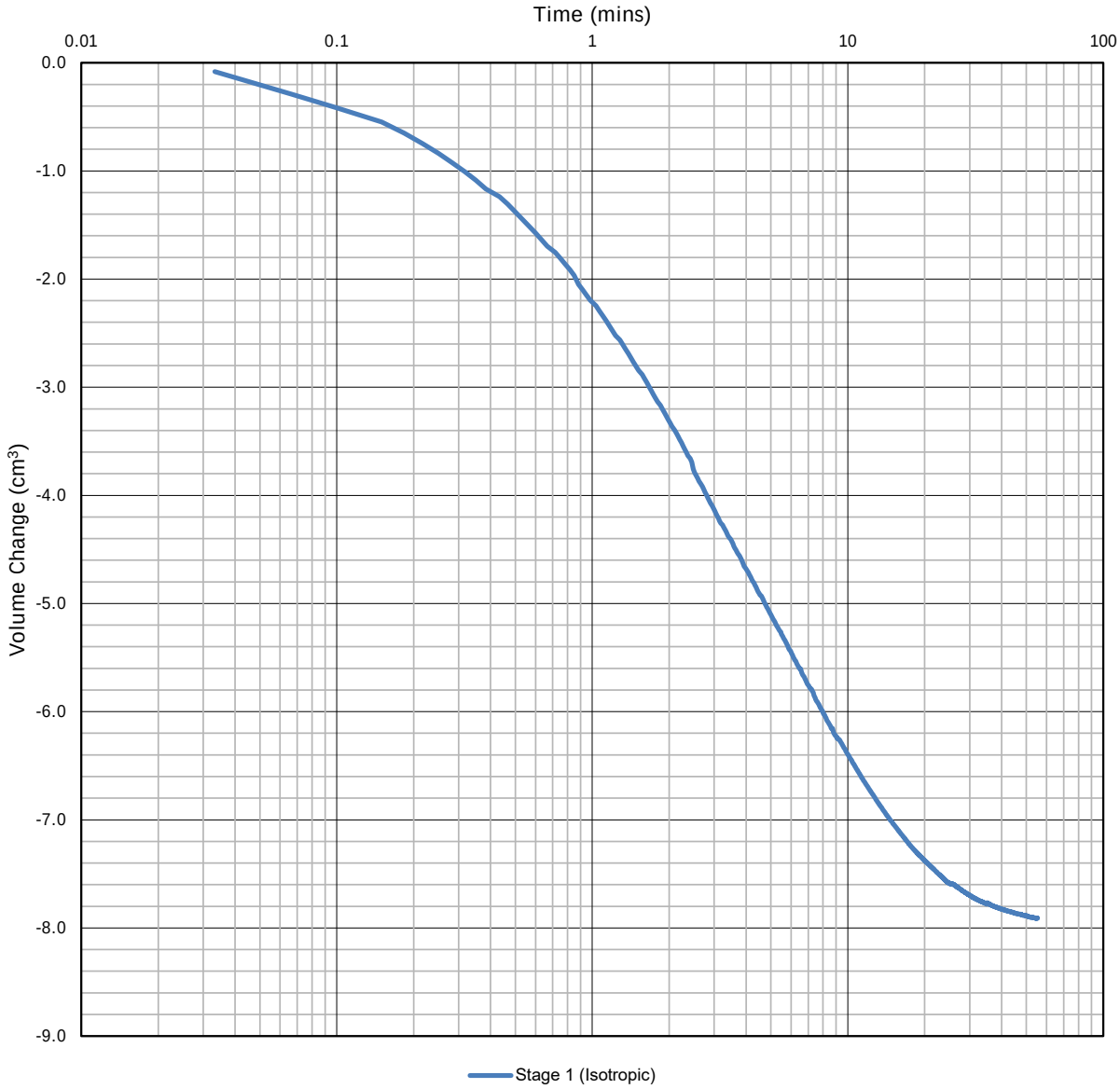
	Placed[2]	Saturated[2]	
Volume, V:	673.72	679.64	cm^3
Dry Density, ρ_d:	1.85	1.84	t/m^3
Void Ratio, e:	0.46	0.48	
Moisture Content, w:	12.20	17.55	%
Degree of Saturation, S:	71	100	%
Effective Confining Pressure, σ'_3:	0	18	kPa



Skempton's B-Value: 0.92 maximum recorded over a 5 minute period.

[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



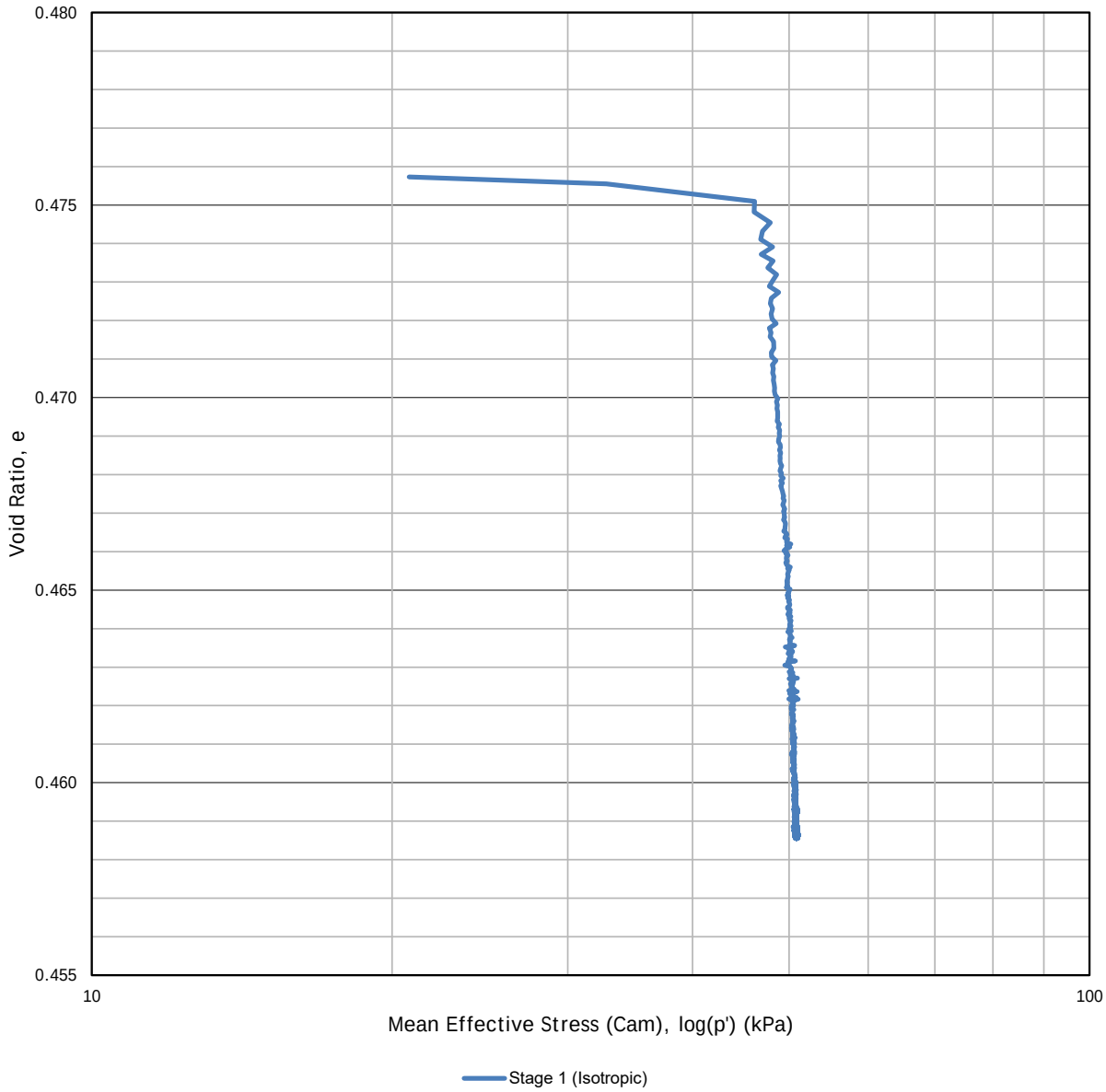
Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	51	-	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	51	-	-	-	-	-	-	kPa
Deformation During Stage, ΔH:	0.35	-	-	-	-	-	-	mm
Volume Change, ΔV:	-7.91	-	-	-	-	-	-	cm^3
Total Volume of Sample, V:	671.72	-	-	-	-	-	-	cm^3
Coefficient of Consolidation, C_v:	241	-	-	-	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	2.70E-08	-	-	-	-	-	-	m/s

MMG Dugald River
PAF Pad Detailed Design
Triaxial - CIU (Multi-stage) - Consolidation (Pre-shearing)

89524
PB 103 Clay-Dark Red
Test 1 of 1

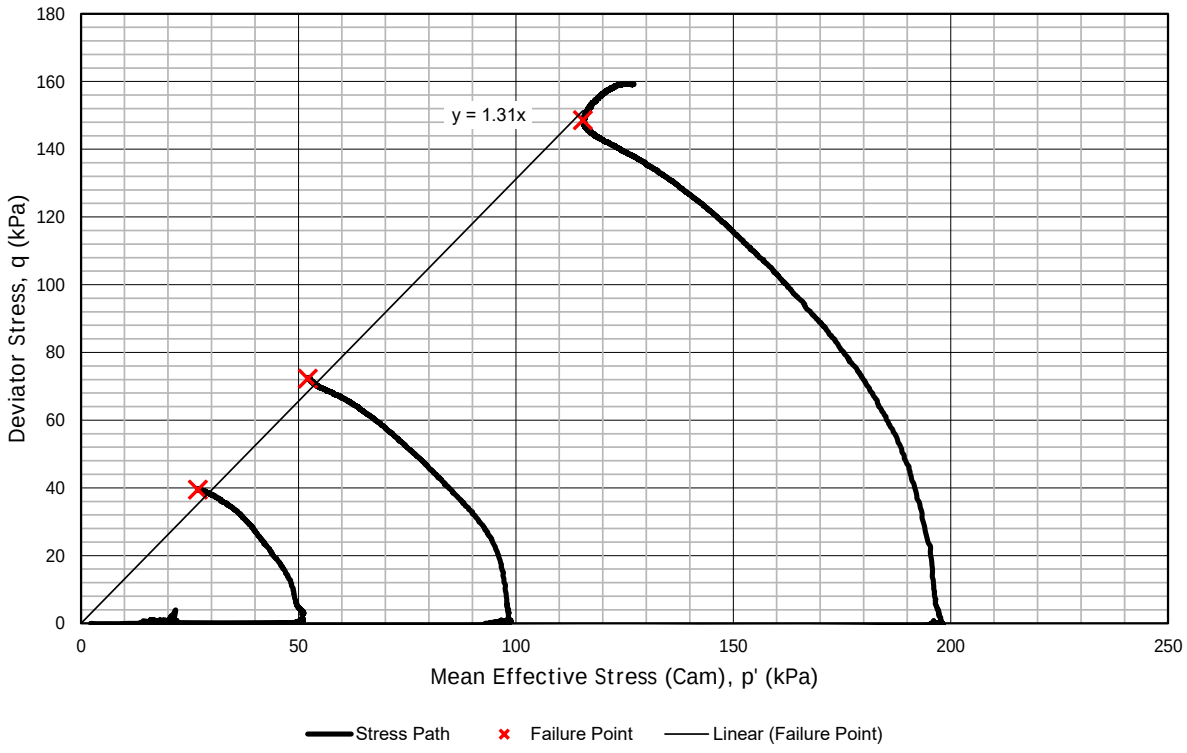
Job No: 240261.02
Date: 14/01/2025

FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	51	-	-	-	-	-	-	kPa
Effective Confining Pressure, σ'_3:	51	-	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	51	-	-	-	-	-	-	kPa
Dry Density, ρ_d:	1.86	-	-	-	-	-	-	t/m^3
Void Ratio, e:	0.46	-	-	-	-	-	-	
Moisture Content (Calculated), w:	16.9	-	-	-	-	-	-	%

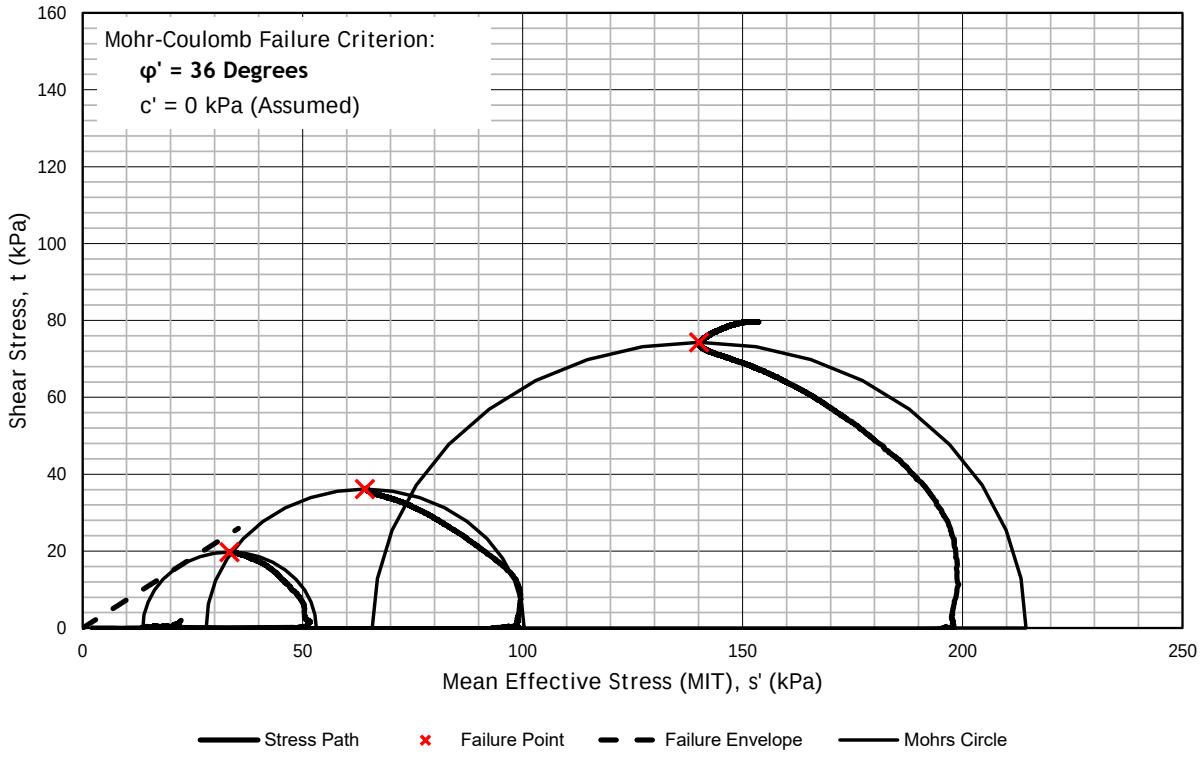
MMG Dugald River PAF Pad Detailed Design Triaxial - CIU (Multi-stage) - Stress Path (Pre-shearing) - e/log(p')	89524 PB 103 Clay-Dark Red Test 1 of 1
ATC WILLIAMS	Job No: 240261.02 Date: 14/01/2025
	FIGURE 2

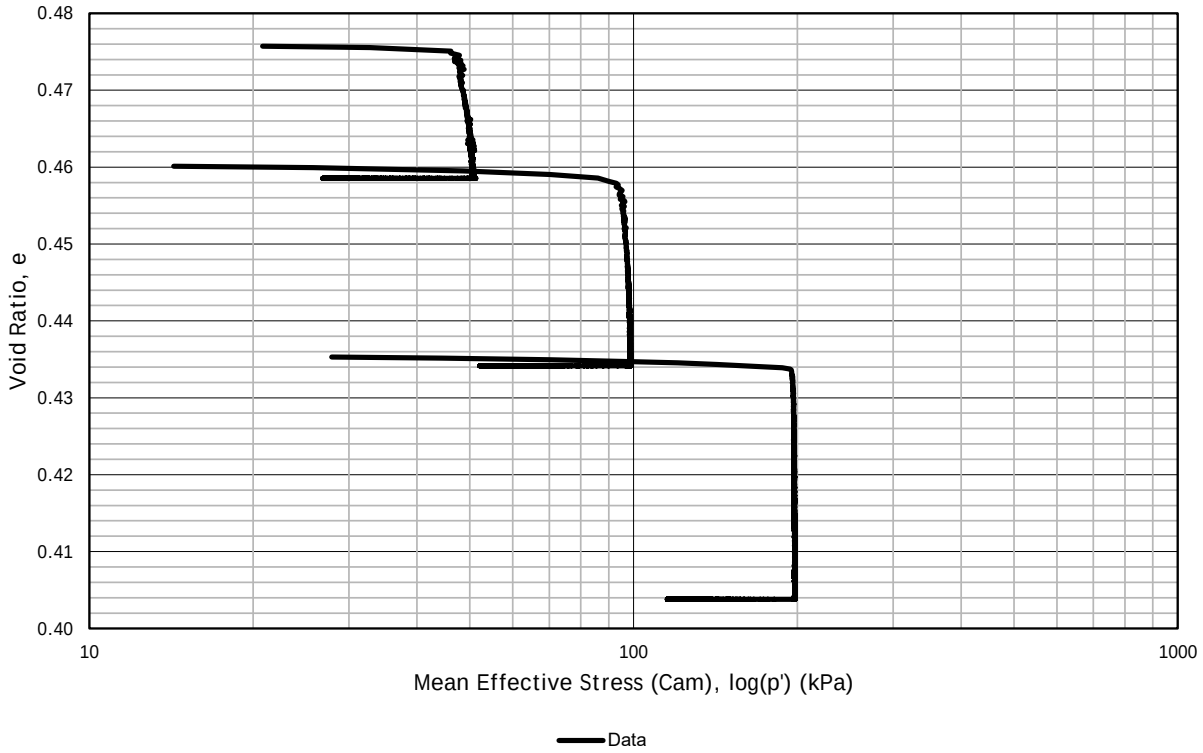


Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	51	99	198	kPa
Initial Effective Confining Pressure, σ'_3:	51	98	198	kPa
Initial Effective Axial Pressure, σ'_1:	52	99	198	kPa
Dry Density, ρ_d:	1.86	1.89	1.93	t/m^3
Void Ratio, e:	0.46	0.43	0.40	
Moisture Content (Calculated), w:	16.9	16.0	14.9	%
Shear Rate, è:	0.05	0.05	0.05	mm/min
Failure Criteria:	QSS	QSS	QSS	
Axial Strain at Failure, ε_a:	1.1	2.5	3.7	%
Deviator Stress at Failure[1], q:	39	72	149	kPa
Undrained Shear Stress at Failure, S_u:	20	36	74	kPa
Mean Effective Stress (Cam) at Failure, p':	27	52	115	kPa
Mean Effective Stress (MIT) at Failure, s':	33	64	140	kPa
Effective Confining Pressure at Failure, σ'_3:	14	28	66	kPa
Effective Axial Stress at Failure, σ'_1:	53	100	214	kPa
Excess Pore Pressure at Failure, u:	37	70	132	kPa
Mode of Failure:		Barrelling		
Undrained Shear Strength Ratio, S_u/σ'_1:	0.38	0.37	0.38	
Internal Friction Angle, ϕ':		36		°

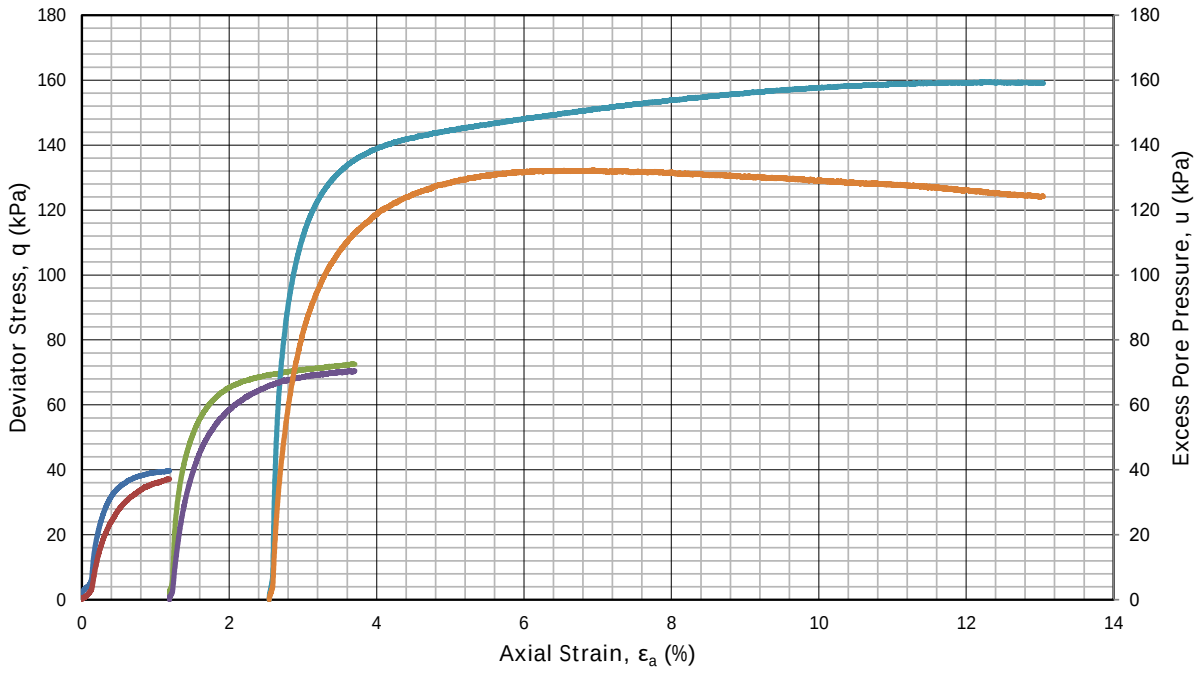
[1] Membrane correction has been applied.

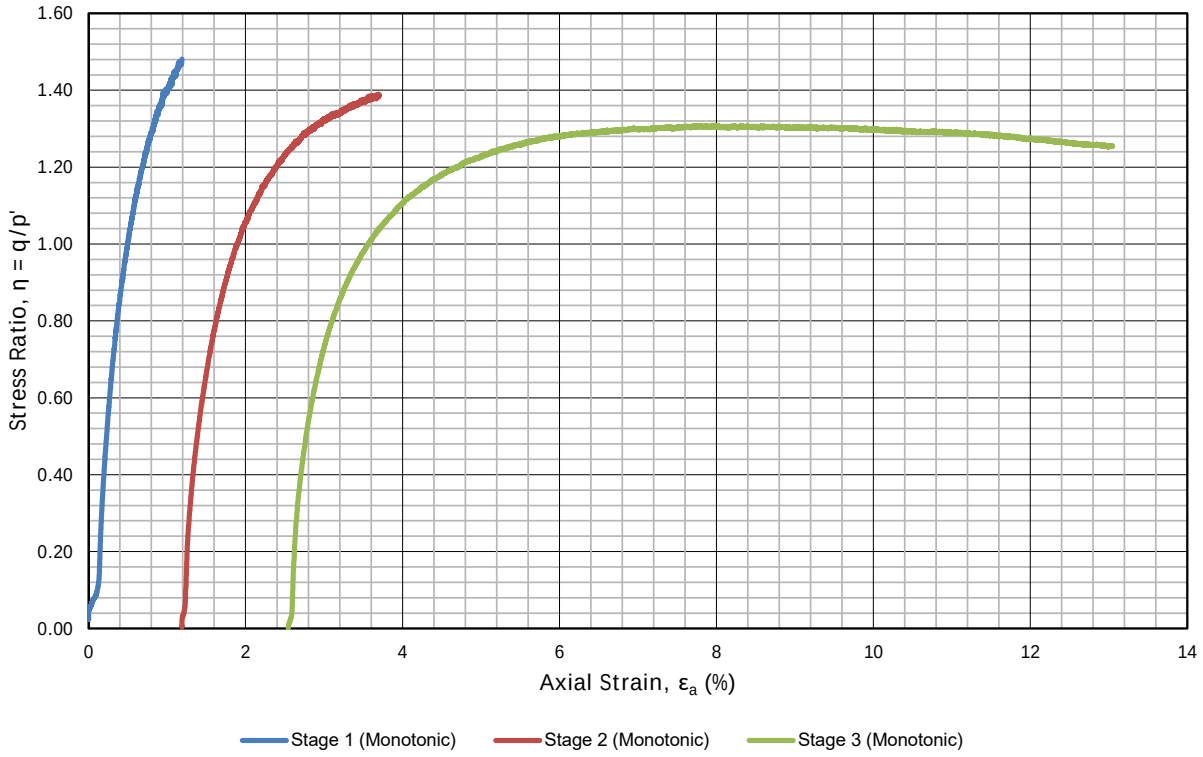
MMG Dugald River PAF Pad Detailed Design Triaxial - CIU (Multi-stage) - Stress Path - q/p'	89524 PB 103 Clay-Dark Red Test 1 of 1
ATC WILLIAMS	Job No: 240261.02 Date: 14/01/2025
	FIGURE 3





MMG Dugald River PAF Pad Detailed Design Triaxial - CIU (Multi-stage) - Stress Paths - S_u/s' and e/log(p')	89524 PB 103 Clay-Dark Red Test 1 of 1
ATC WILLIAMS	Job No: 240261.02 Date: 14/01/2025
	FIGURES 4 & 5





MMG Dugald River PAF Pad Detailed Design **Triaxial - CIU (Multi-stage) - q, u and q/p' vs ε_a**	89524 PB 103 Clay-Dark Red Test 1 of 1
ATC WILLIAMS	Job No: 240261.02 Date: 14/01/2025
	FIGURES 6 & 7



Sample prior to shearing.



Sample after shearing, still within membrane.



Sample after removal from membrane.



Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	0	°

MMG Dugald River PAF Pad Detailed Design Triaxial - CIU (Multi-stage) - Images and Angle of Shear Plane	89524 PB 103 Clay-Dark Red Test 1 of 1
ATC WILLIAMS	Job No: 240261.02 Date: 14/01/2025 FIGURES 8 to 11

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

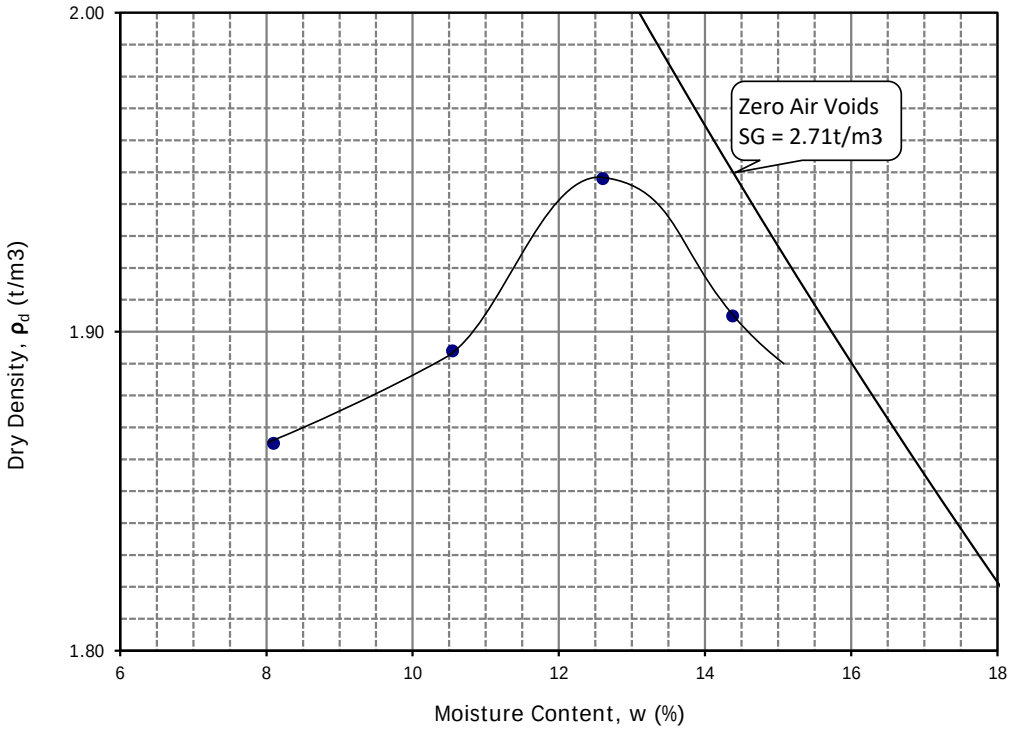
ATC WILLIAMS

Client:	MMG Dugald River Mine	**NATA Report No.:**	**R108624**
Address:	Dugald River Mine Cloncurry QLD 4824	**Job No.:**	240261.02
		Register No.:	89524
Project:	PAF PAD Detailed Design	**Location:**	QLD

Sample Description: PB 103 Clay Dark Red	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 1.95 t/m^3 Optimum Moisture Content 12.5 %

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: _____ Date Tested: 04-06/12/2024

Name of Signatory: Luke Renkin Date Reported: 12/12/2024

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melbourne@atcwilliams.com.au www.atcwilliams.com.au ABN 64 005 931 288

Moisture Content of a Soil

TEST IN ACCORDANCE WITH AS 1289.2.1.1

Client: MMG Dugald River ..... **Lab Report No.: R108124**

Address: Dugald River Mine Cloncurry QLD 4824..... **Job No.:** 240261.02.....

.....

Project: PAF PAD Detailed Design..... **Location:** QLD.....

Register Number	Sample Description	Condition	Moisture Content (%)
89524	PB103 Clay- Dark Red	As Received	6.6
89624	PB104 Clay-Grey	As Received	5.0

Notes:

☒ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1, Clause 6.5.4

☐ Sample provided by the client

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:28/11/2024

Name of Signatory Luke Renkin Date Reported:12/12/2024

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Form RSN 001.9
Date of Issue: June 2024

APPENDIX B – SCHEDULE OF QUANTITIES

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MMG DUGALD RIVER

Dugald River Mine - Stage 4 PAF PAD Expansion Civil Works

SCHEDULE OF QUANTITIES

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT RATE ($)	AMOUNT ($)
1.0	**MOBILISATION AND SITE PREPARATION**				
1.1	Site Establishment Establishment of all personnel, equipment and support facilities on site, including removal at completion and clean-up	Item	1		
1.2	Site Clearing Removal of all debris, shrubs, trees and fallen timber from the PAF Pad and Borrow area. Rate to include haulage and forming into stockpiles within 500 m of works areas if required.	m^2	Rate Only		
1.3	Unsuitable Material Removal of all Unsuitable Materials from Works excavations as directed by the Superintendent. Rate to include all activities associated with excavation, haulage and forming into stockpiles as specified within 500 m of works areas. Where PAF Material is removed this, shall be stockpiled on the PAF PAD.	m^2	Rate Only		
1.4	PAF Dam 1 Removal Removal of PAF Dam 1 and associated infrastructure at the direction of the Superintendent. Cost to include all activities associated with excavation, haulage and forming into stockpiles as specified within 500 m of works areas.	Item	1		
1.5	Borrow Area Development and Management Borrow area development to excavate suitable Type 2 materials for use within the Works. Includes but is not limited to management of the borrow area, removal and temporary stockpile of vegetation/shrub/debris, material compliance testing and final Borrow area closure in accordance with the Specifications and any Principal requirements.	Item	1		
1.6	Topsoil Clearing, grubbing and stripping of 0.2 m of Topsoil within the footprint of the Type A Foundation over Natural Surface.	m^3	6,700		
2.0	**FOUNDATION PREPARATION AND Excavation**				
2.1	Type A - Natural Surface Foundation Preparation Foundation Preparation at the contact areas between PAF Pad fill and undisturbed natural ground. Following the topsoil removal, the area shall be compacted and proof rolled per the specification requirements.	m^2	33,400		
2.2	Type B - Existing Surface Foundation Preparation Foundation Preparation at the contact areas between the PAF Pad fill and the existing PAF Pad. Excavation works shall consist of the excavation of all overlain existing, loose or wet soil and rockfill to the design lines and levels. Type B foundation preparation for the encapsulation layer will generally not be necessary given existing PAF PAD 1 and PAF rockfill only present. However it should be considered and covered under item 3.3.	m^2	1,530		

MMG DUGALD RIVER

Dugald River Mine - Stage 4 PAF PAD Expansion Civil Works

SCHEDULE OF QUANTITIES

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT RATE ($)	AMOUNT ($)
3.0	**PAF PAD AND PERIMETER DRAIN CONSTRUCTION**				
3.1	Type 2 Capping Material - PAF PAD Construction of the PAF Pad impermeable Liner. Win from Borrow and/or temporary stockpiles, haul, spread, moisture treatment (as necessary) and compaction to achieve 98% SMDD (validated by testing) in accordance with the Specifications to the lines and levels shown in the Drawings.	m^3	24,700		
3.2	Type 2 Capping Material - PAF PAD PERIMETER DRAINS Construction of the PAF Pad impermeable Liner. Win from Borrow and/or temporary stockpiles, haul, spread, moisture treatment (as necessary) and compaction to achieve 98% SMDD (validated by testing) in accordance with the Specifications to the lines and levels shown in the Drawings.	m^3	2,200		
3.3	PAF - Rockfill Remove any wet soils, spread and compact existing PAF PAD 1 PAF Rockfill to the required design lines and levels per specification requirements. Win from Stage 1 PAF PAD and PAF WRD, haul, spread, moisture treatment (as necessary) and compact in accordance with the Specifications to the lines and levels shown in the Drawings.	m^3	16,000		
3.4	NAF - Rockfill Construction of the PAF PAD and Perimeter Drains. Win from NAF WRD, temporary stockpiles and/or permanent stockpiles, haul, spread, moisture treatment (as necessary) and compact in accordance with the Specifications to the lines and levels shown in the Drawings.	m^3	70,000		
3.5	NAF - Crushed Rockfill Construction of the PAF PAD and Perimeter Drains. Win by crushing NAF Rockfill, temporary stockpile, haul, spread, moisture treatment (as necessary) and compact in accordance with the Specifications to the lines and levels shown in the Drawings.	m^3	17,100		
3.6	NAF - Crushed Rockfill (Crushed by Principal) Construction of the PAF PAD and Perimeter Drains. Win from temporary stockpiles, haul, spread, moisture treatment (as necessary) and compact in accordance with the Specifications to the lines and levels shown in the Drawings.	m^3	17,100		
3.7	NAF - Rock Armour (Erosion Protection Rockfill) Construction of the PAF Perimeter Drains. NAF (Rock armour D50 150 mm) Placement of Rock Armour within the PAF Perimeter Drains and required locations. Produce at borrow sources, stockpile (as necessary), haul, spread and shape in accordance with the Specification to form the lines and levels shown in the Drawings	m^3	200		
3.8	Geotextile Placement, overlapping and securing of a Bidim A64 Geotextile Underlay within the PAF Perimeter Drains to the lines and levels shown in the Drawings and in accordance with the Specifications				
3.8.1	*PAF PAD 2 Drain Modification (D50 = 150)*	m^2	620		
3.8.2	*Stage 4 PAF PAD Dam 1 inlet (New Drain) (D50 = 150).*	m^2	300		

APPENDIX P: Tailings Storage Facility – Stage 3 Raise Detailed Design Report (ATCW, 2026d)

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:

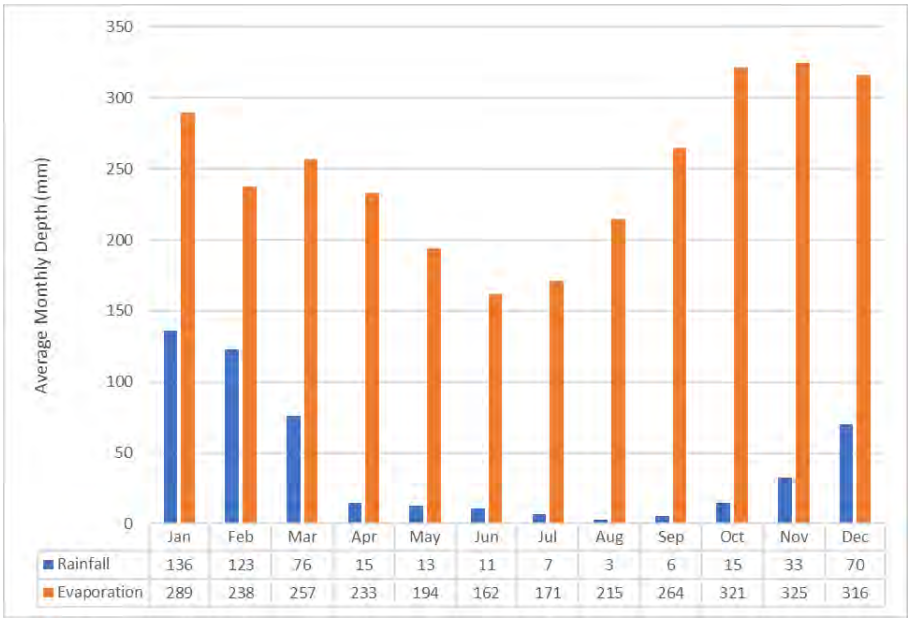
- There are no significant aquifers within the Knapdale Quartzite. The mylonitic fault which separates the quartzite from the Corella Formation to the east is considered to form a low permeability groundwater disconnect.
- Minor perched zones occur in the upper 10 m of the quartzite formation where unloading 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

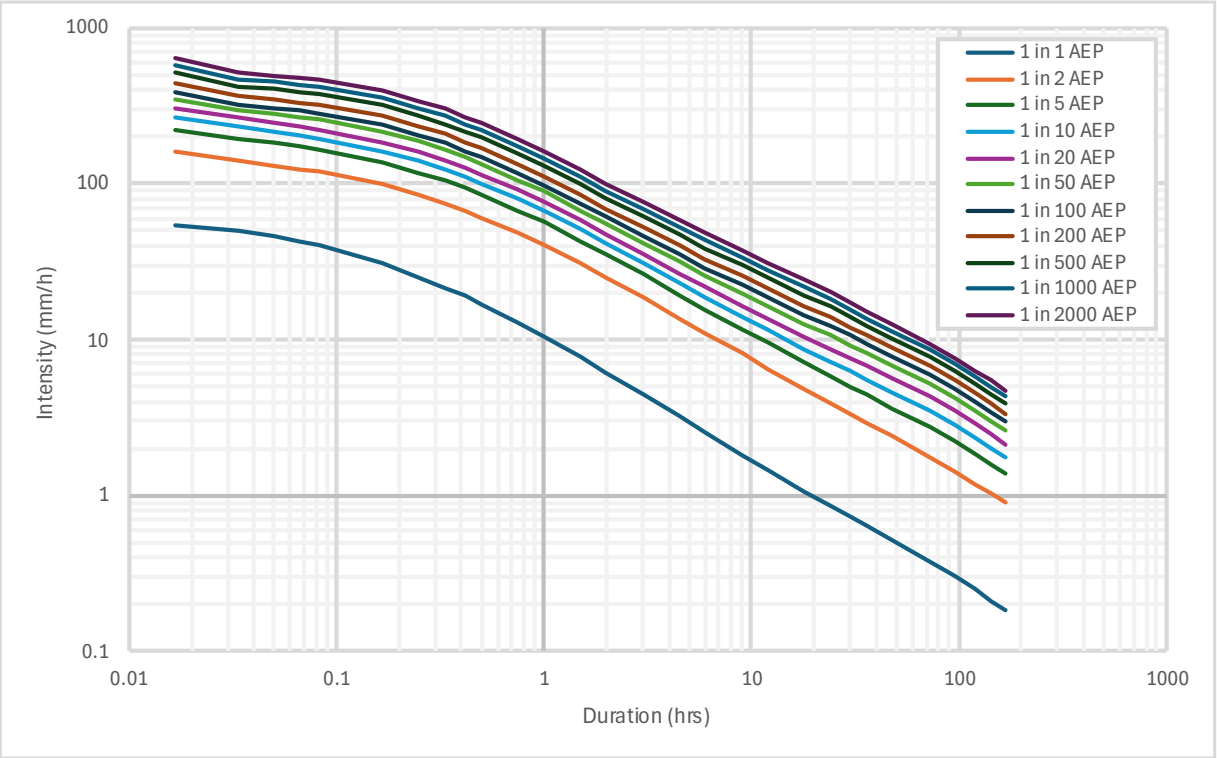


TABLE 5.1 – DESIGN RAINFALL DEPTHS

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’.

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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

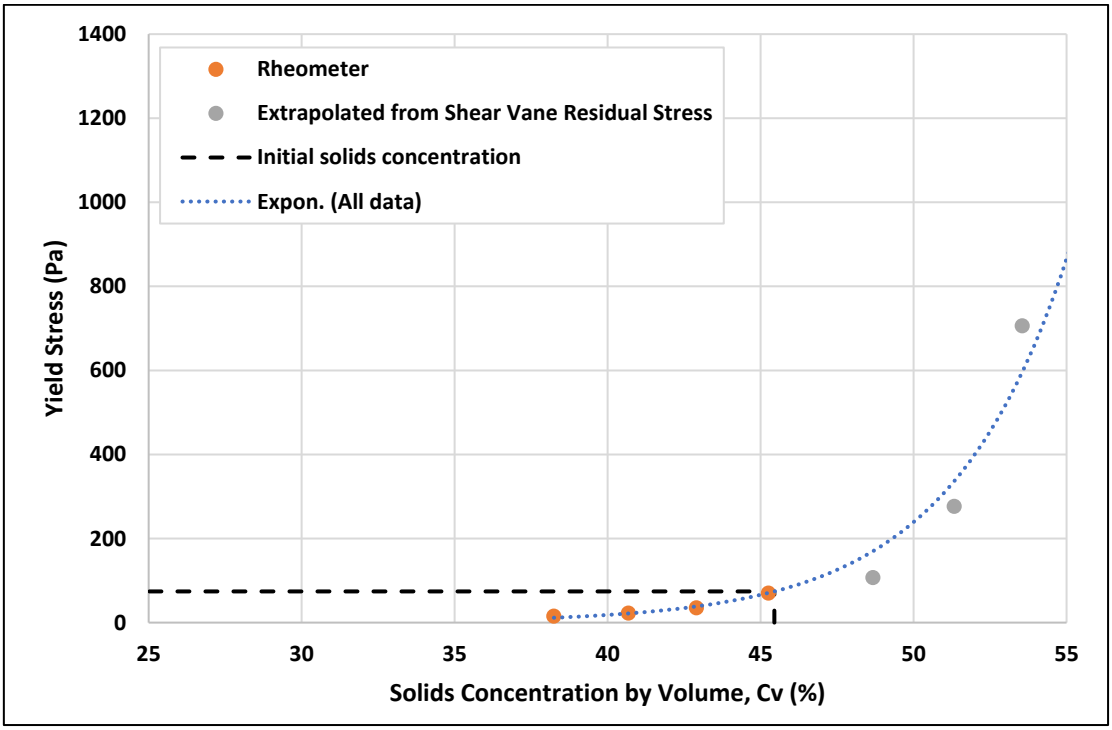
The tailings rheological parameters define the non-Newtonian flow characteristics of the liquefied tailings, and have been obtained from the following laboratory testing which have been completed in ATCW's Melbourne laboratory:

- Bob and Cup Rheology Test
- Shear Vane with Shrinkage Limit Density Testing

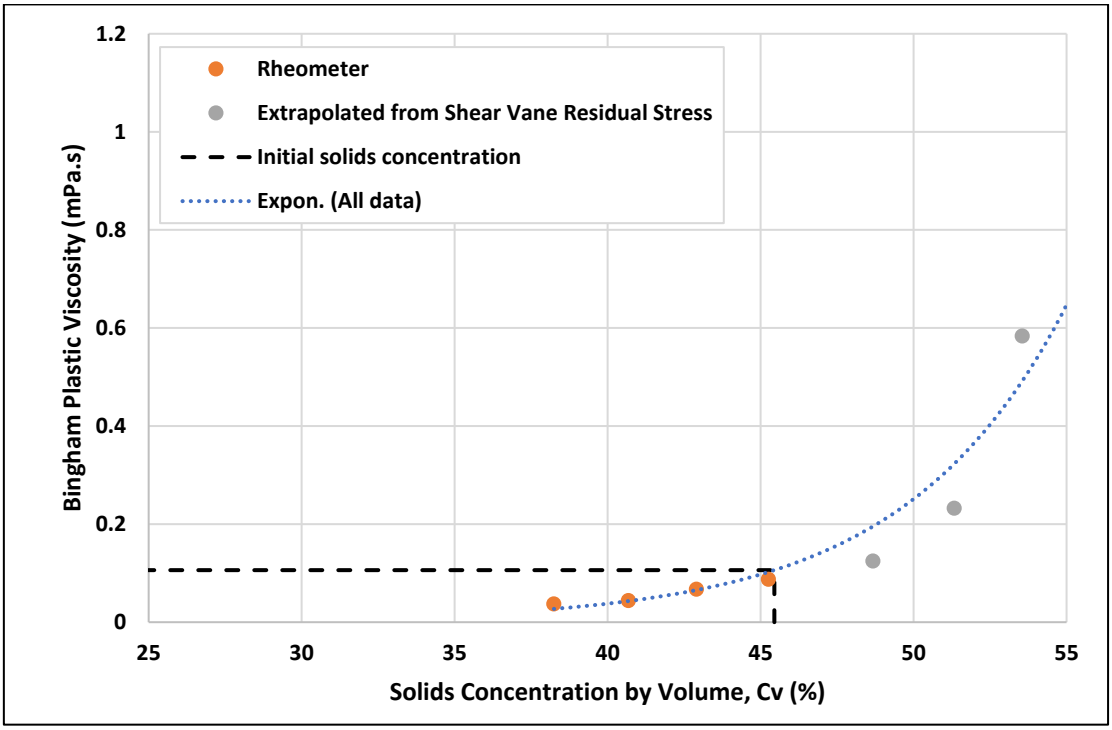
The exponential relationships between the Bingham Plastic yield stress and the Bingham Plastic viscosity versus solids concentration is presented in **Graph 7.1** and **Graph 7.2**.

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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

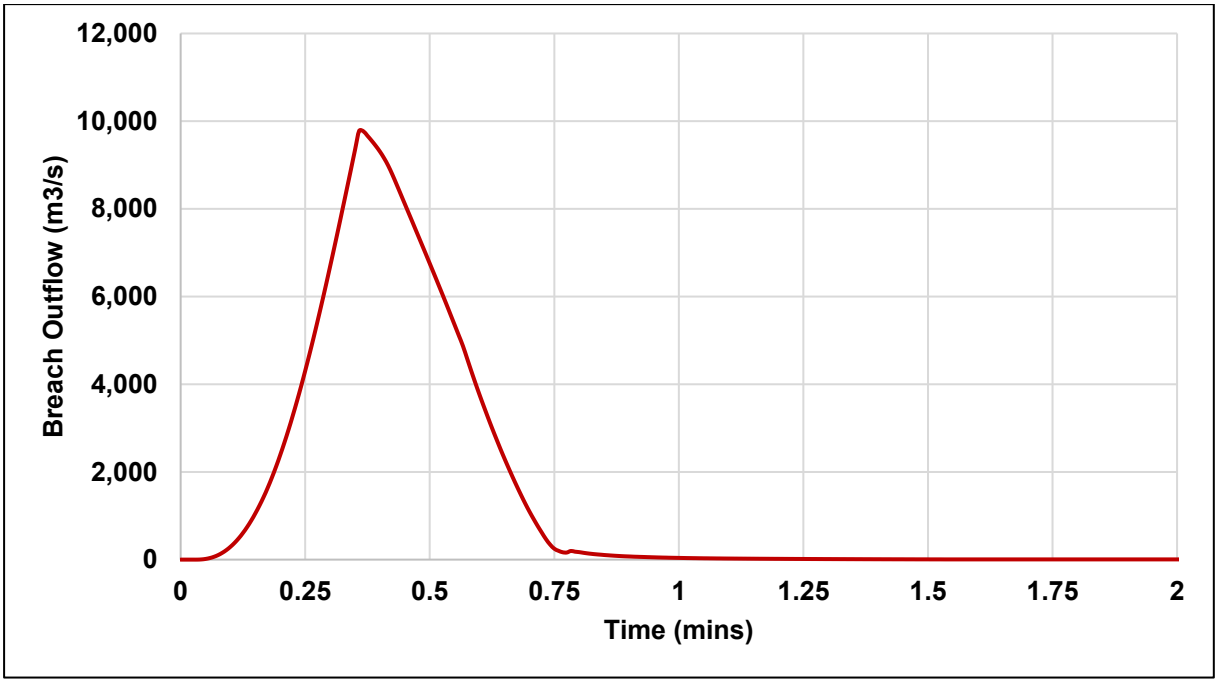
Parameter	SDF
Tailings Release Volume	3,859,700 m3
Water Release Volume	7,248,500 m3

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.

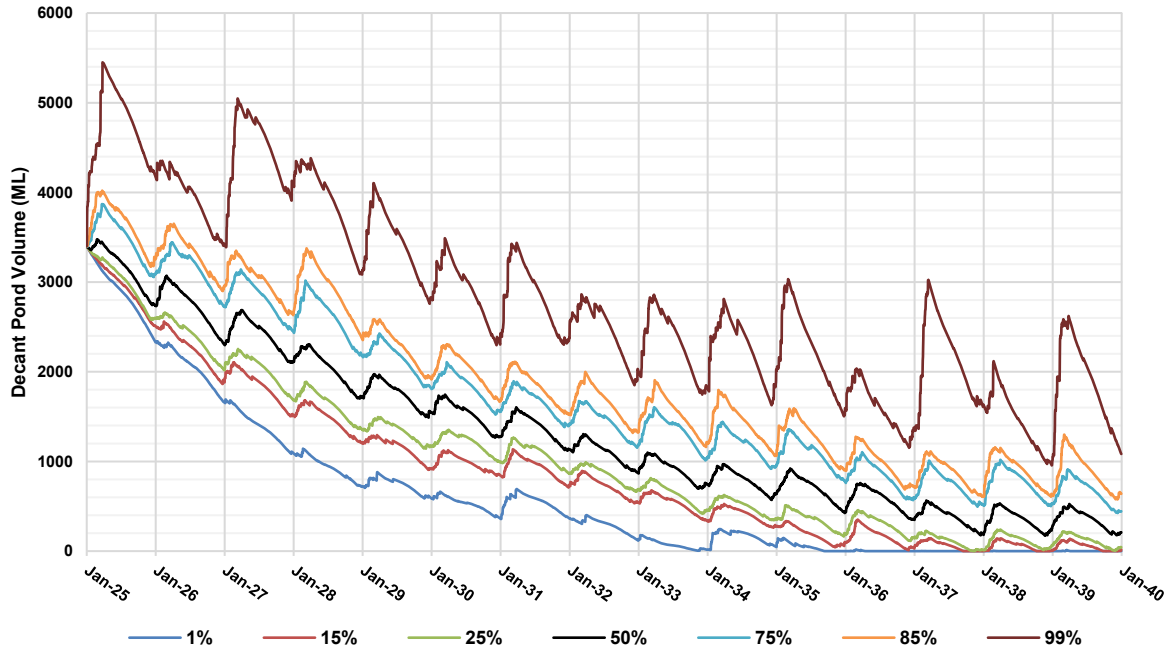
9.1.2 Operating Pond

The outcomes from the water balance study are shown in **Graph 9.1** and **Graph 9.2**.

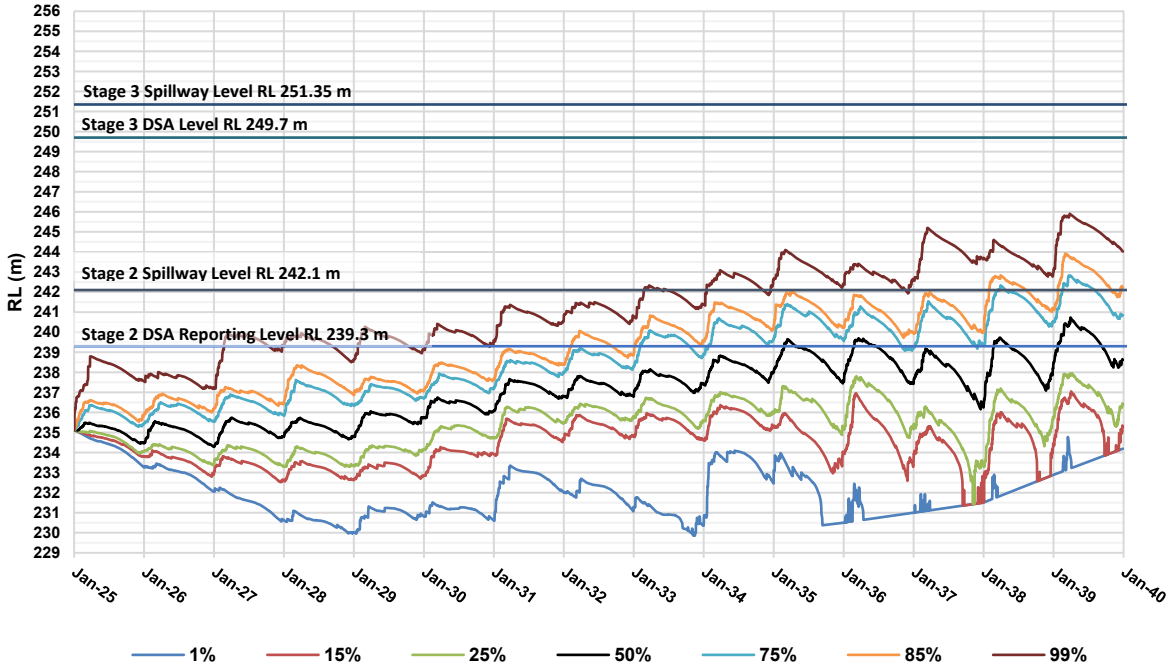
The results of the water balance modelling indicate the following:

- 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

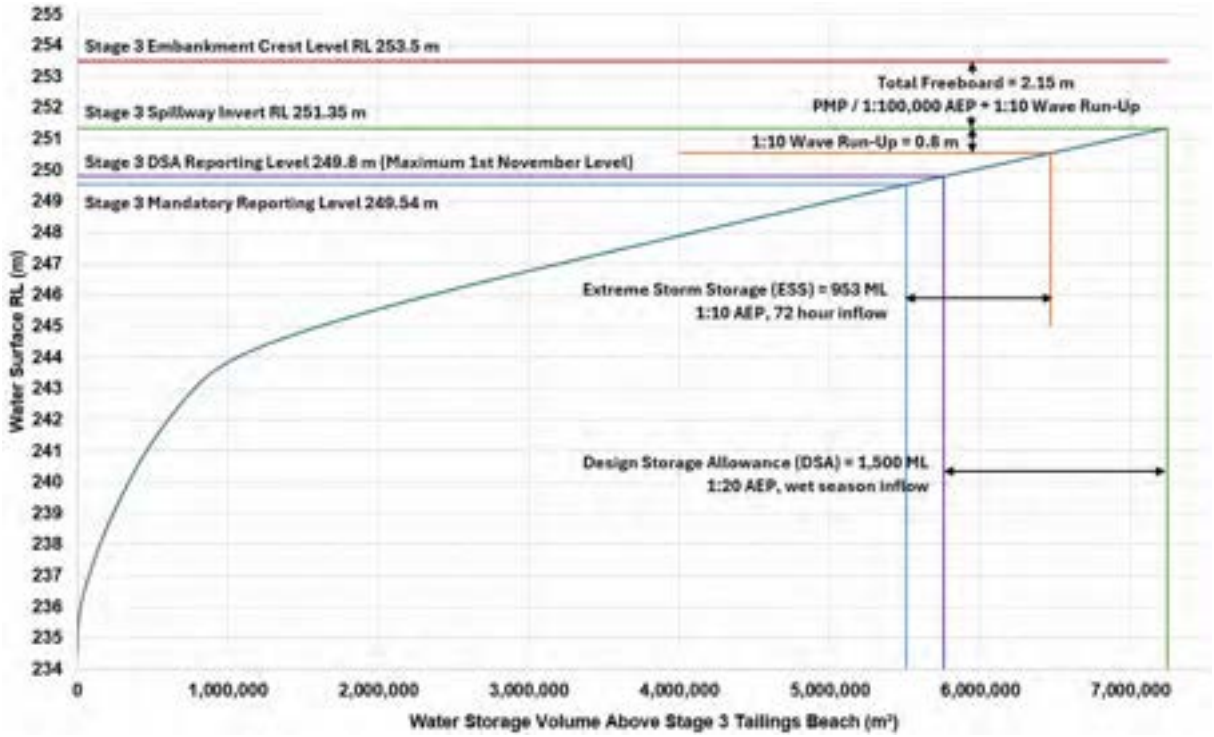
A spillway invert level of RL 251.35 m has been set for the Stage 3 TSF as discussed in **Section 9.3**.

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

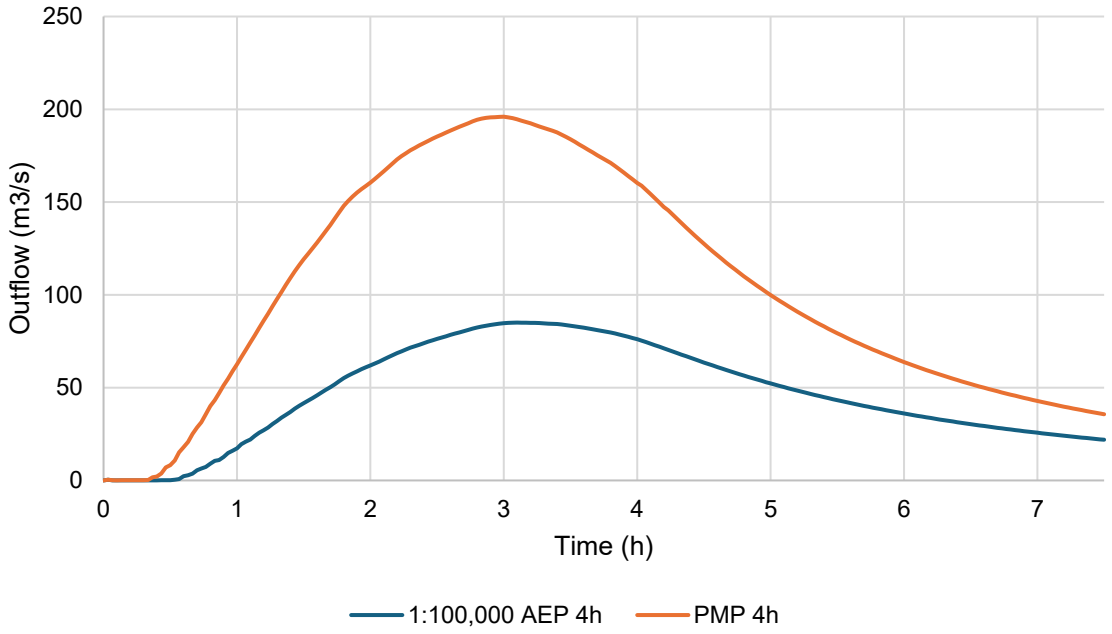
The TUFLOW model was run for both the 1:100,000 AEP and PMP design rainfall estimates, for the 0.25 hr to 6 hr durations. The results of the spillway routing assessment are summarised in **Table 9.7** and represent the critical duration event as determined from the hydraulic modelling.

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.

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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.

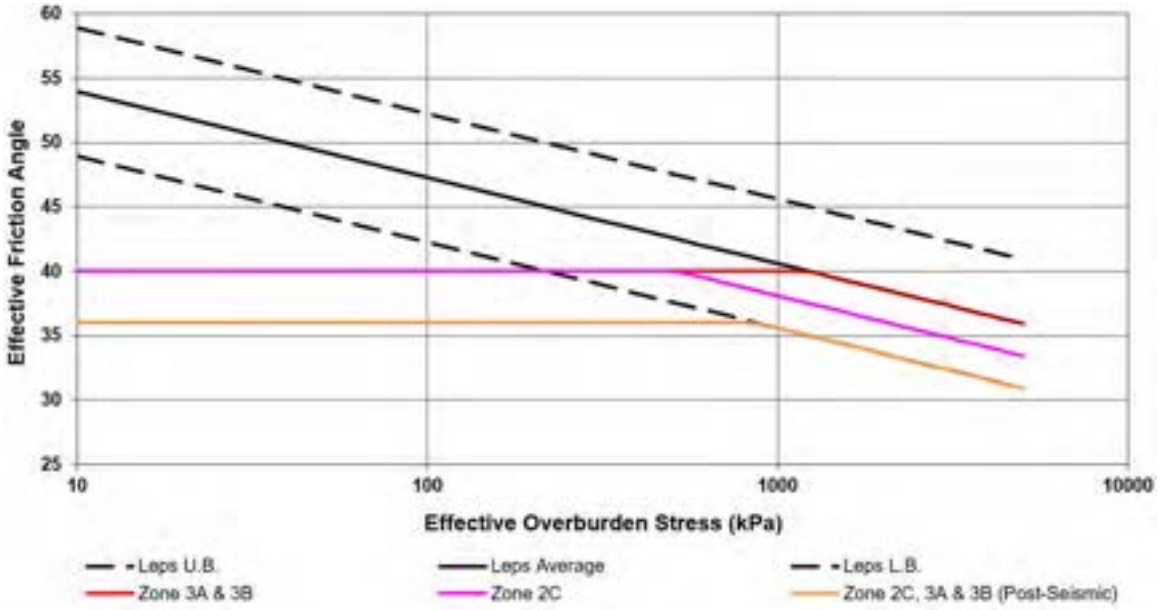
In order to represent the strength of the rockfill material, Leps **[33]** functions have been adopted. Leps is a database method which adopts upper, average and lower bound strength functions based on varying materials of different grading, density and strength. The database is based on a large amount 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.

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**.

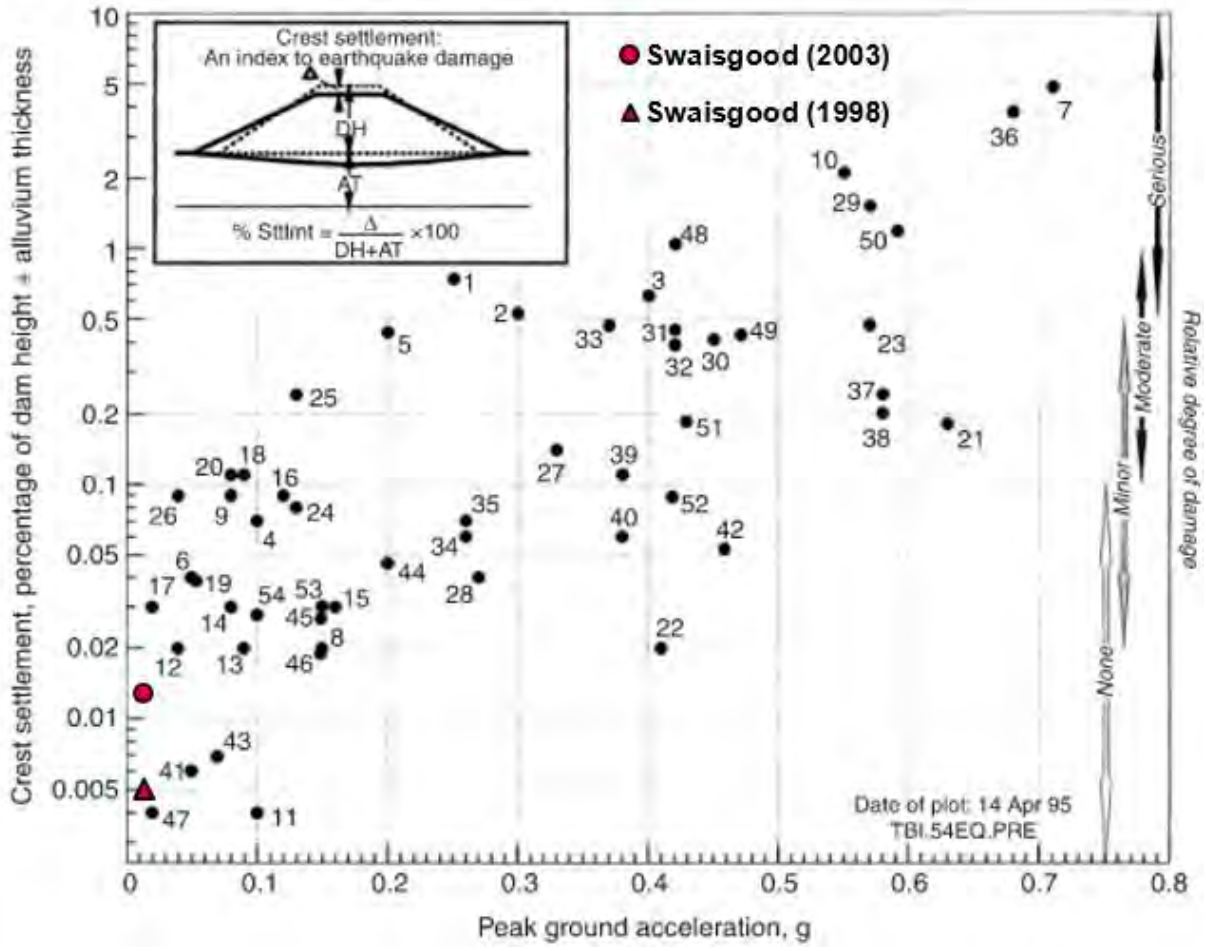
The results of Swaisgood **[34] [35]** estimates crest settlements in the range of 0 to 6 mm, which indicates a relative degree of damage of “None” as shown in **Graph 14.1.**

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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)

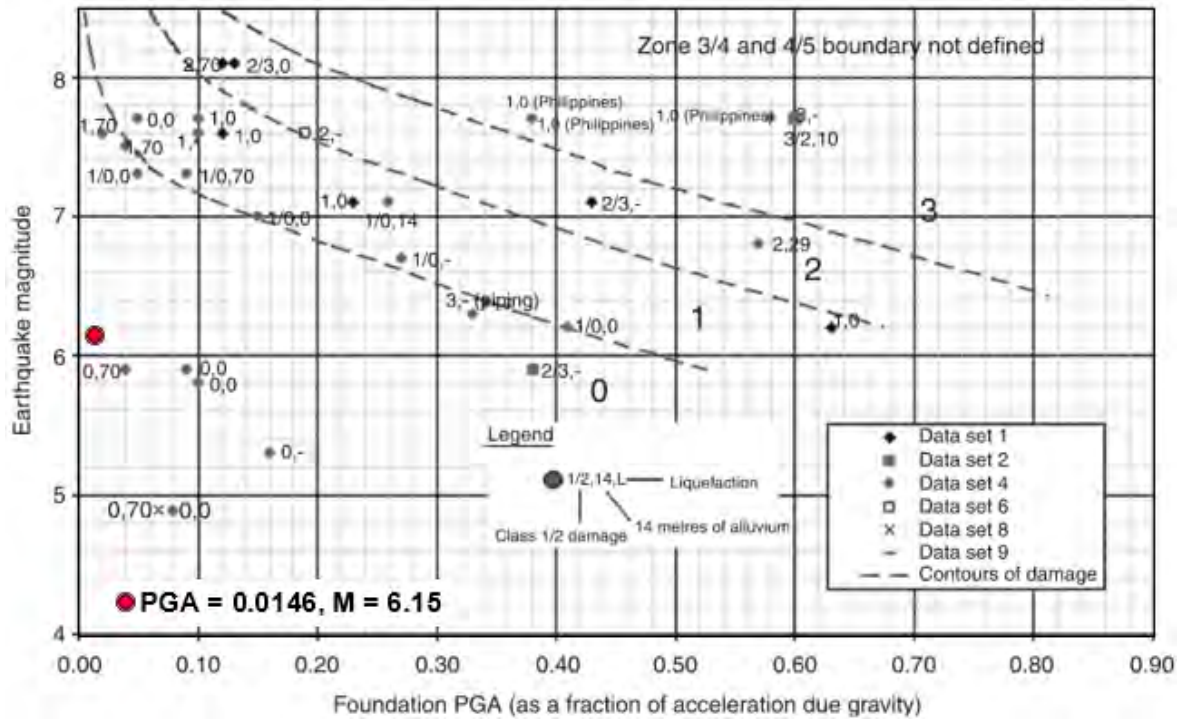


TABLE 14.2 – DAMAGE CLASSIFICATION SYSTEM (PELLS AND FELL 2003)

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.

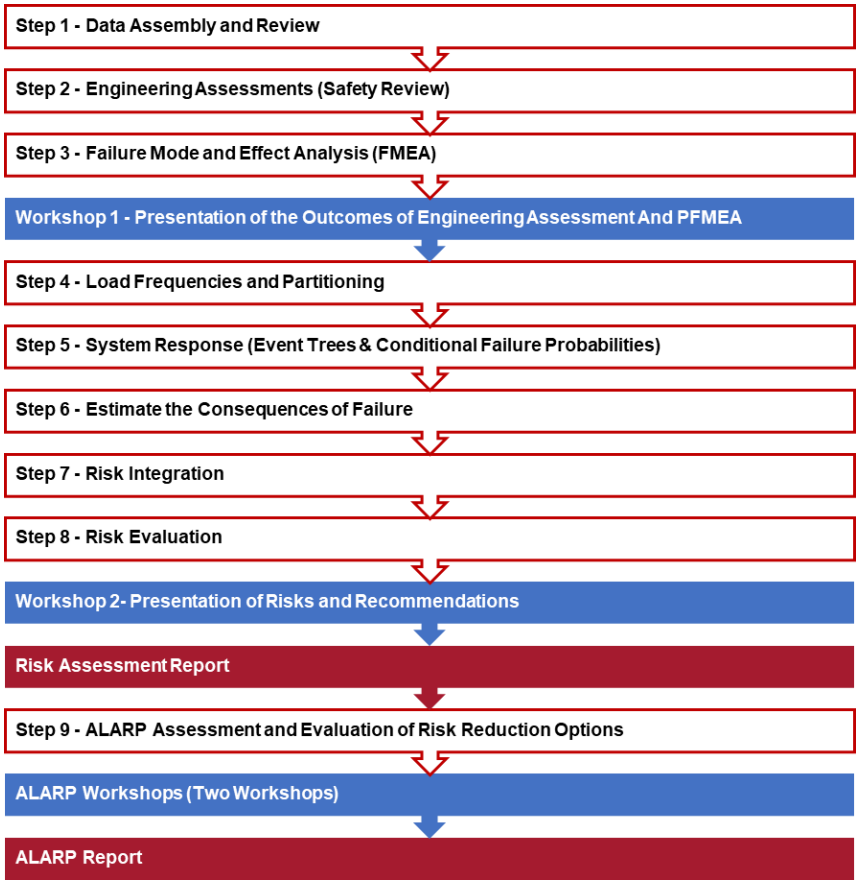
15.2 Methodology

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.

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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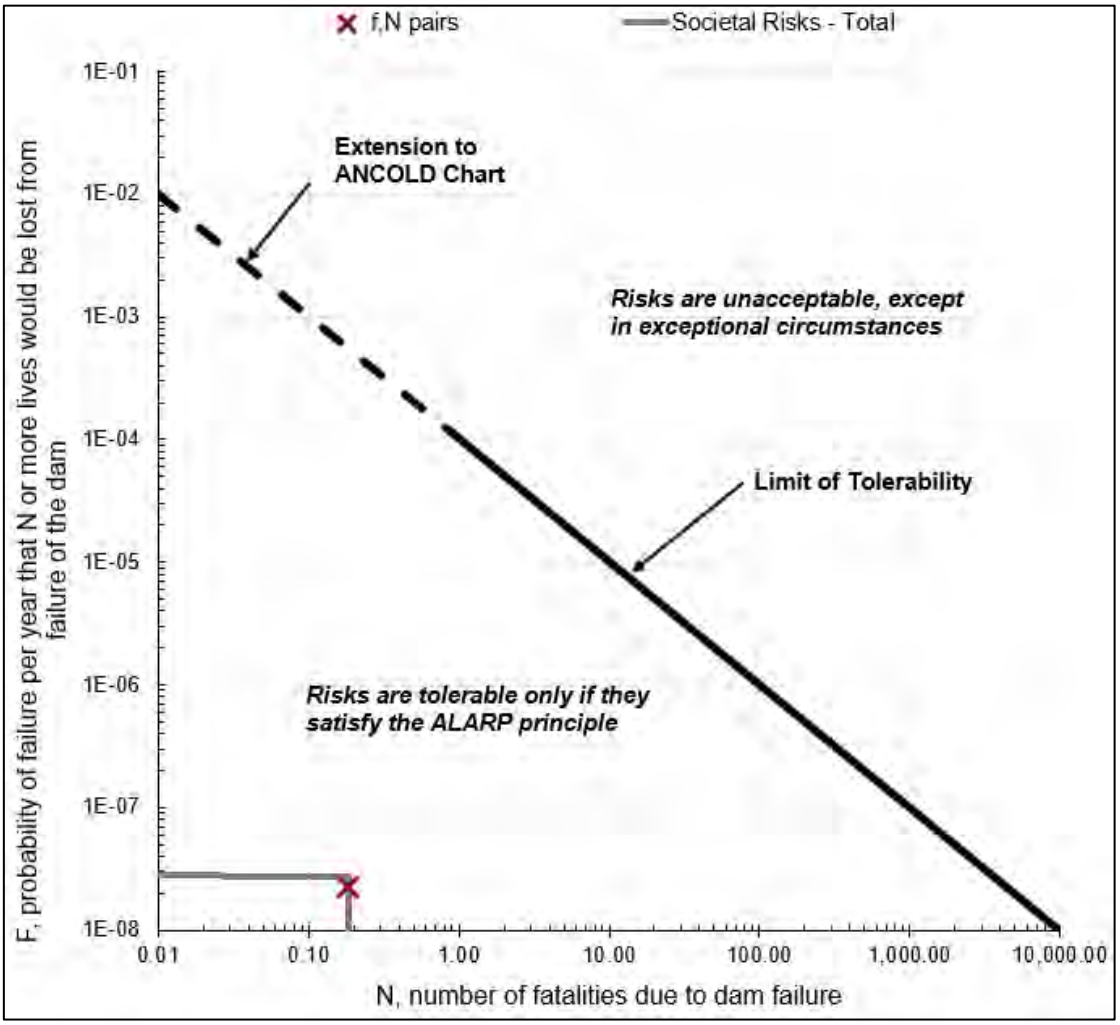
The total societal risk due to failure of the Stage 3 TSF is assessed to be **5.2E-09**. This satisfies the ANCOLD societal risk criteria for new dams or major augmentations of not greater than 1E-04.

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

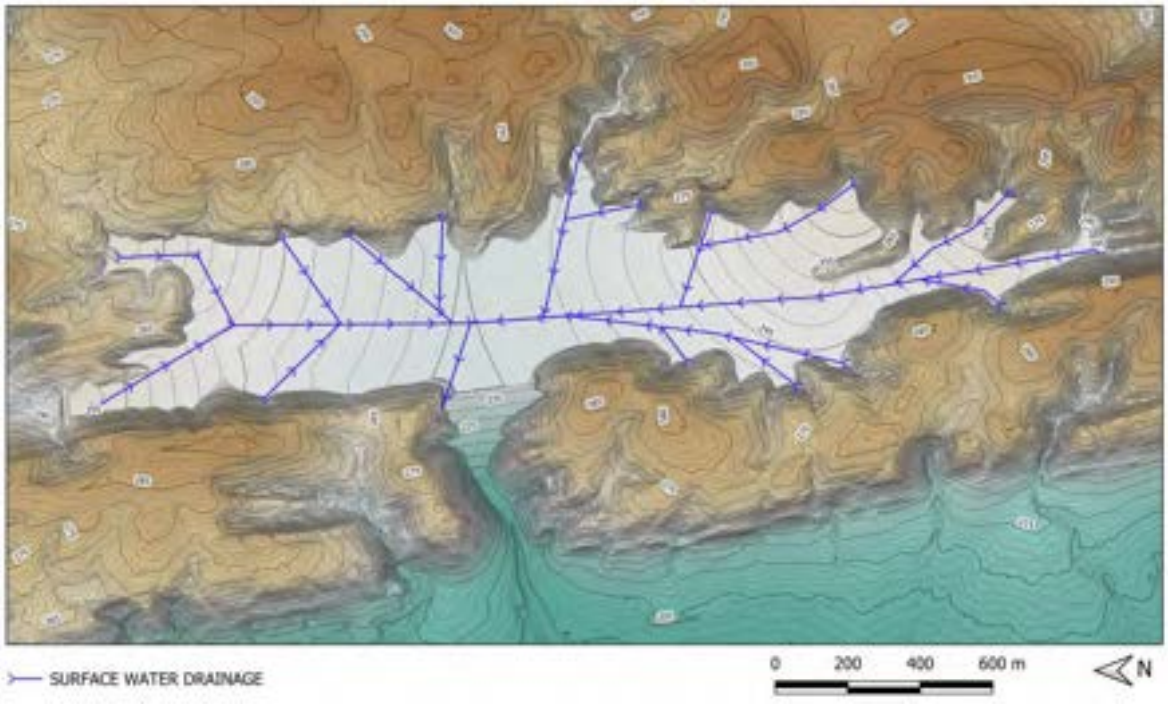
The general approach to closure will incorporate a low water flux cover system that includes a capillary break, sealing layer, waste rock layer and revegetated topsoil. Four cover options have been proposed to be modelled to assess their relative performance regarding net percolation and to determine 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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CONDITIONS OF 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
SD2 ACCESS ROAD
SD1 ACCESS ROAD
SOUTHERN DISCHARGE POINT 3 (SD3)
NORTHERN DISCHARGE POINT 1 (ND1)
RETURN WATER SYSTEM (PAD, DECANT & BOOSTER PUMPS)
SD3 ACCESS ROAD
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 7765000
N 7764000
N 7763000
N 7762000

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MMG DUGALD RIVER
STAGE 3 TAILINGS STORAGE FACILITY - DETAILED DESIGN

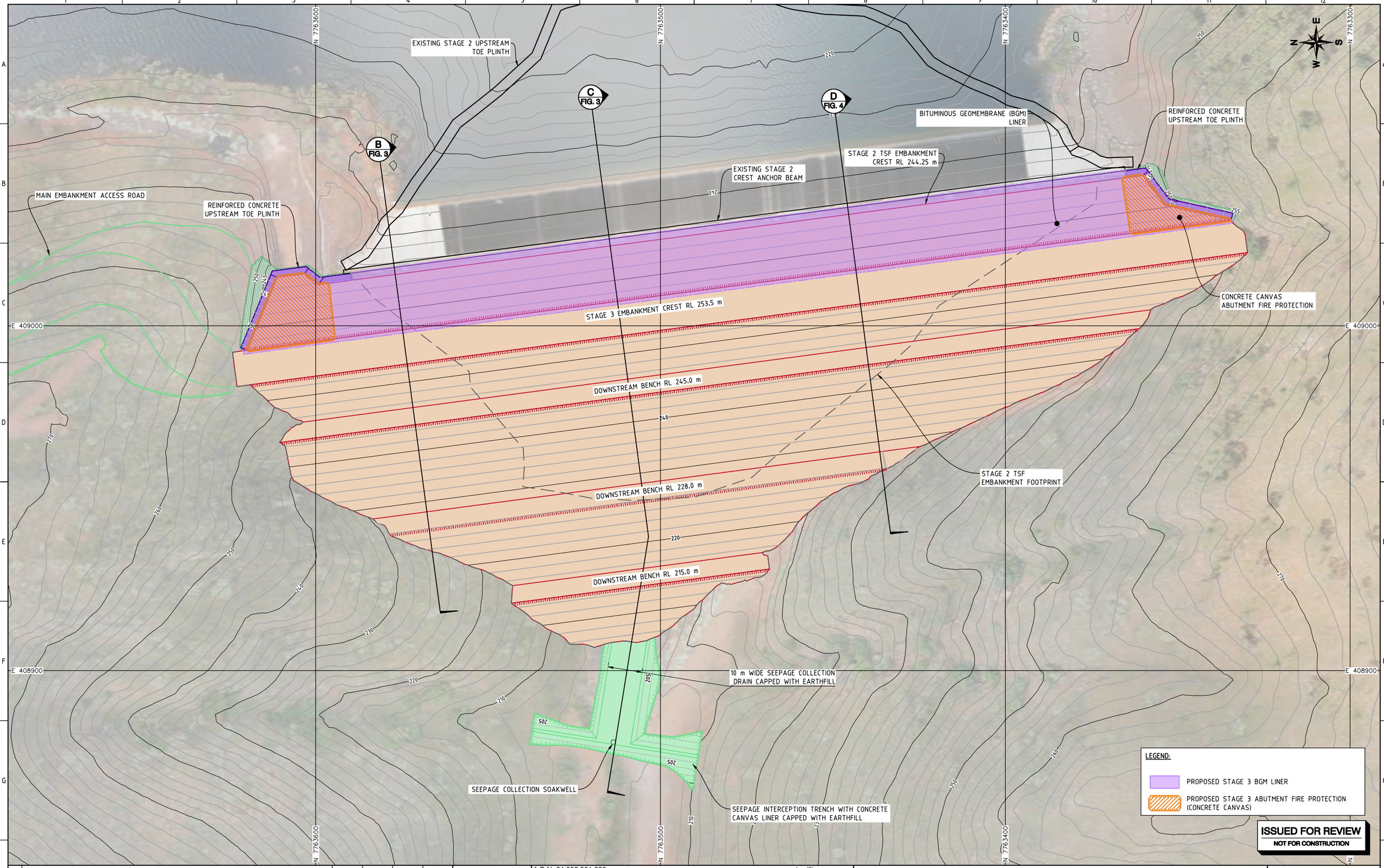
CIVIL WORKS AREAS
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MMG DUGALD RIVER
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TSF EMBANKMENT AREA GENERAL LAYOUT

DWG. No. **FIGURE 2**

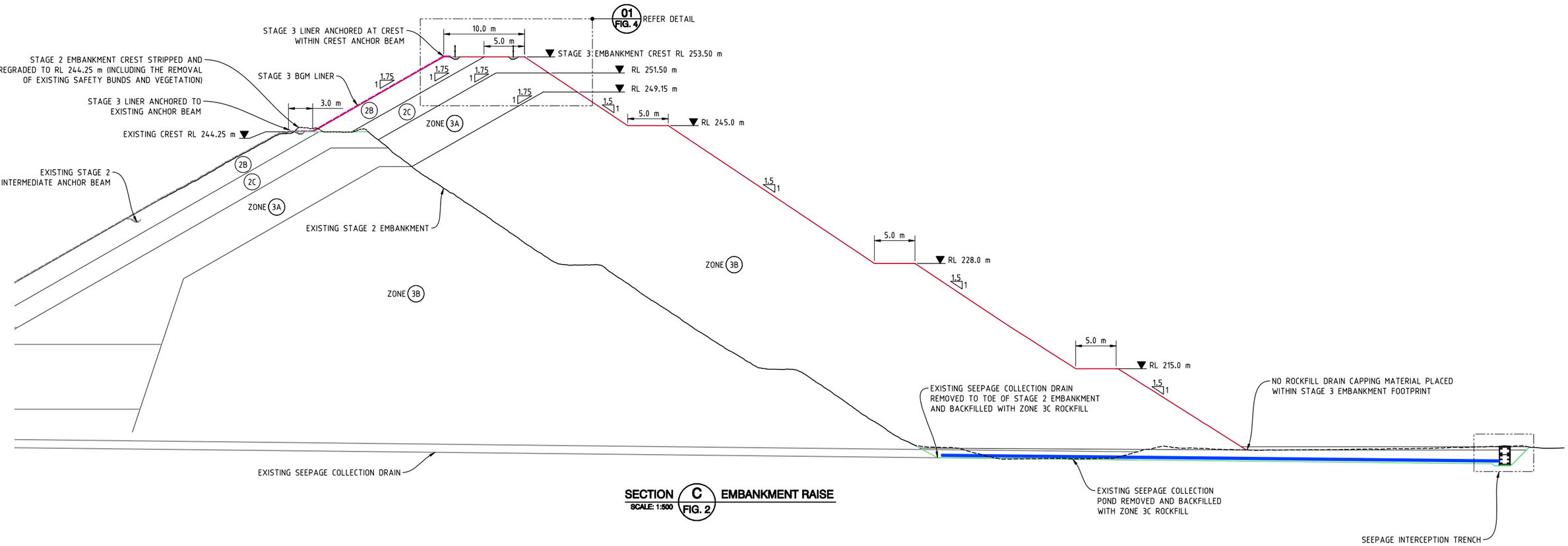
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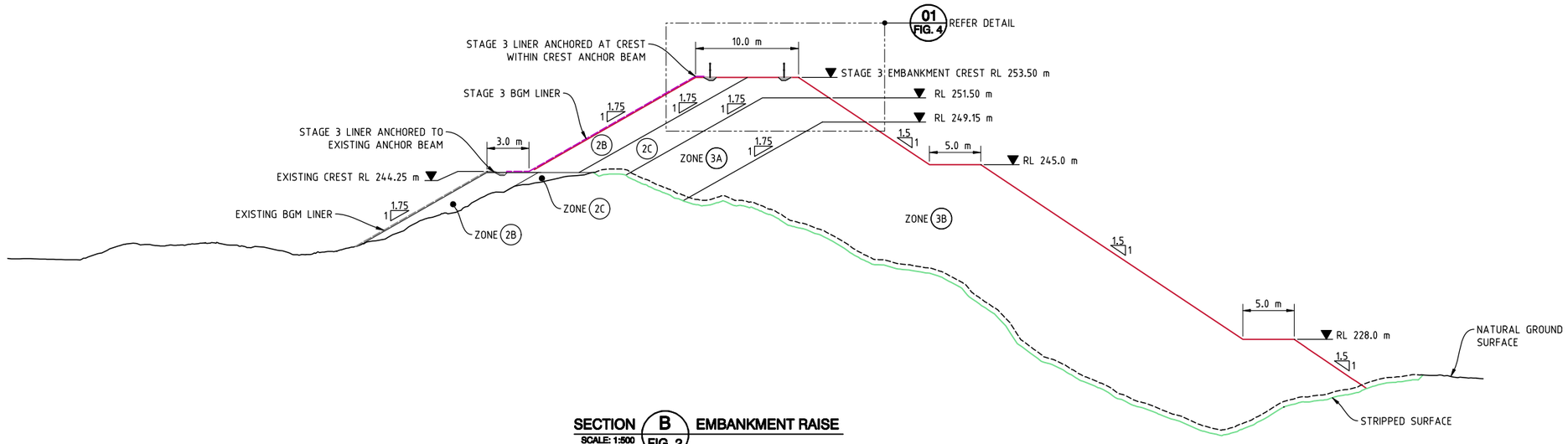
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S:\Dugald\250542 - TSF Raise Design\CADD\CAD\Stage 3 - Detailed Design Report Figures\Figure 2 TSF Embankment Area - General Layout.dwg

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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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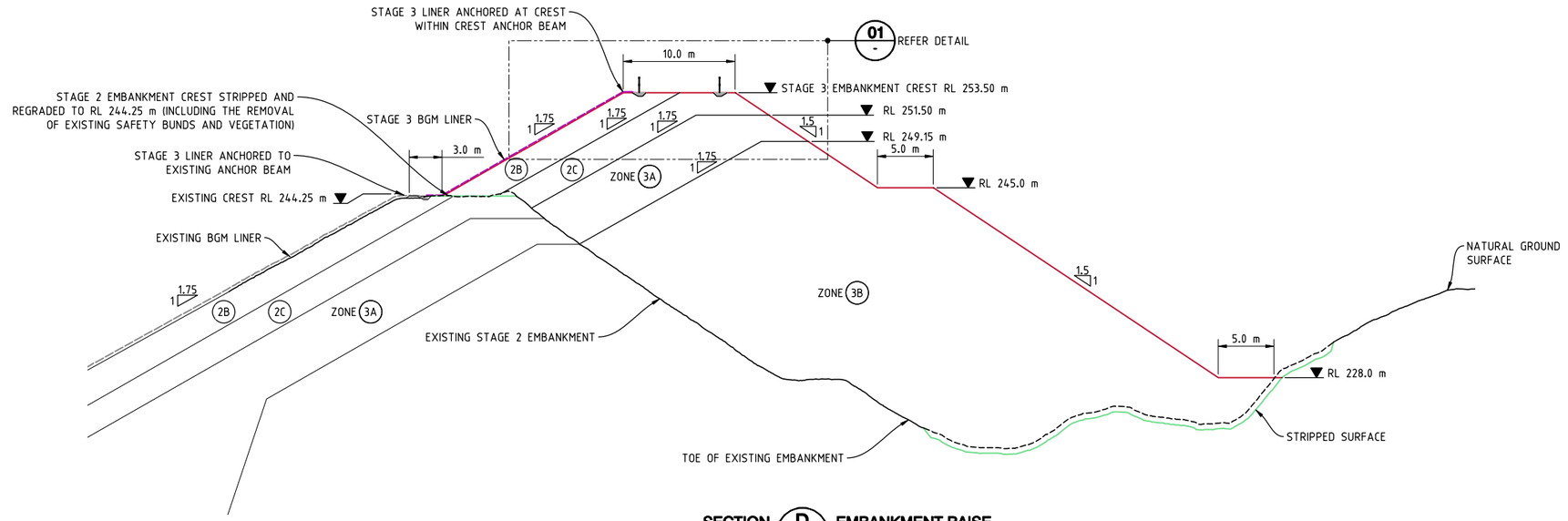
TSF EMBANKMENT AREA
SECTIONS (SHEET 1 OF 2)

DWG. No.
FIGURE 3

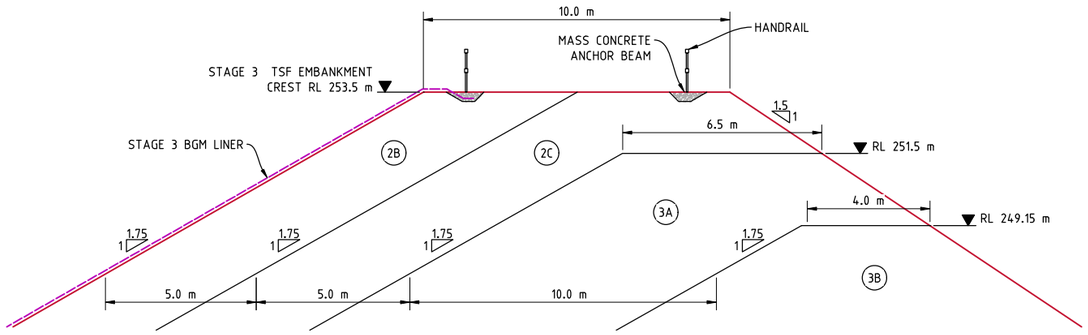
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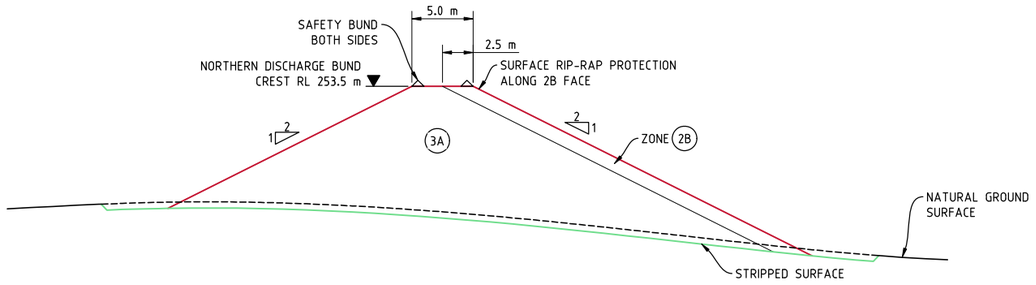
SHEET 1 OF 2



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
SECTIONS (SHEET 2 OF 2)

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LAB REPORT

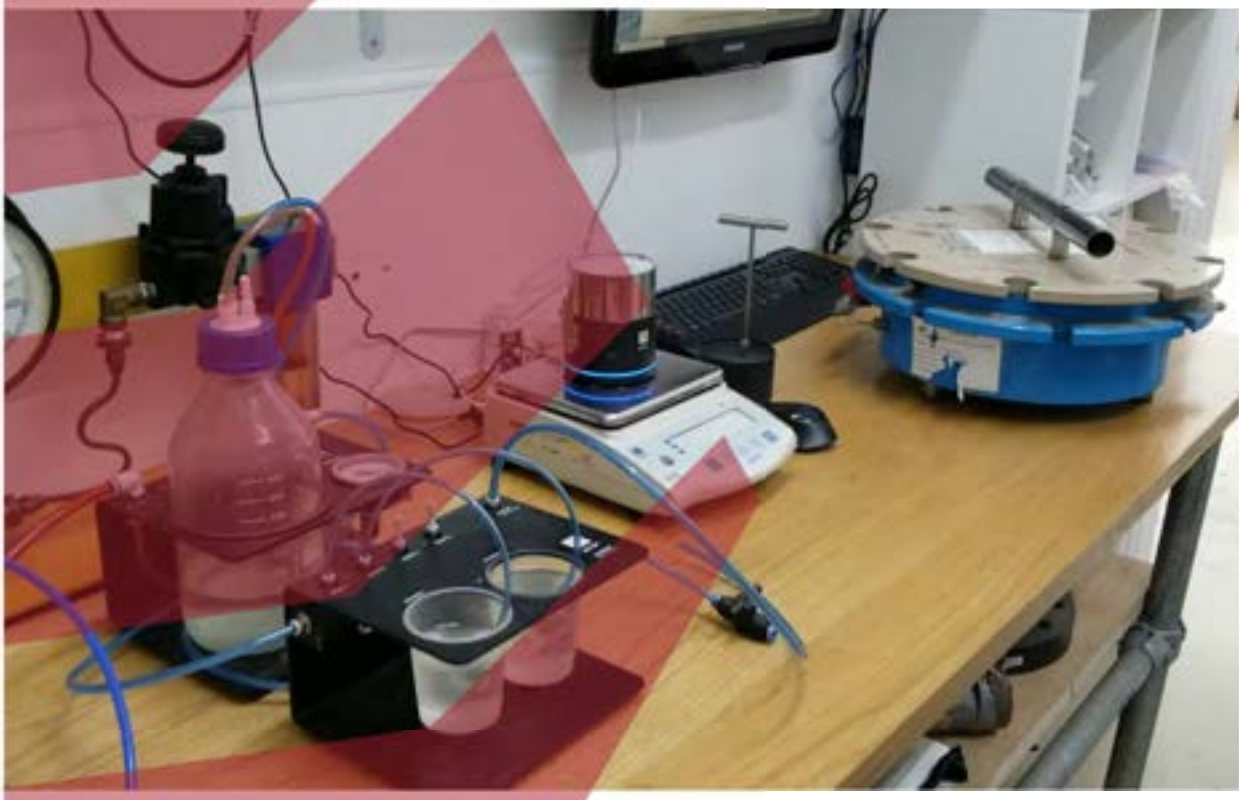
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Dugald River TSF Stage 3 Raise Detailed Design

Laboratory Factual Report

L250542-R01-RevA

May 2025



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Document Control

Project Name:	Dugald River TSF Stage 3 Raise Detailed Design
Document Title:	Laboratory Factual Report
File Location:	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/Reports/Lab Report/250542 Dugald River Lab Report - Copy.docx
Project Number:	250542
Revision Status:	A

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
A	Draft Issue	01/05/2025	Sampath De Silva	Michael Munro
B	Issued for Client Review			
0	Issued as Final			

Issue Register

Distribution List	Date
MMG Australia Limited	

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TAILINGS.WATER.WASTE.

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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**
10	Initial Settled Density (Undrained)	**Section 12**
11	Shrinkage Limit Density	**Section 13**
12	Shear Vane / Evaporative Strength Gain	**Section 14**
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;

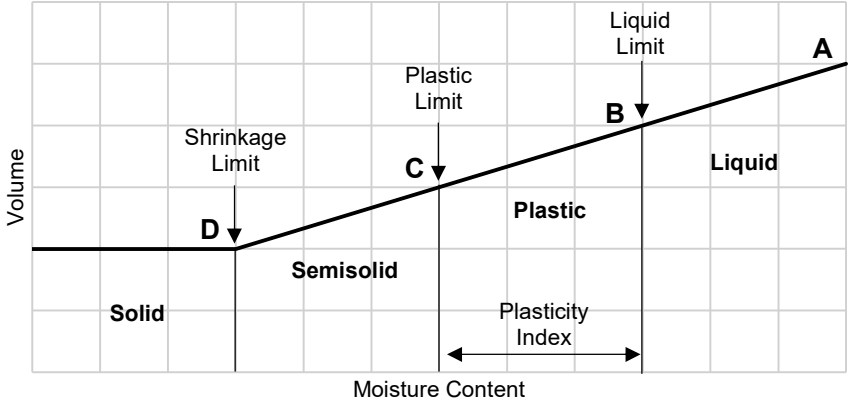
PL is the plastic limit; and

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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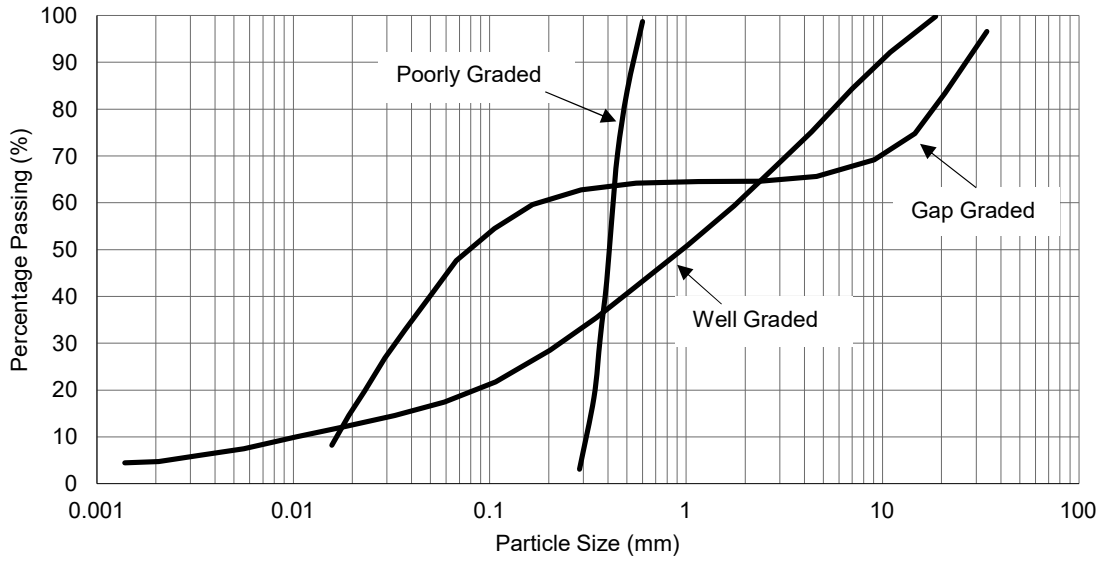
6.2 Definition

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

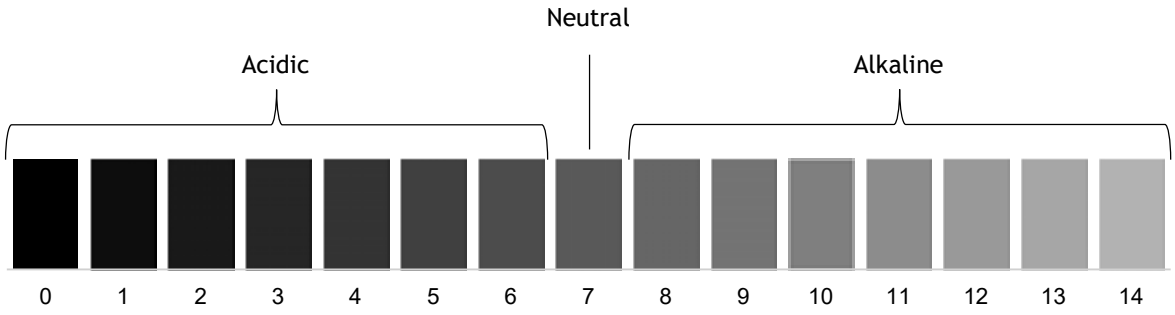
10.1 Procedure

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.

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

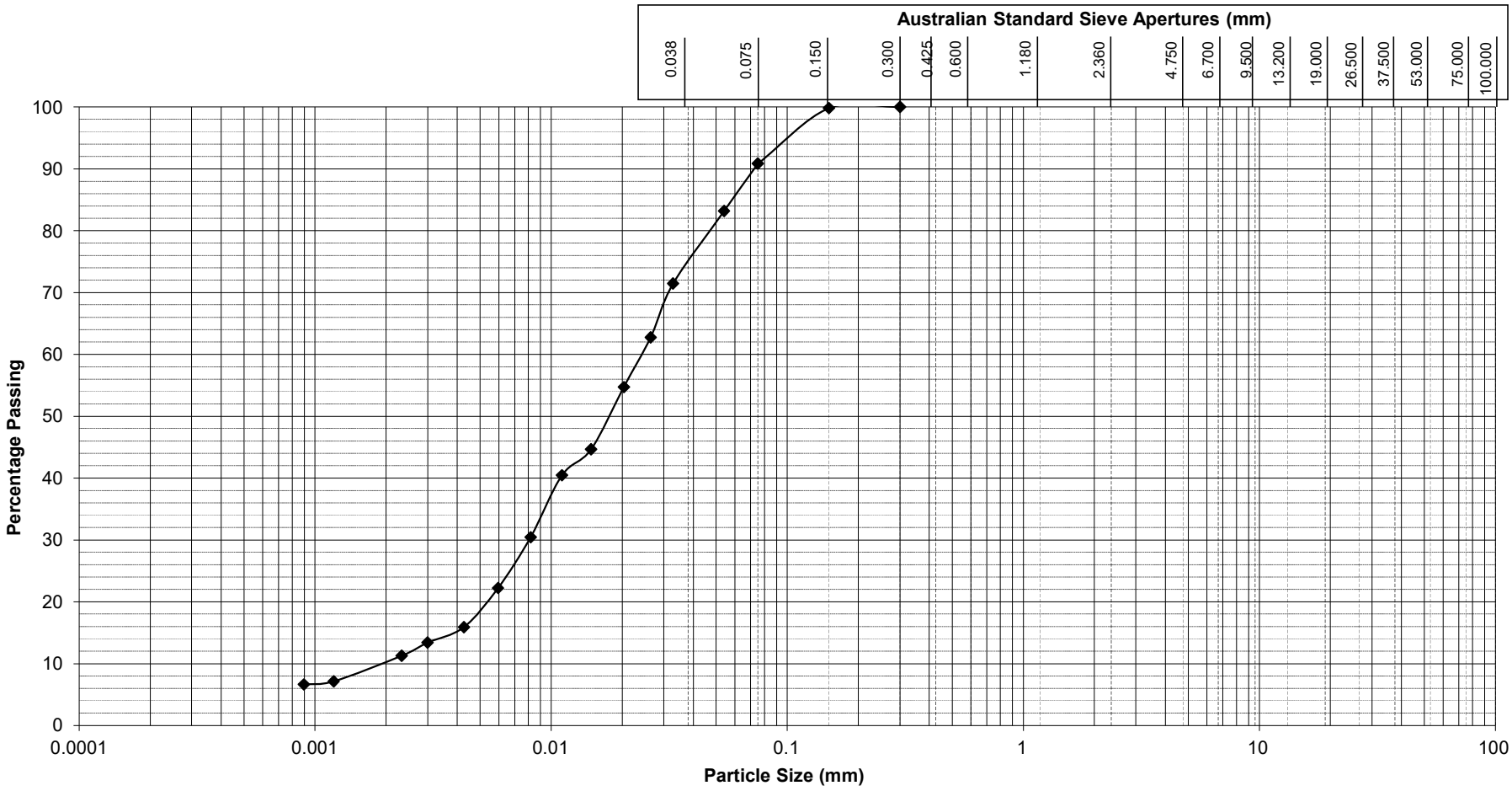
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FIGURES



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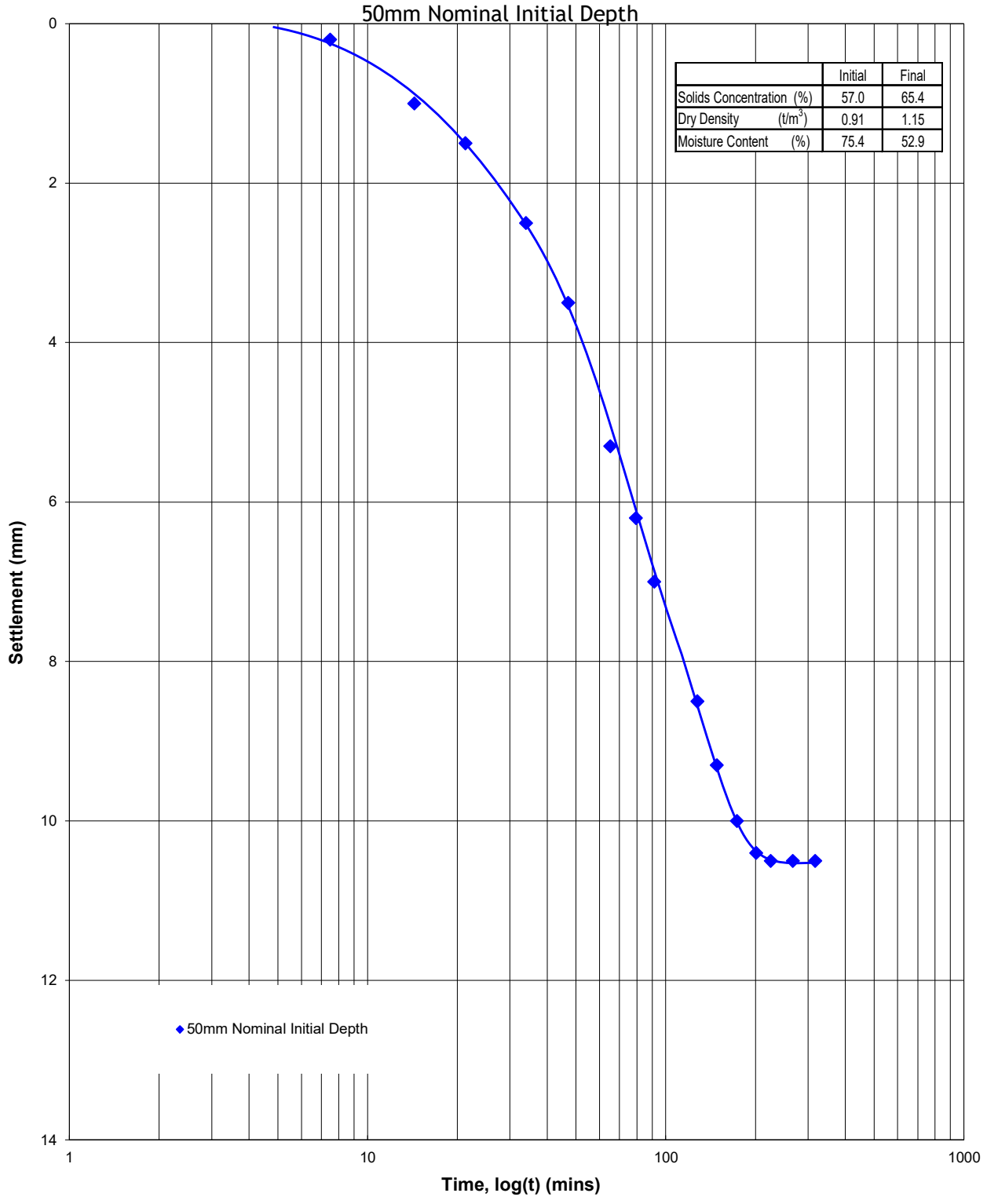
Dugald River TSF Raise Design

Tailings Sample No: 14325

Date: 19/03/2025 **Job No:** 250542

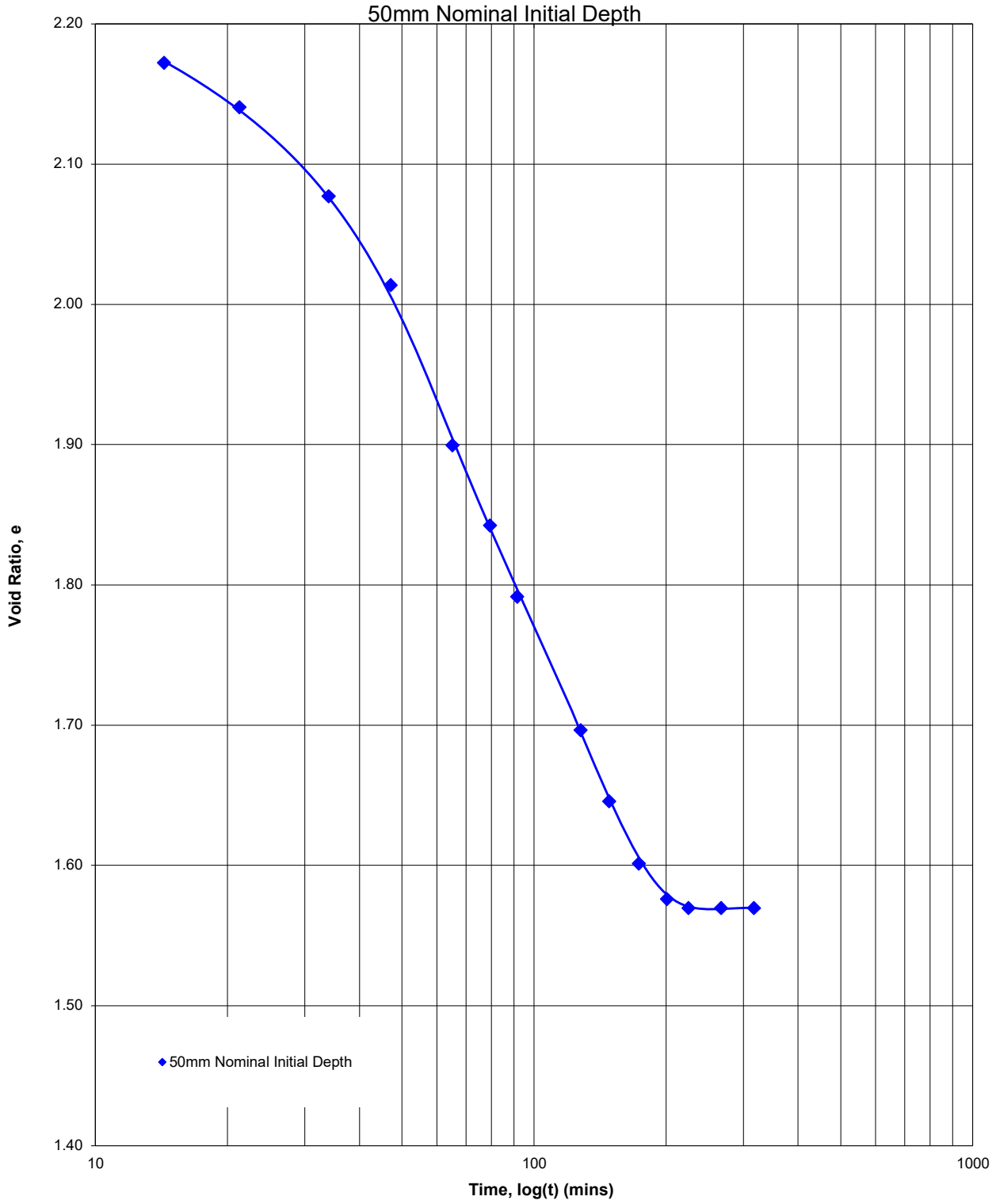
FIGURE 1

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)



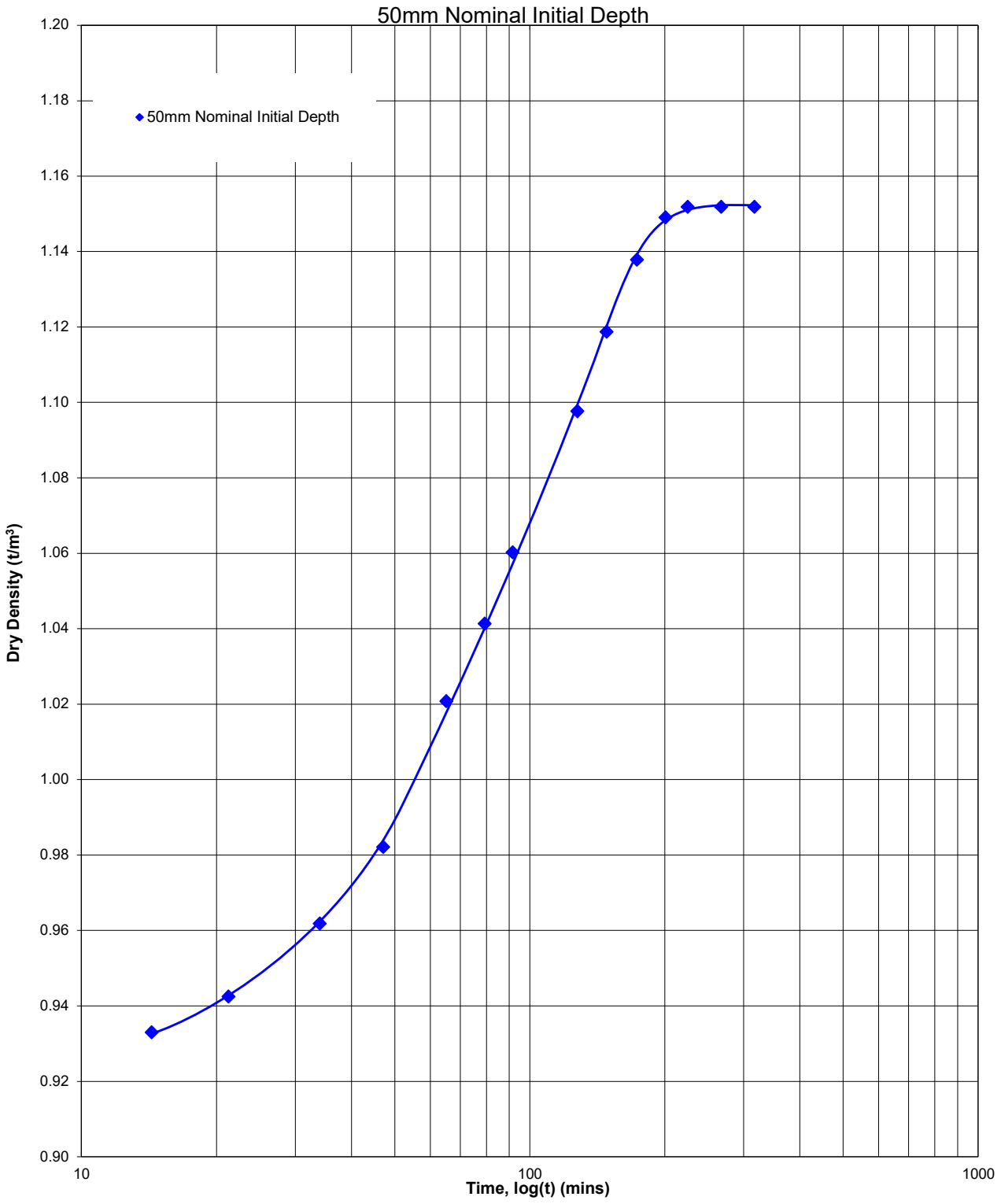
Dugald River TSF Raise Design **MMG Limited** **Flocculated Tailings (Magnaflocc 338, 23g/t)**	**Undrained Settled Density** **Settlement vs Time** **Sample No. 15325**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 31/03/2025 **FIGURE 2**

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



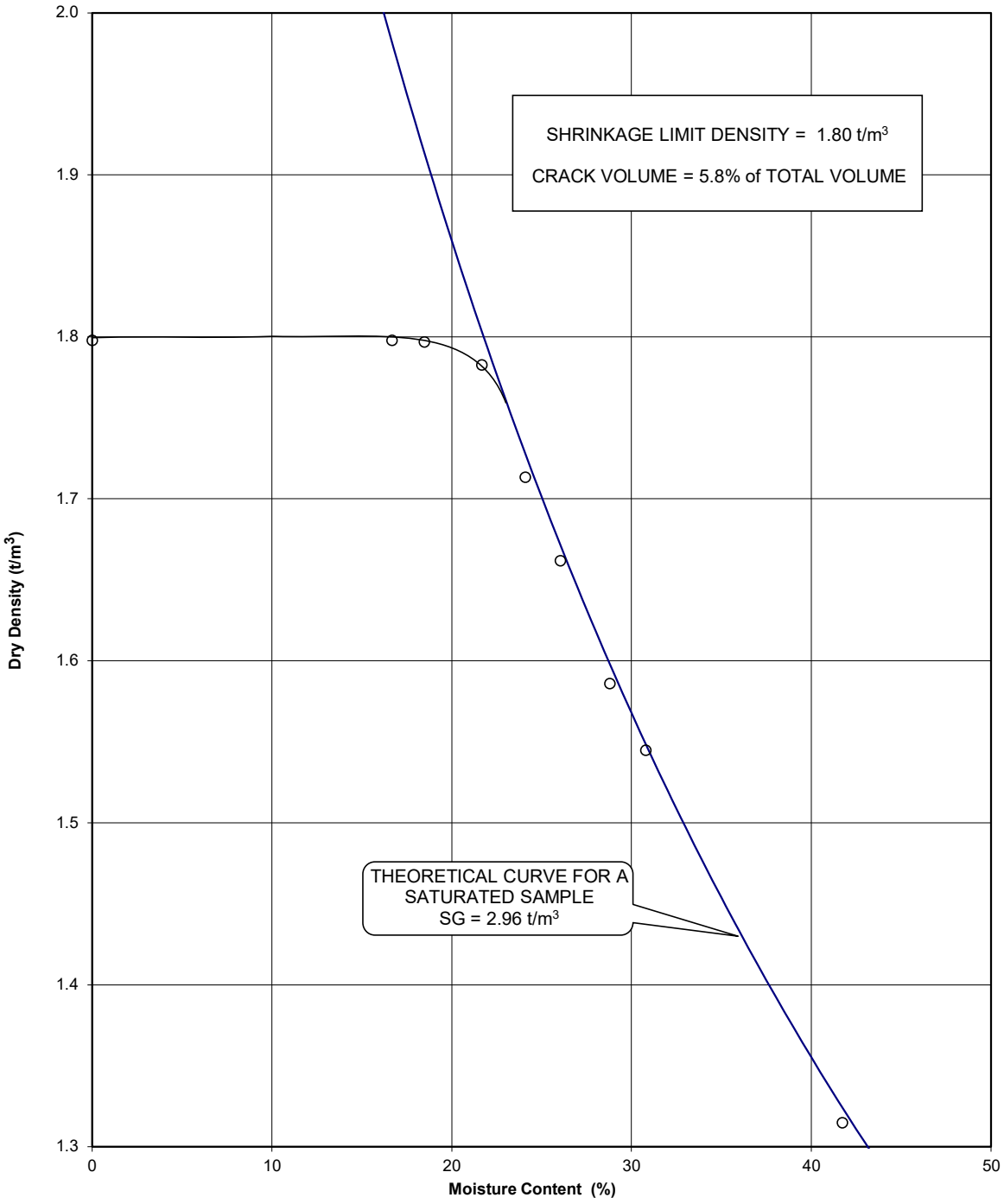
Dugald River TSF Raise Design **MMG Limited** **Flocculated Tailings (Magnaflocc 338, 23g/t)**	**Undrained Settled Density** **Void Ratio vs Time** **Sample No. 15325**
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https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 -ISD with density and solids concentration (Including Salt Correction) ATC



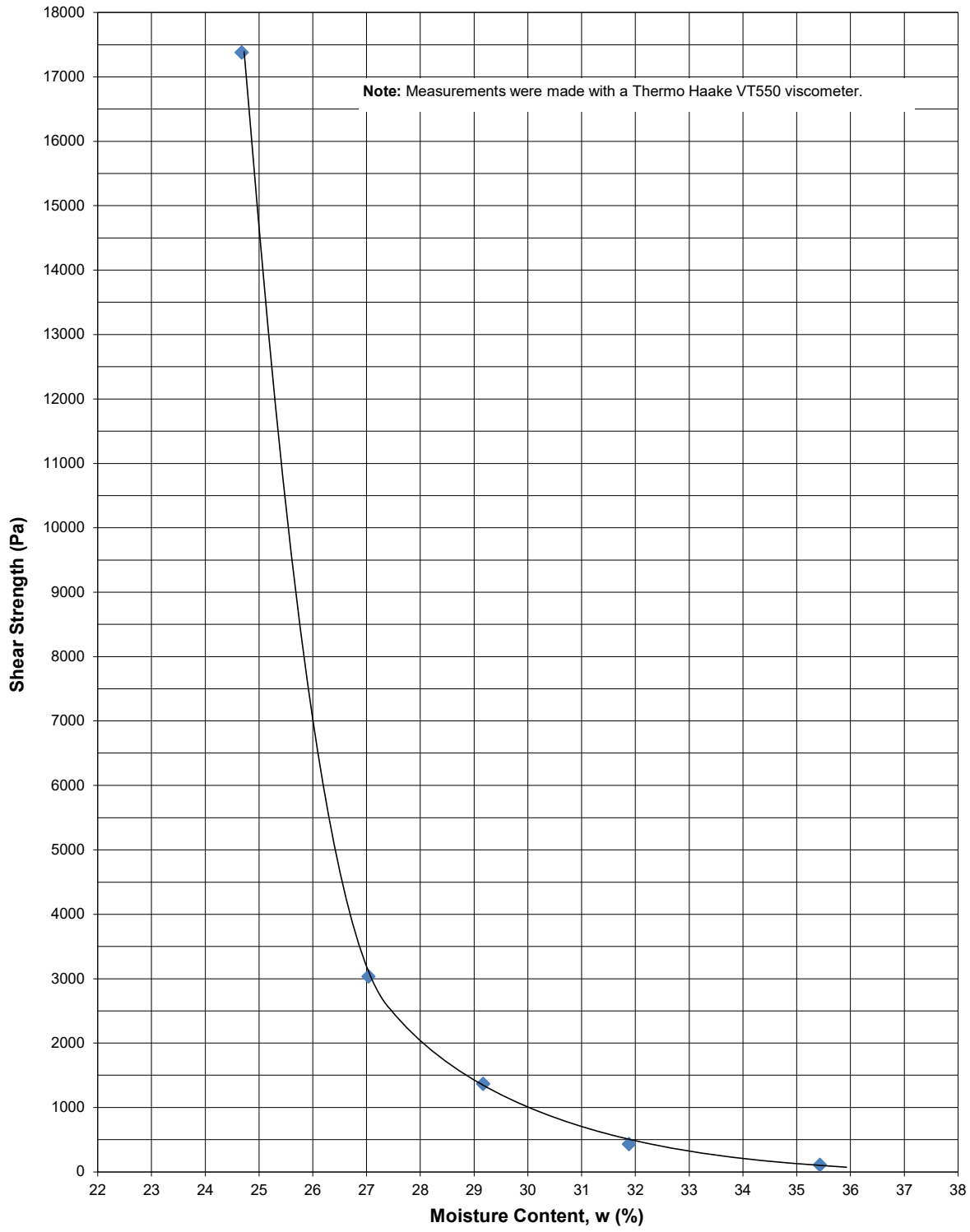
Dugald River TSF Raise Design **MMG Limited** **Flocculated Tailings (Magnaflocc 338, 23g/t)**	**Undrained Settled Density** **Dry Density vs Time** **Sample No. 15325**
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https://atcw1.sharepoint.com/sites/Lab/Shared Documents/Lab Drive/Synergy V5 Projects/Dugald/L250542 (formerly L108003.67) Dams Support - TSF Stage 3 Raise DD/Data and Calcs/15325 -ISD with density and solids concentration (Including Salt Correction) ATC



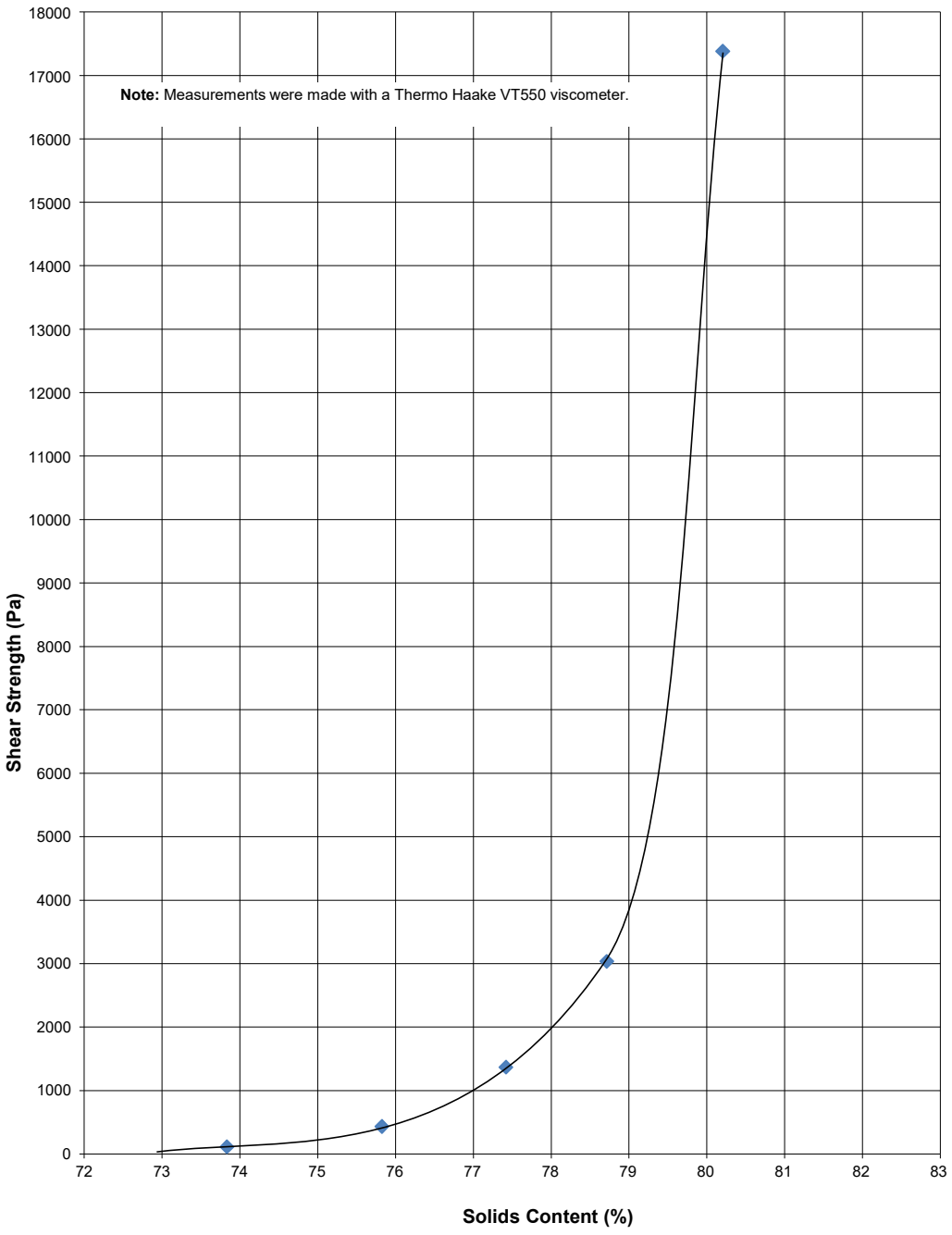
Dugald River TSF Raise Design **MMG Limited** **Unflocculated Tailings Slurry**	**Shrinkage Limit Density** **Sample No: 14325**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 250542 **Date:** 27/03/2025 **FIGURE 5**

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

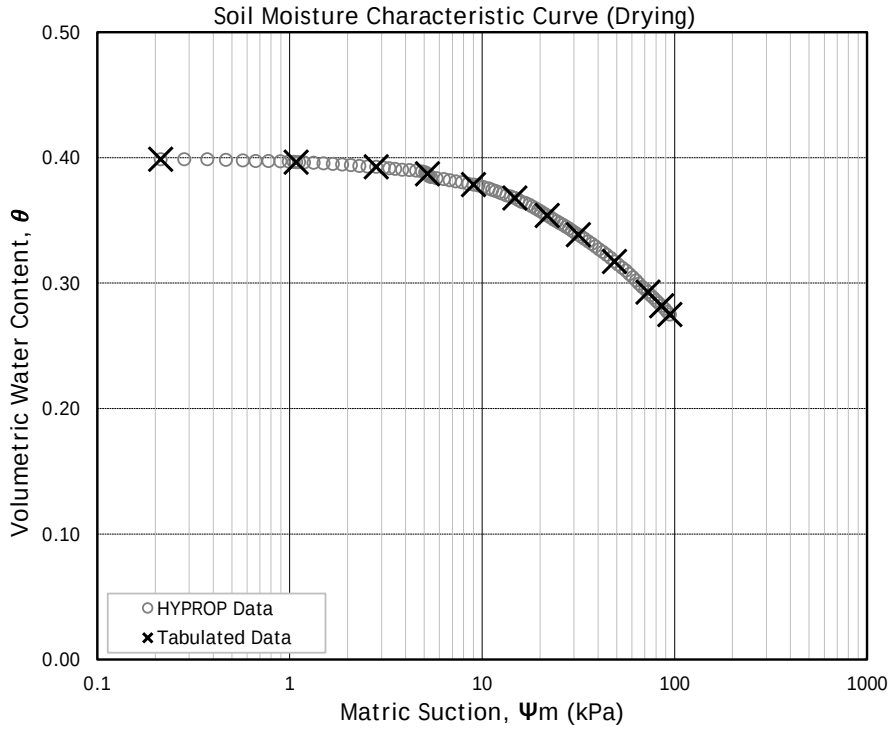
Sample Description: Tailings	Borehole No:	Test Pit Depth:

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

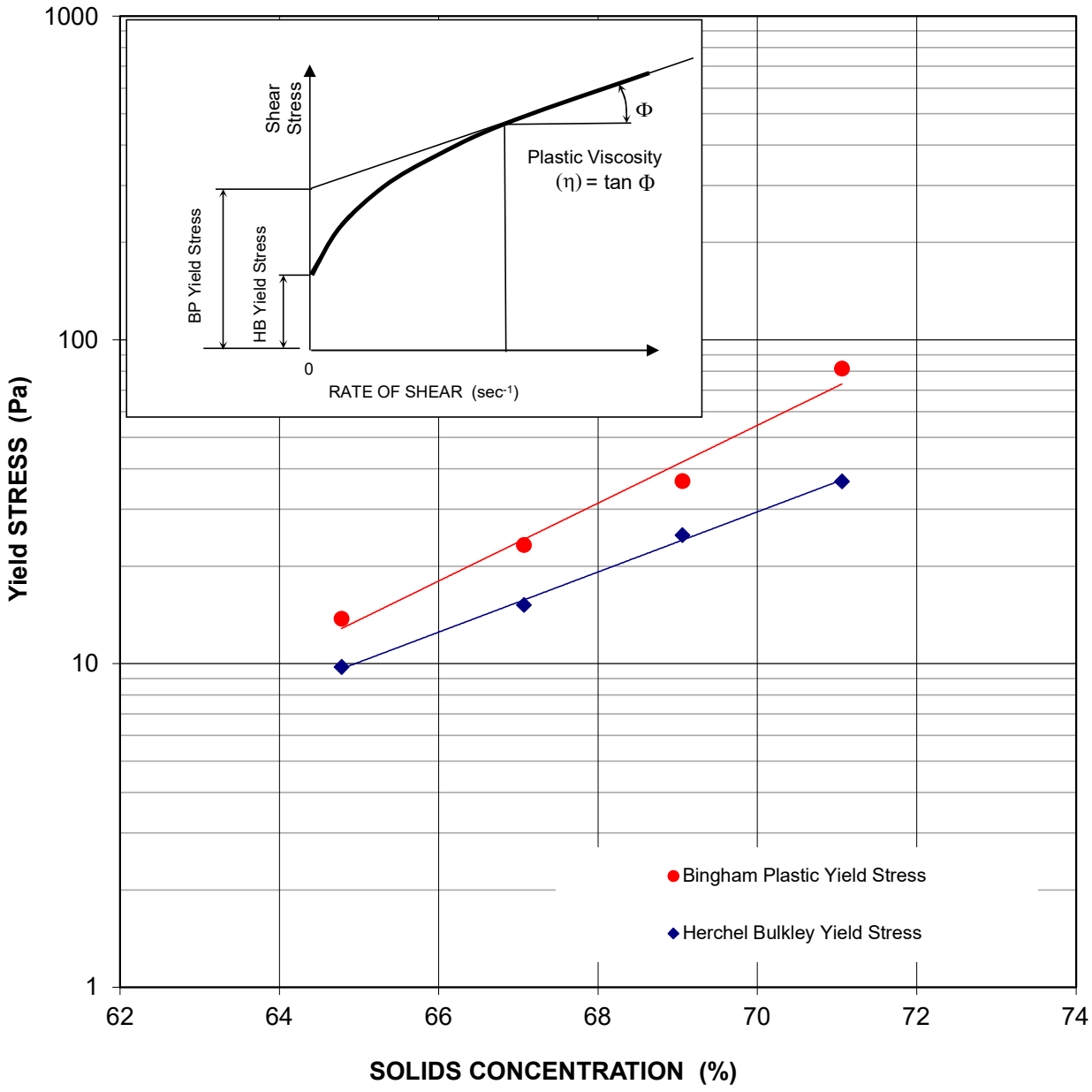
Name of Signatory: Luke Renkin Date Reported:29/04/2025

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FIGURE 8

Date of Issue: Nov 2024

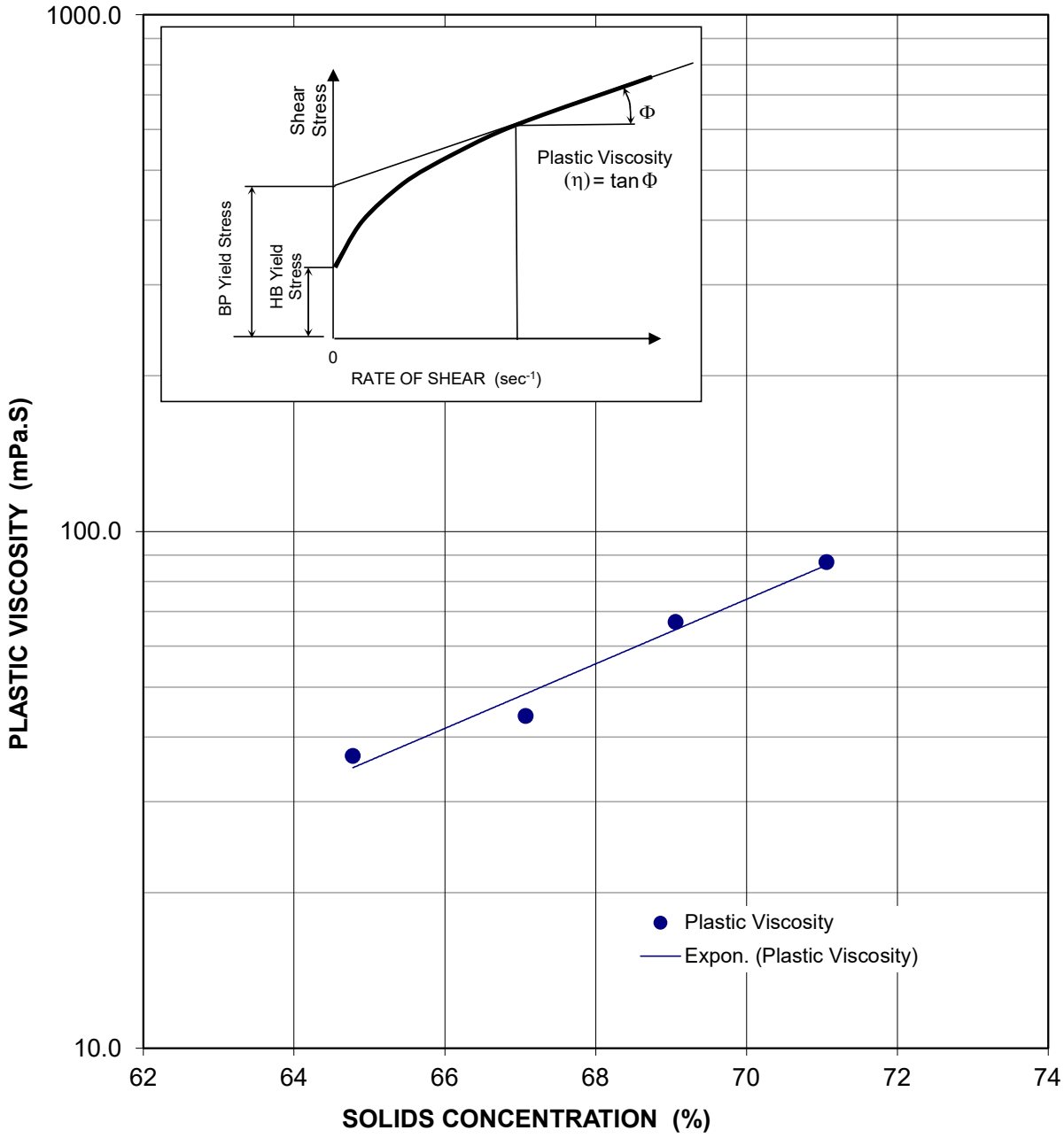
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



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

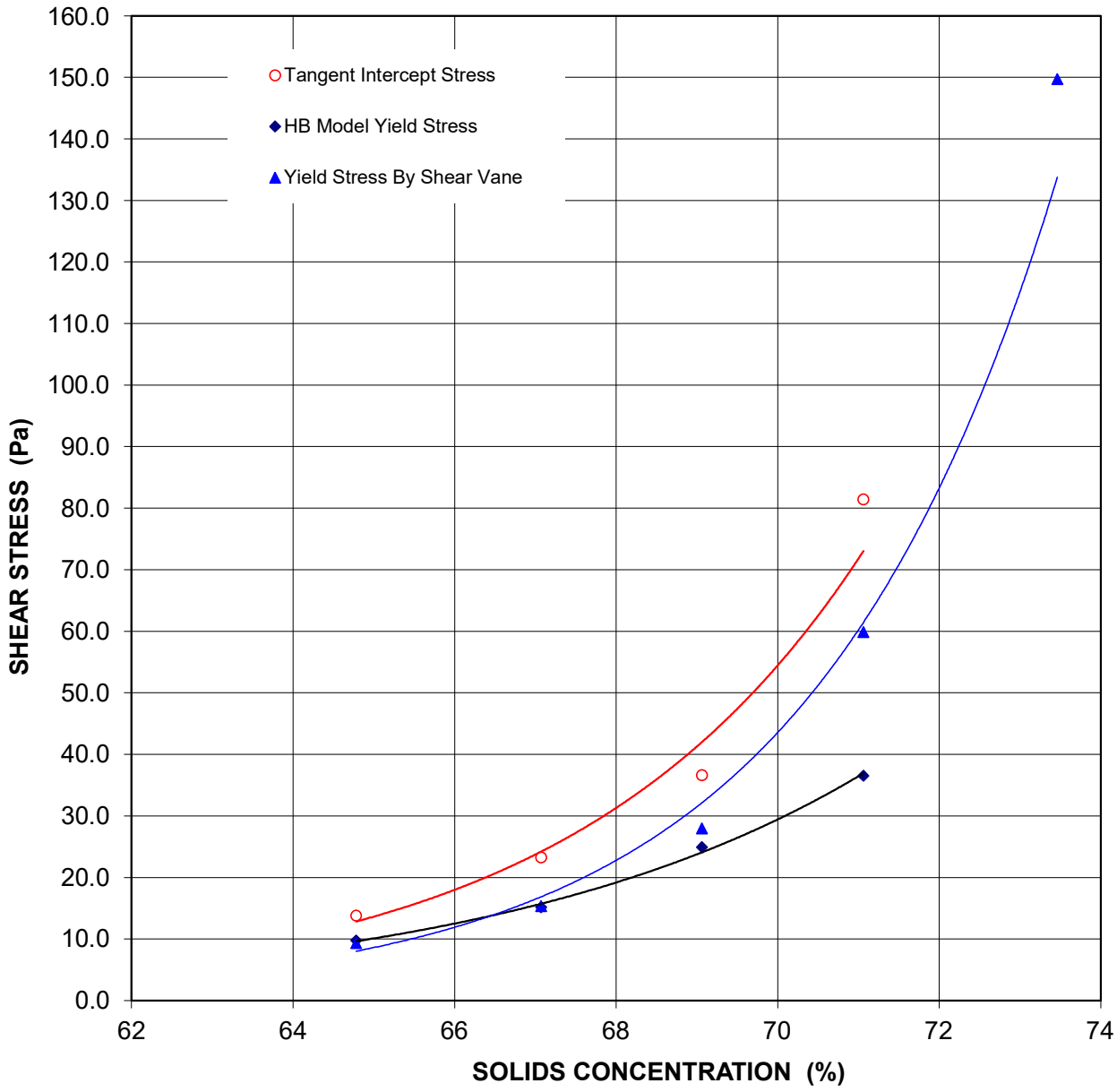
250542 - Dugald River TSF Raise Design
Sample No. 14325
PLASTIC VISCOSITY



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

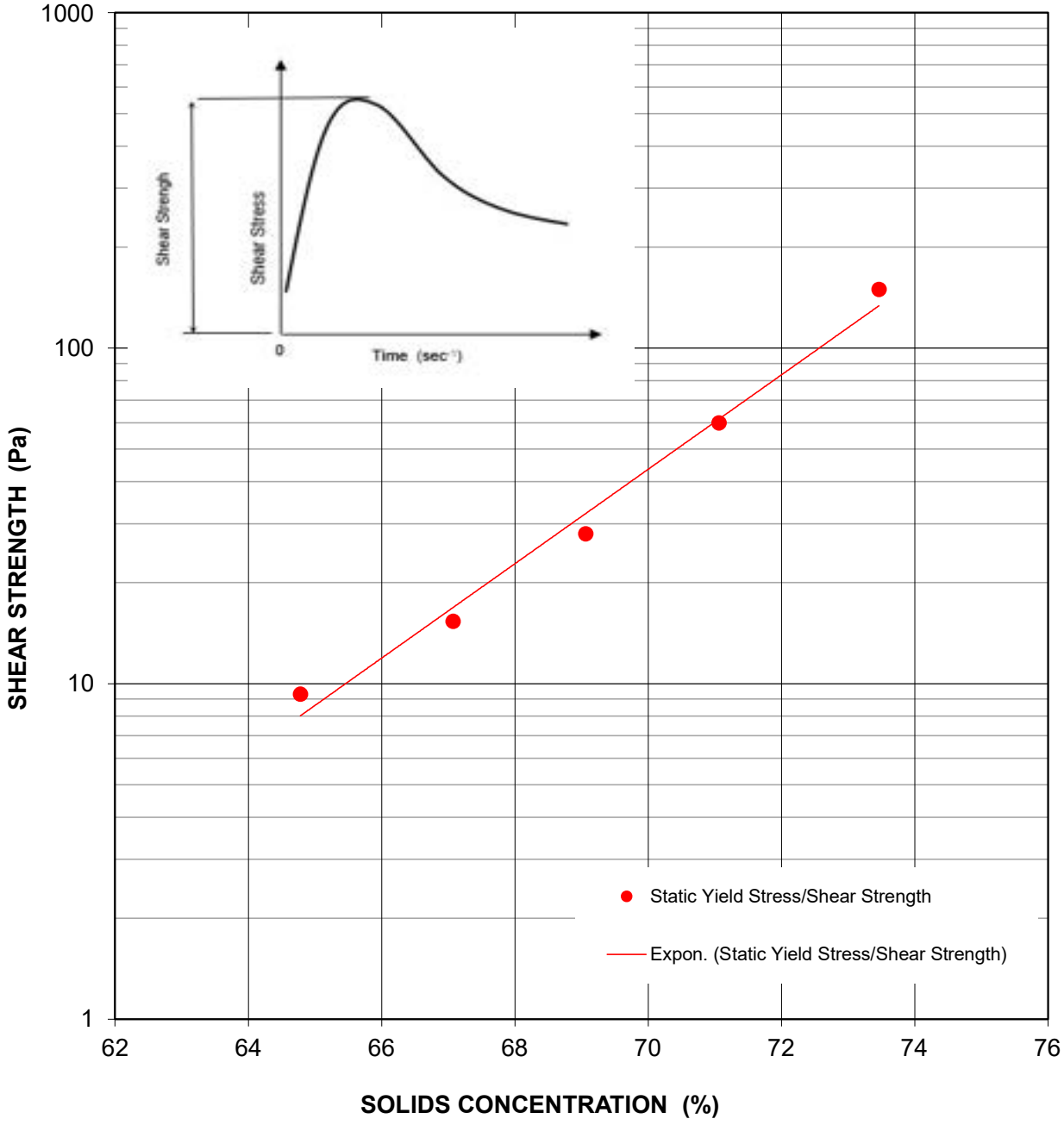
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



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**

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

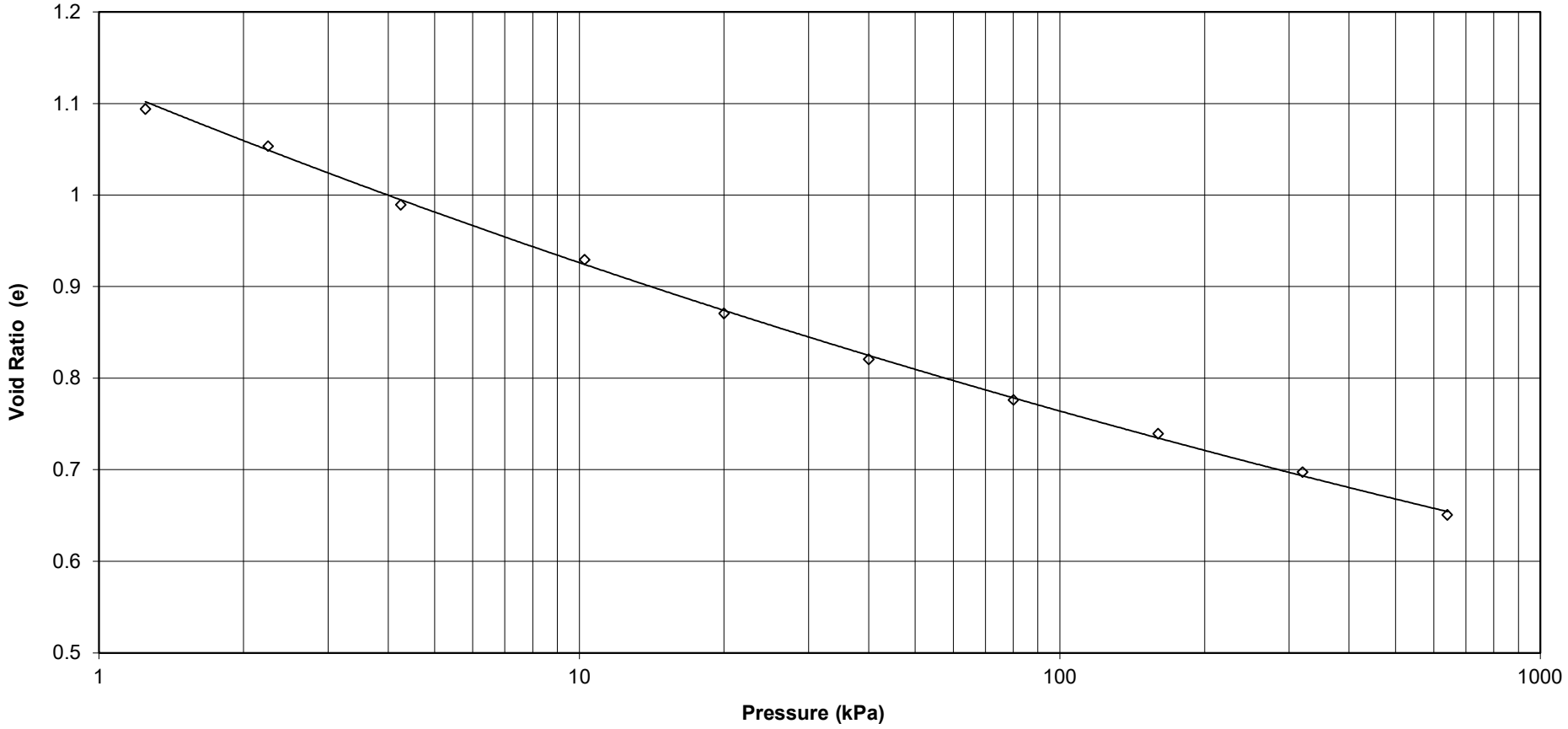
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRENGH



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

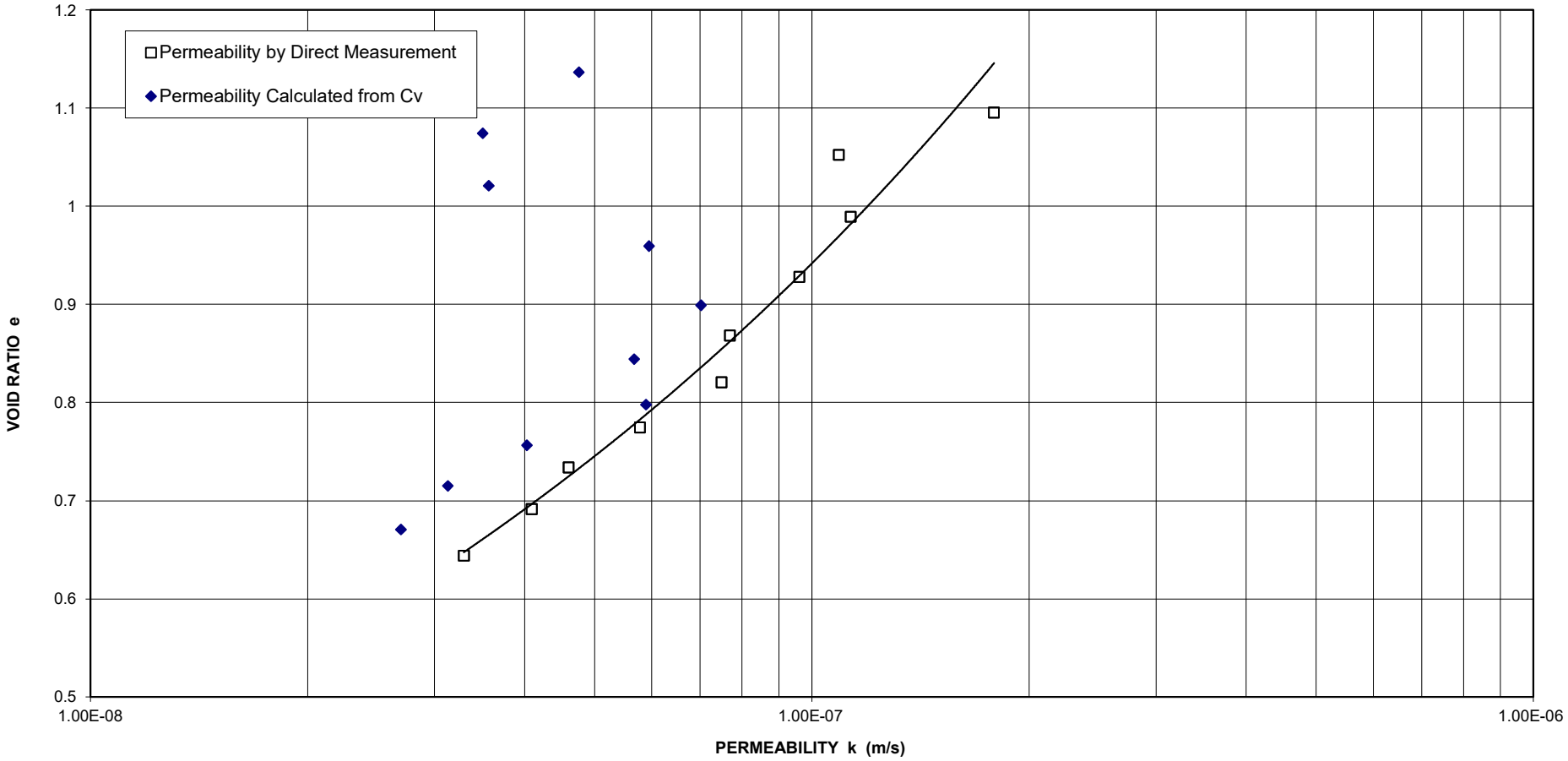
Flocculated Tailings Sample, No:15325

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

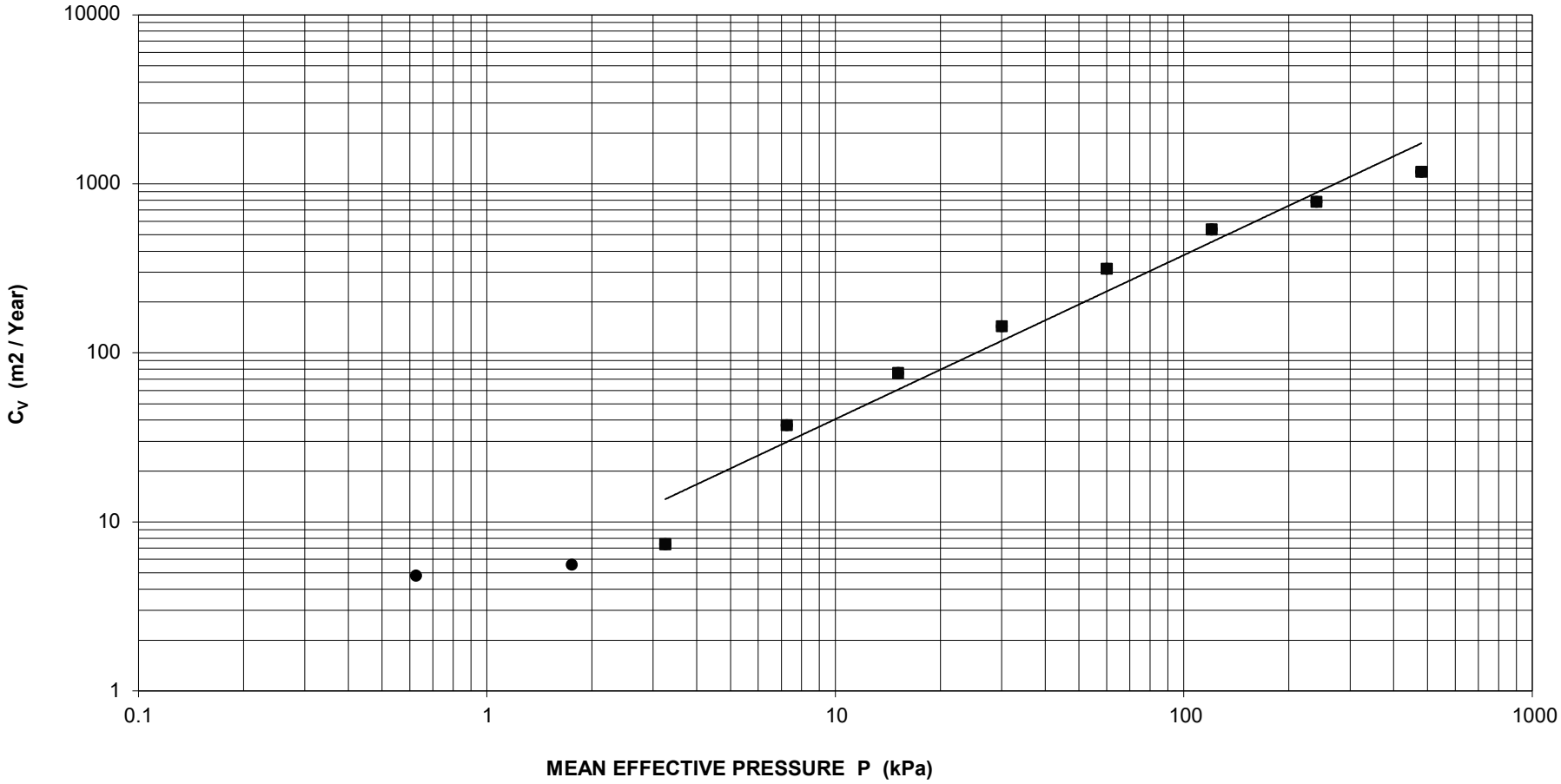
Rowe Cell Consolidation - Void Ratio Versus Log of Permeability

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.

This document is issued in accordance with the laboratory quality system requirements of ATC Williams Pty Ltd.

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

Client: MMG Limited

Address: MMG Dugald River Mine Site
Cloncurry QLD 4824

Project: Duglad River TSF Raise Design

NATA Report No.: R024125

Job No.: 250542

Register No.: 14325

Location: QLD

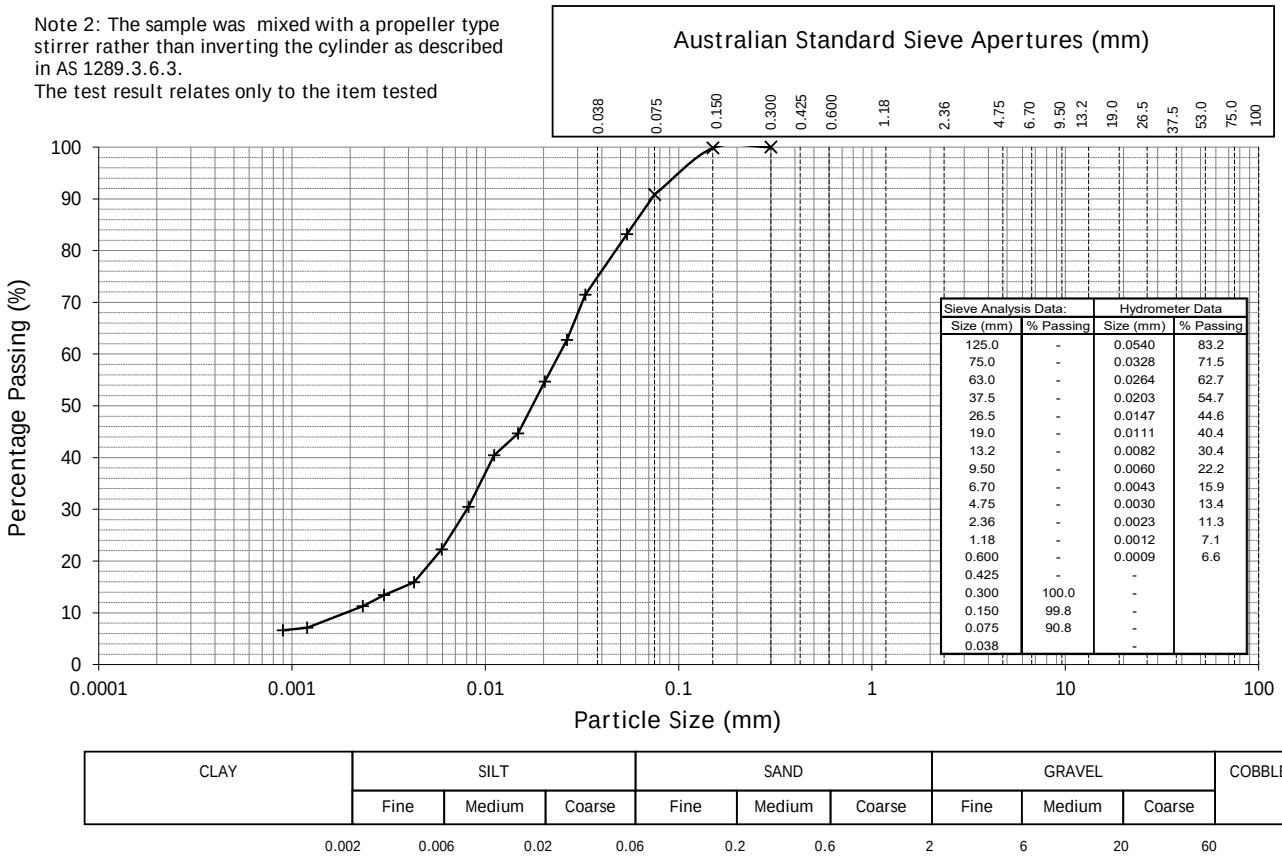
Sample Description: Tailings	Borehole No: ☐	Test Pit Depth: ☐

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.

This document is issued in accordance with the laboratory quality system requirements of ATC Williams Pty Ltd.

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.

This document is issued in accordance with the laboratory quality system requirements of ATC Williams Pty Ltd.

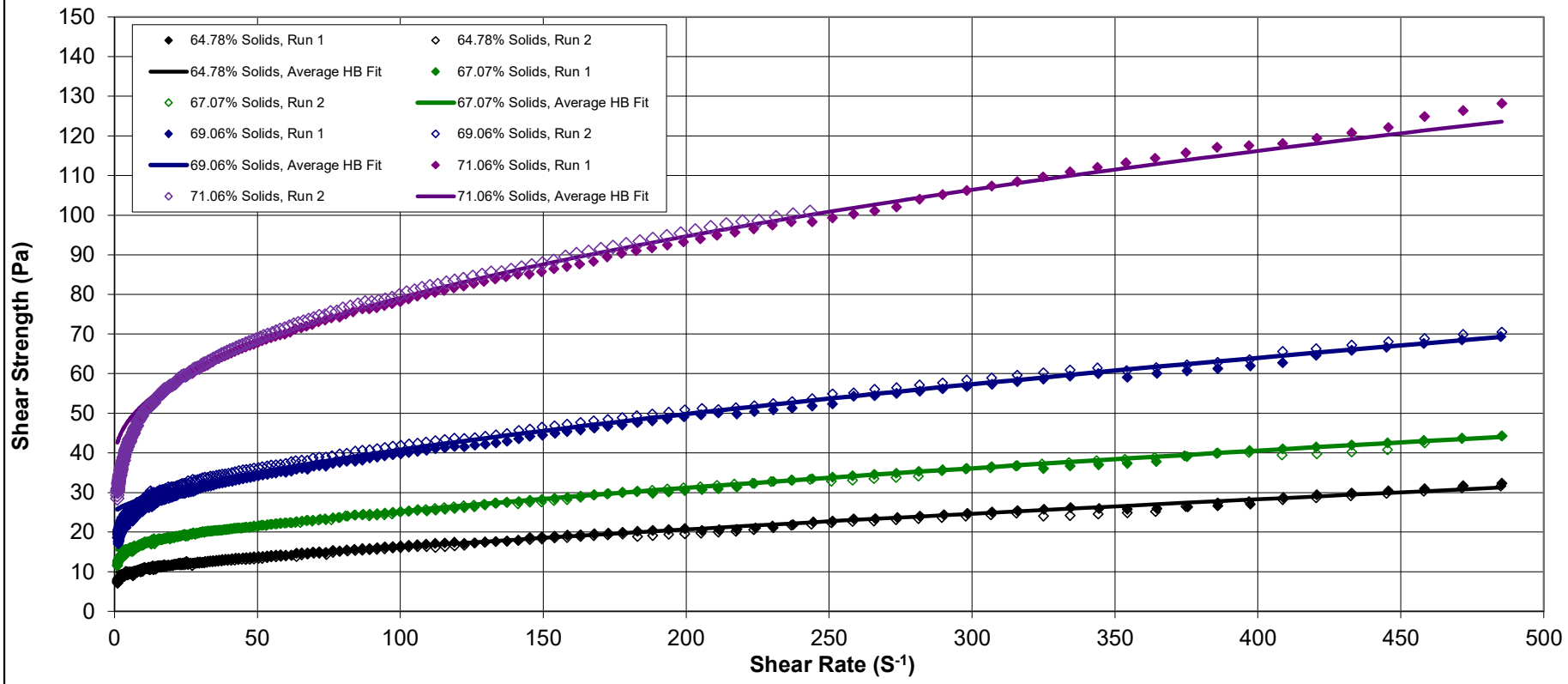
Signatory ..... Date19/03/2025.....

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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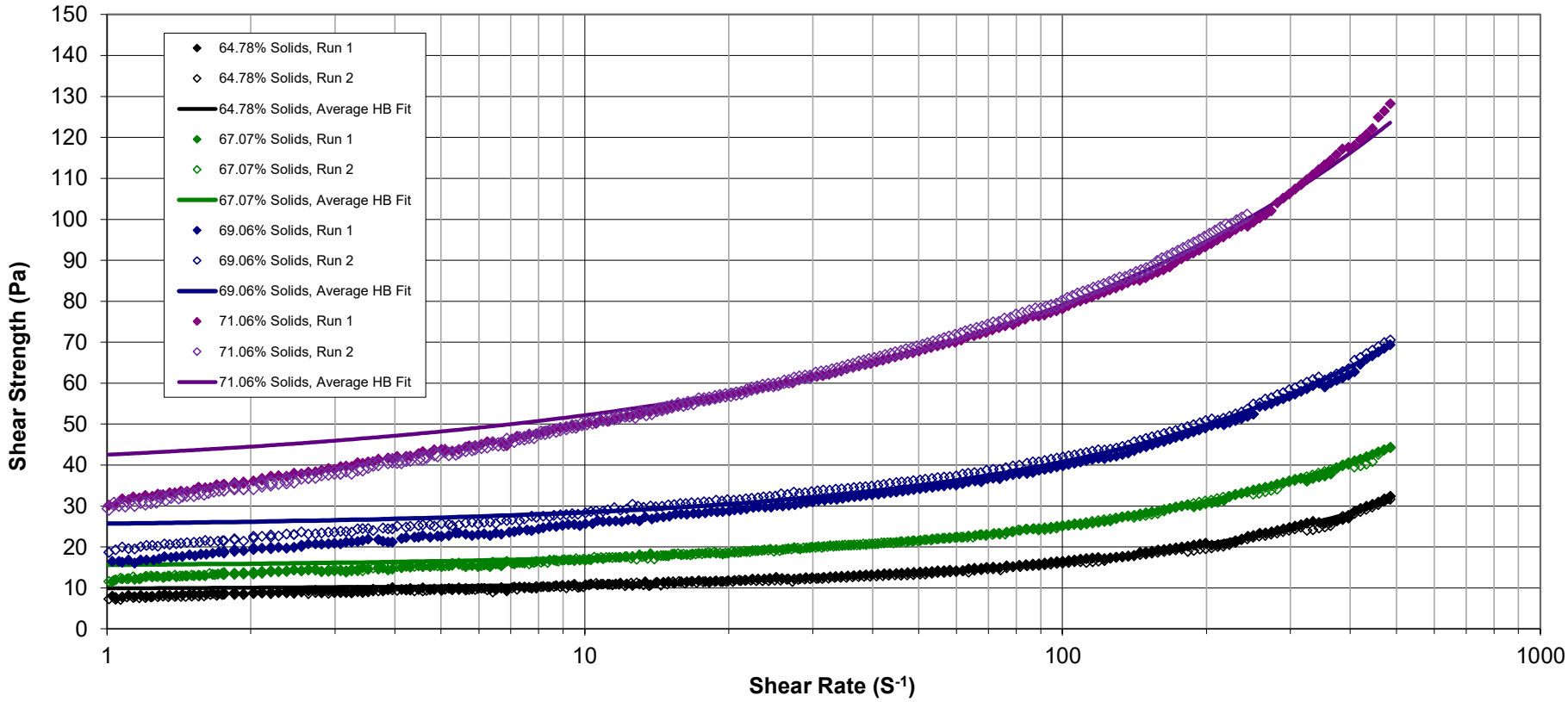
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Tailings Sample No. 1 - Unflocculated

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Appendix B1



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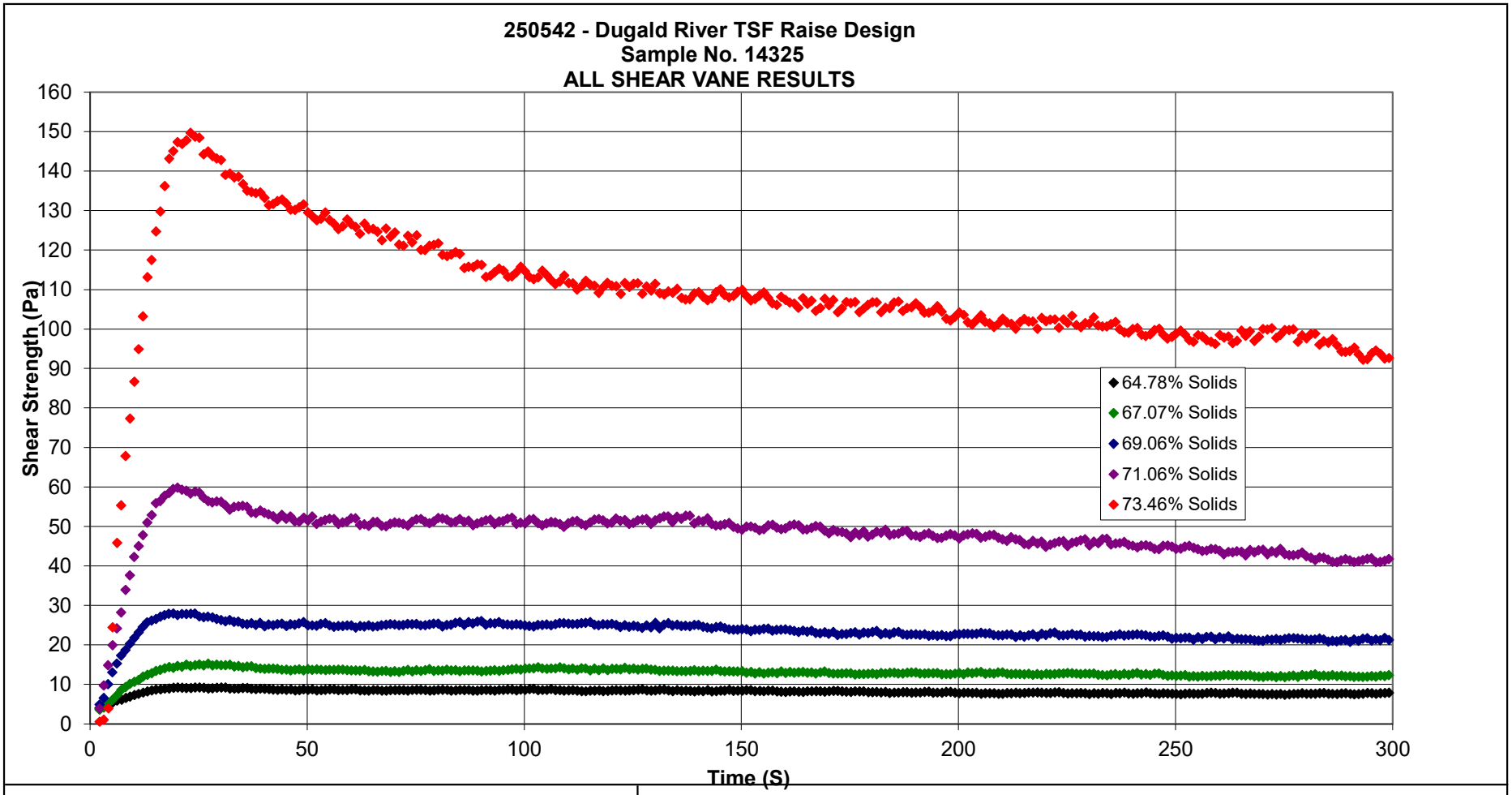
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Appendix B2

APPENDIX C – RHEOLOGY – SHEAR STRENGTH VS TIME



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Appendix C1

APPENDIX B – DAM BREAK AND CONSEQUENCE CATEGORY ASSESSMENT

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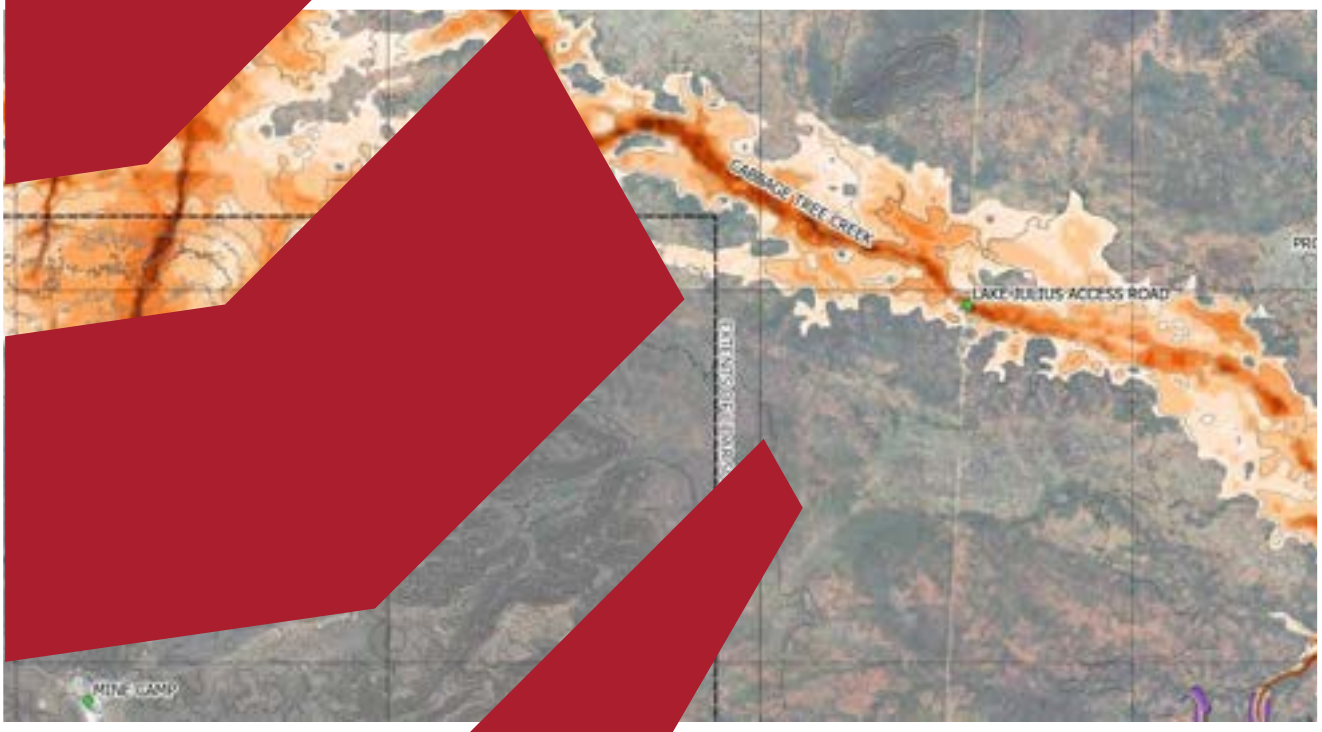
REPORT

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



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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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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.

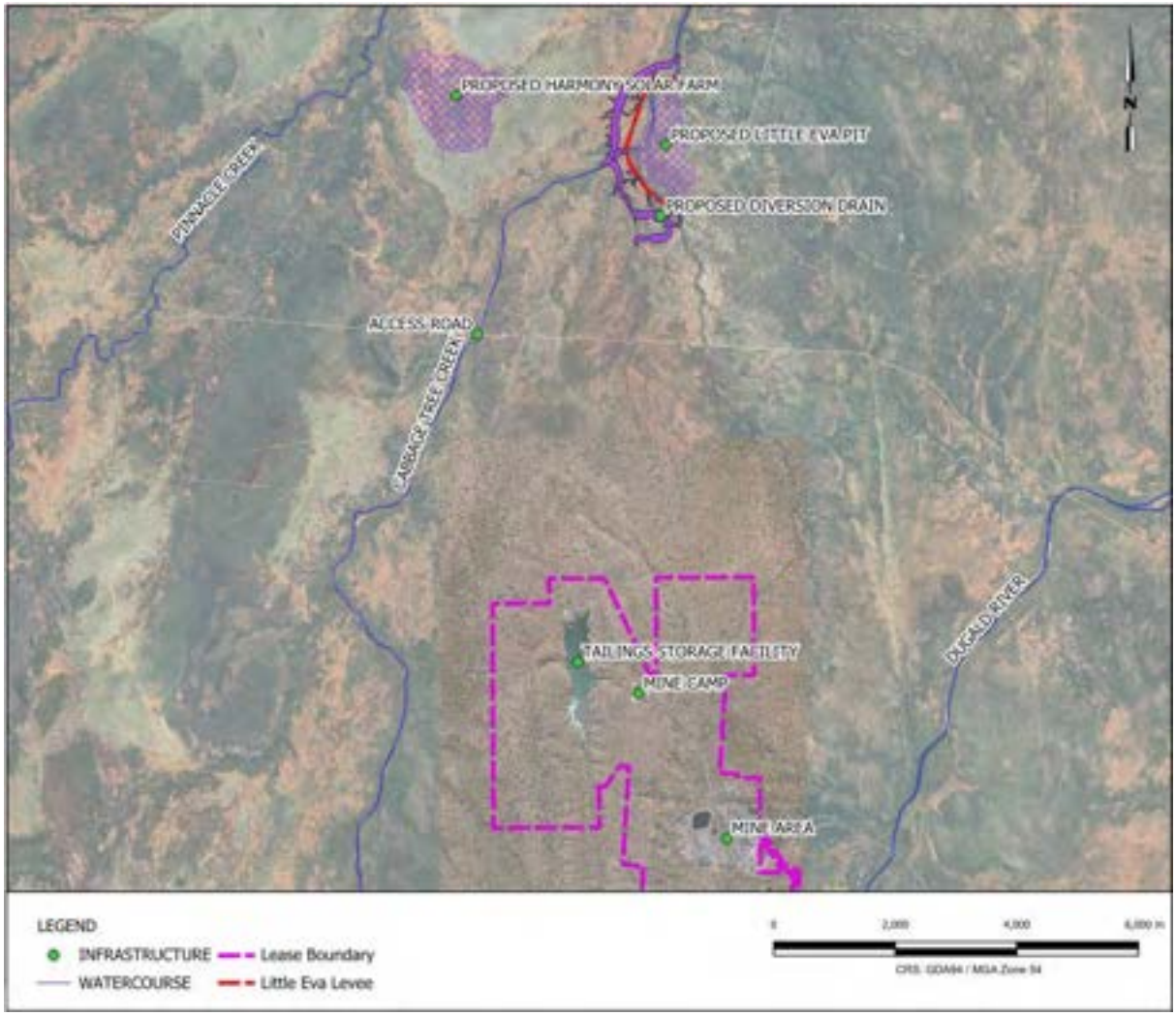
The main purpose of the TSF is to provide storage for tailings, which are produced at the DRM process plant. When the tailings are not transferred to the paste plant (to be used as backfill within the underground mine), the tailings are pumped via a 4 km long pipeline to the TSF.

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**.

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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

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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]**

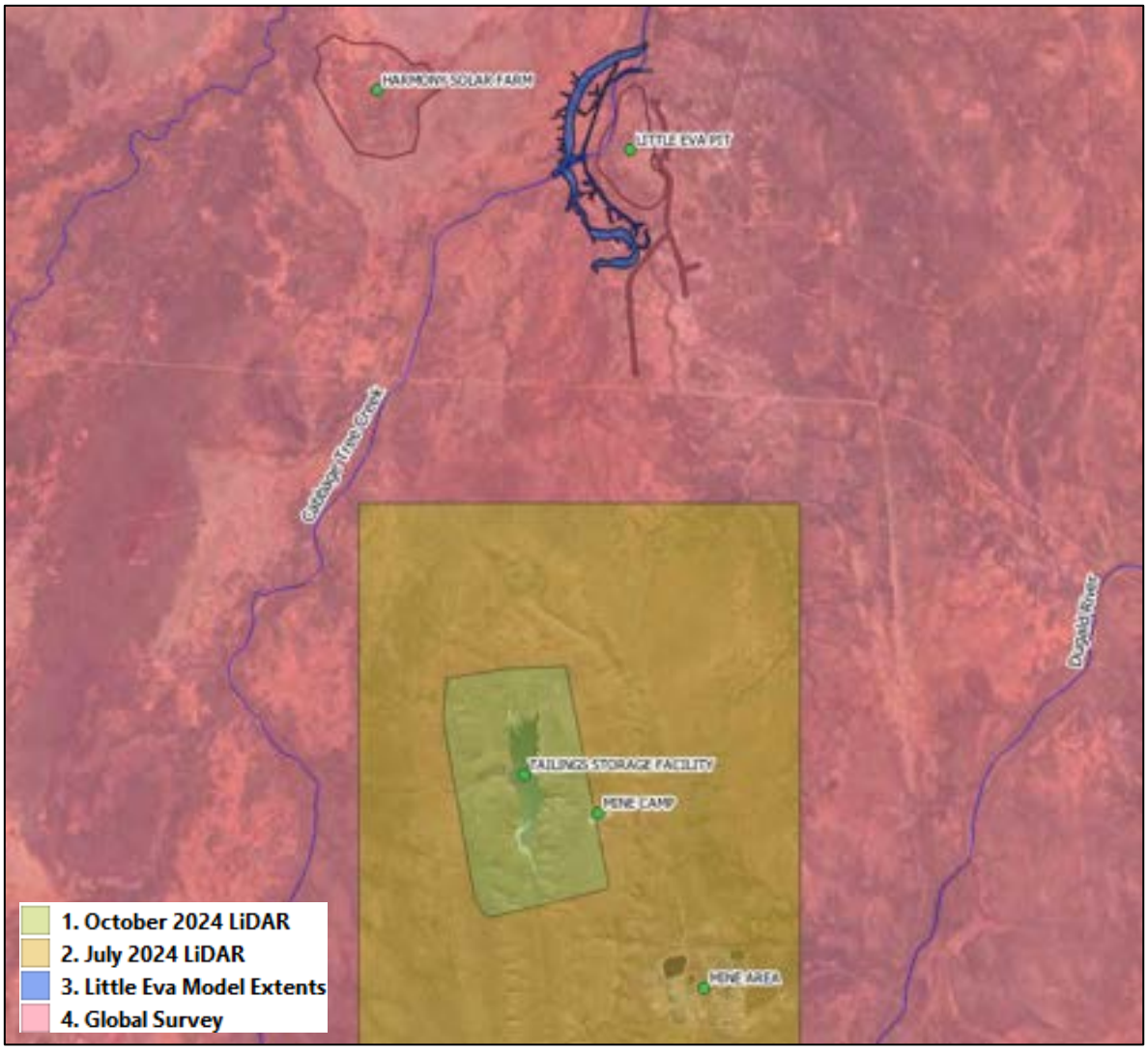
In addition to the topographic survey data, design models have also been incorporated into the model, including:

- 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

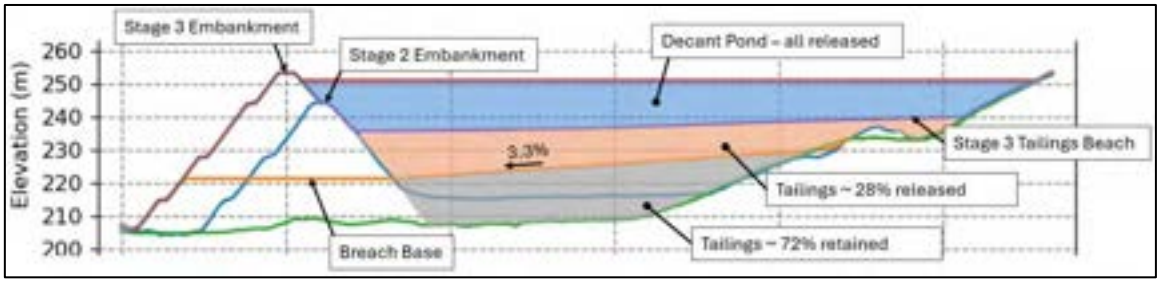
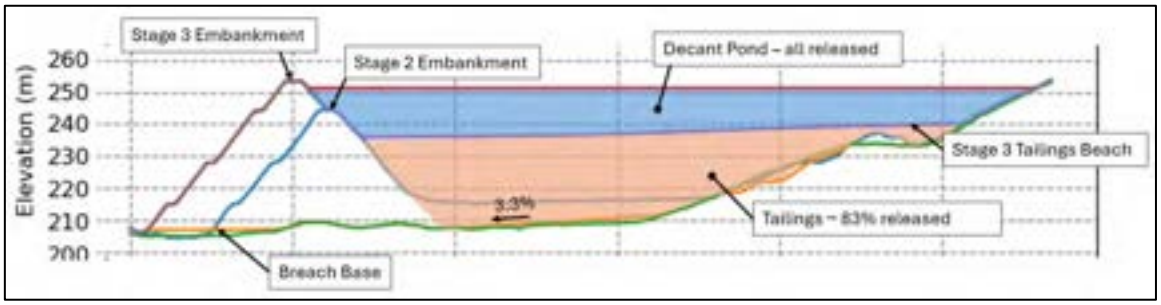


DIAGRAM 2 – FAILURE SCHEMATIC FOR SENSITIVITY CASE



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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)

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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

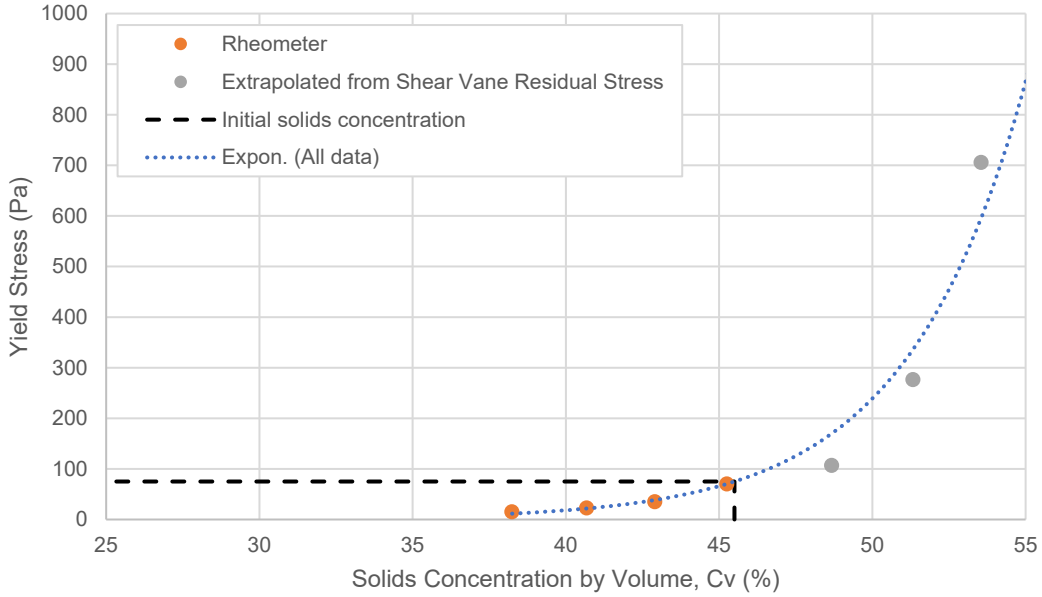
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been extrapolated to estimate the rheology at higher solids concentrations. **Graph 1** and **Graph 2** display the estimated Yield Stress and Bingham Viscosity plots respectively. The adopted tailings parameters utilised in the dam break assessments are summarised in **Table 6**.

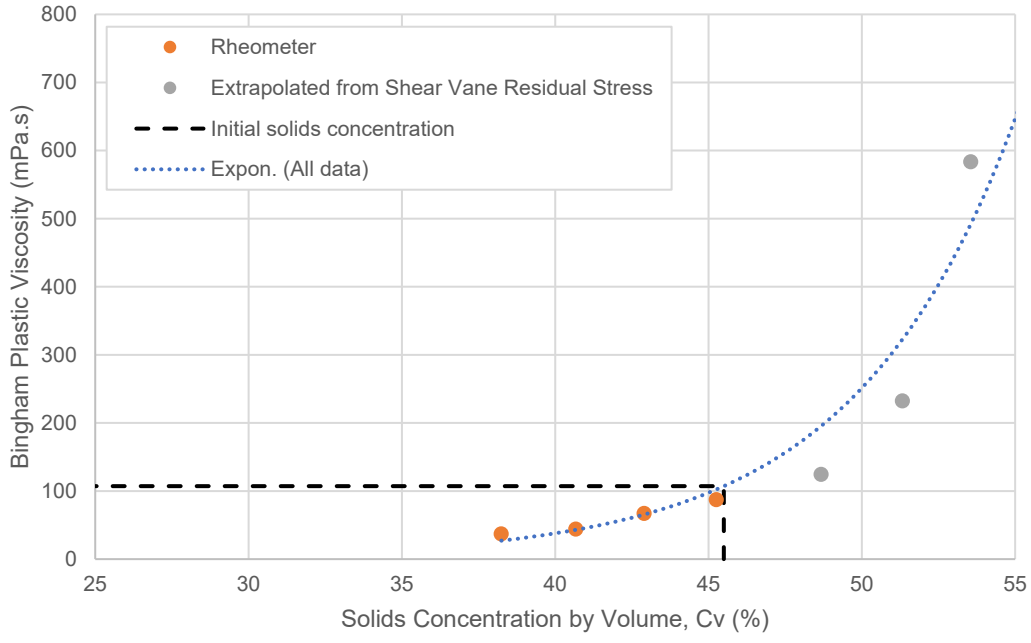
TABLE 6 – ADOPTED TAILINGS PARAMETERS FOR DAM BREAK MODELLING

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**

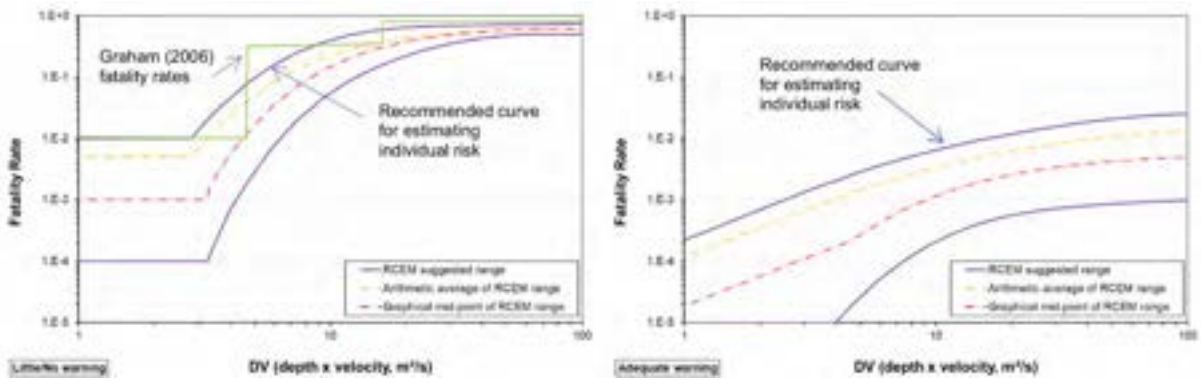
6.3 Potential Loss of Life (PLL)

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.

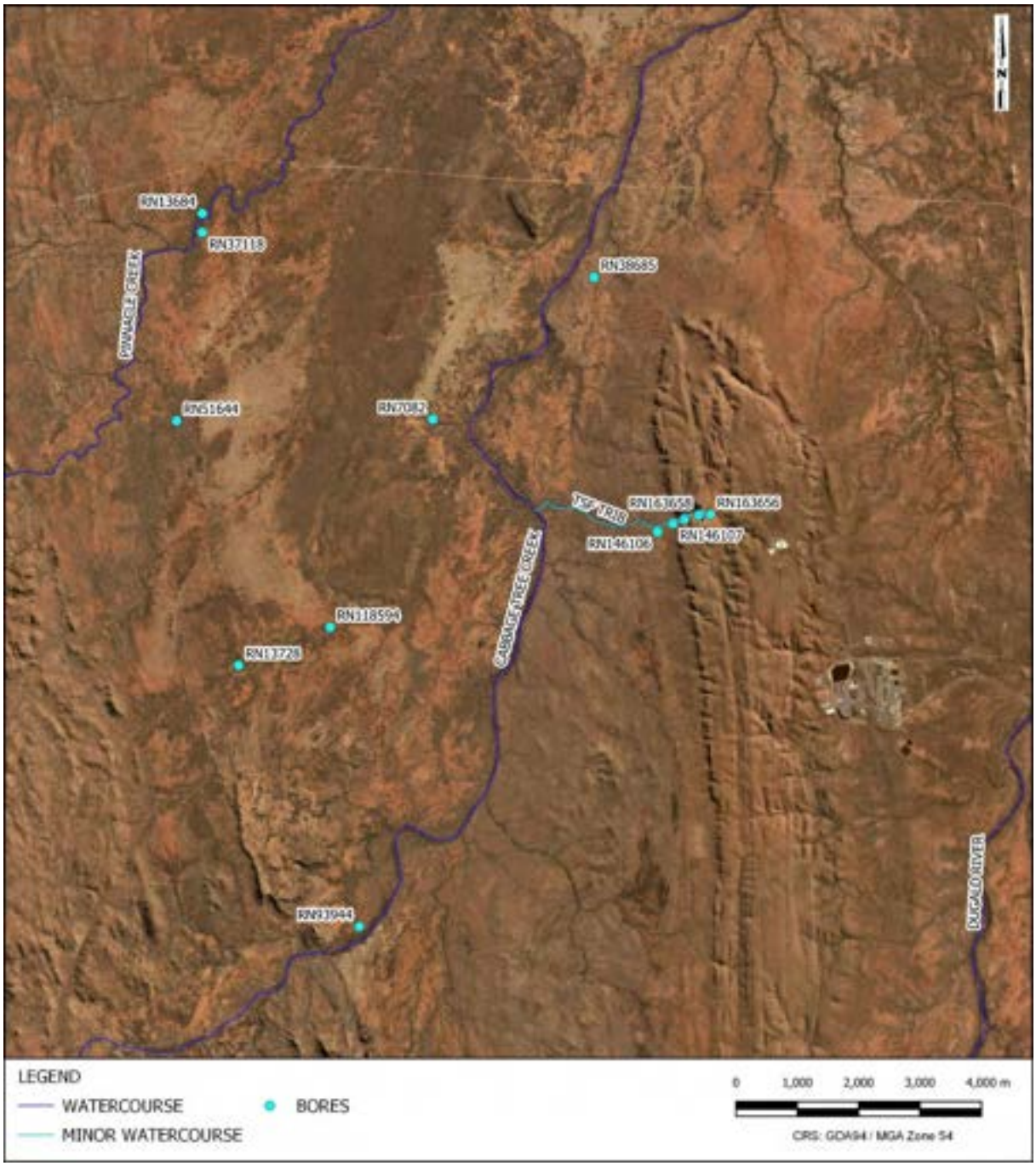
TABLE 16 – REGISTERED LOCAL BOREHOLES ON ML90211 AND LOT 59 ON TG40

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.

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- 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.

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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

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DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

LOCALITY PLAN

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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
410000E
PROPOSED STAGE 3 SEEPAGE COLLECTION SUMP
PROPOSED STAGE 3 SPILLWAY
PROPOSED STAGE 3 EMBANKMENT
NORTHERN DISCHARGE BUND
TAILINGS STORAGE FACILITY
RETURN WATER SYSTEM
200m
210m
220m
230m
240m
250m
260m
270m
280m
290m
300m
310m
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

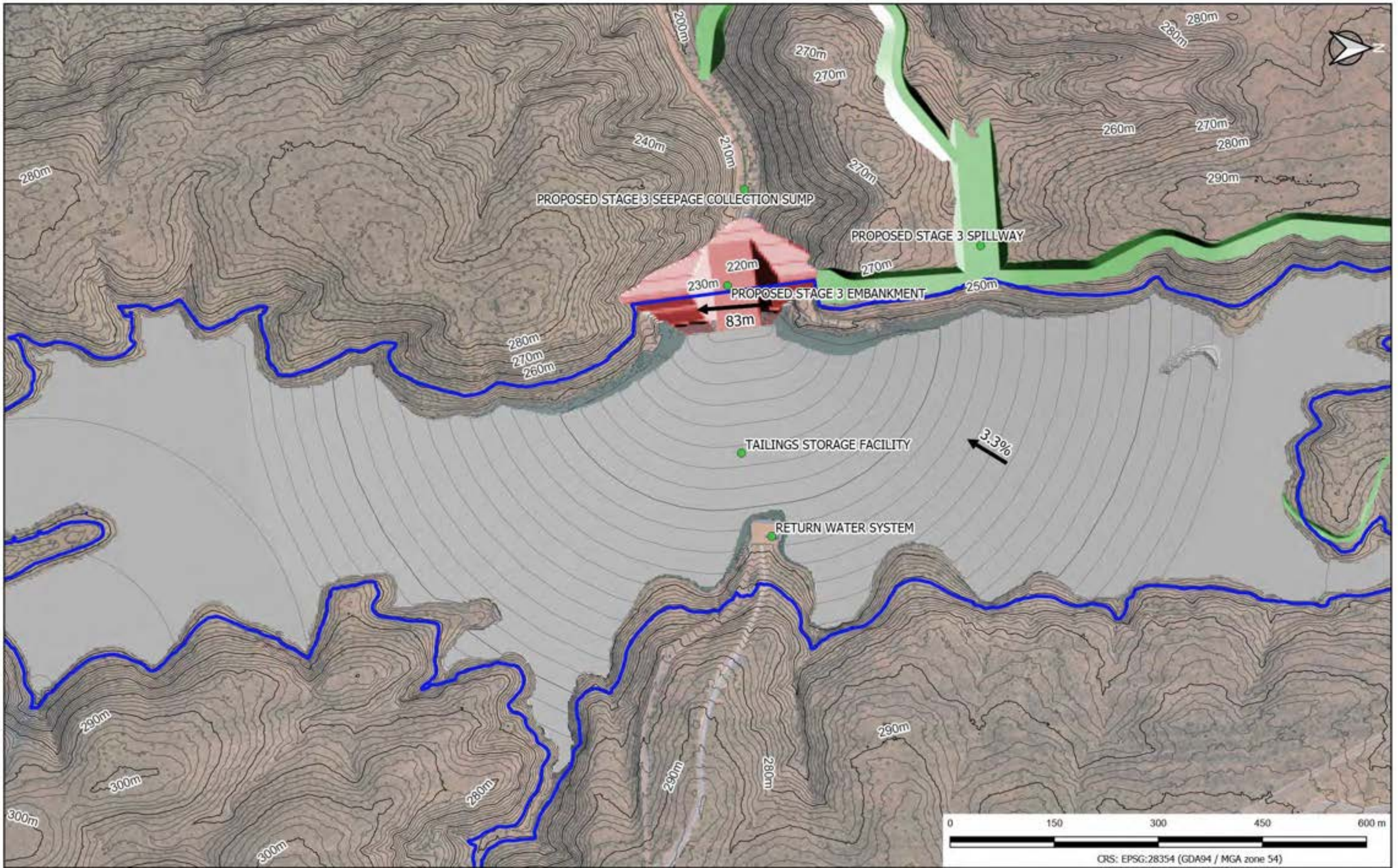
MMG LIMITED
DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

GENERAL ARRANGEMENT

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FIGURE 2
JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:7500 at A3

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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

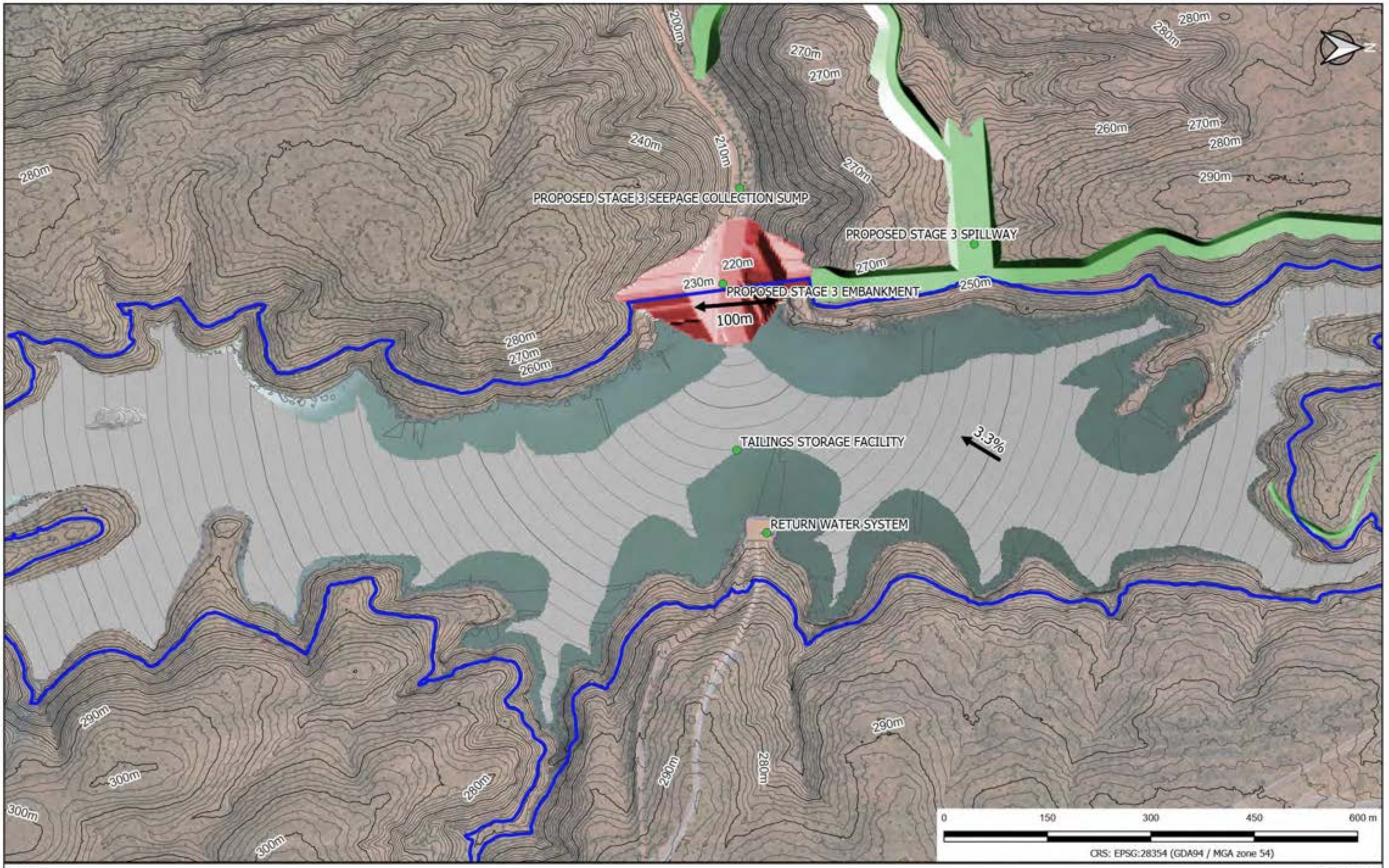
SDF BREACH LAYOUT (BASE CASE)

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FIGURE 3

JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:5000 at A3

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LEGEND
- Points of Interest
- Major Contours (10m)
- Minor Contours (2m)
- Full Supply Level (RL 251.35 m)

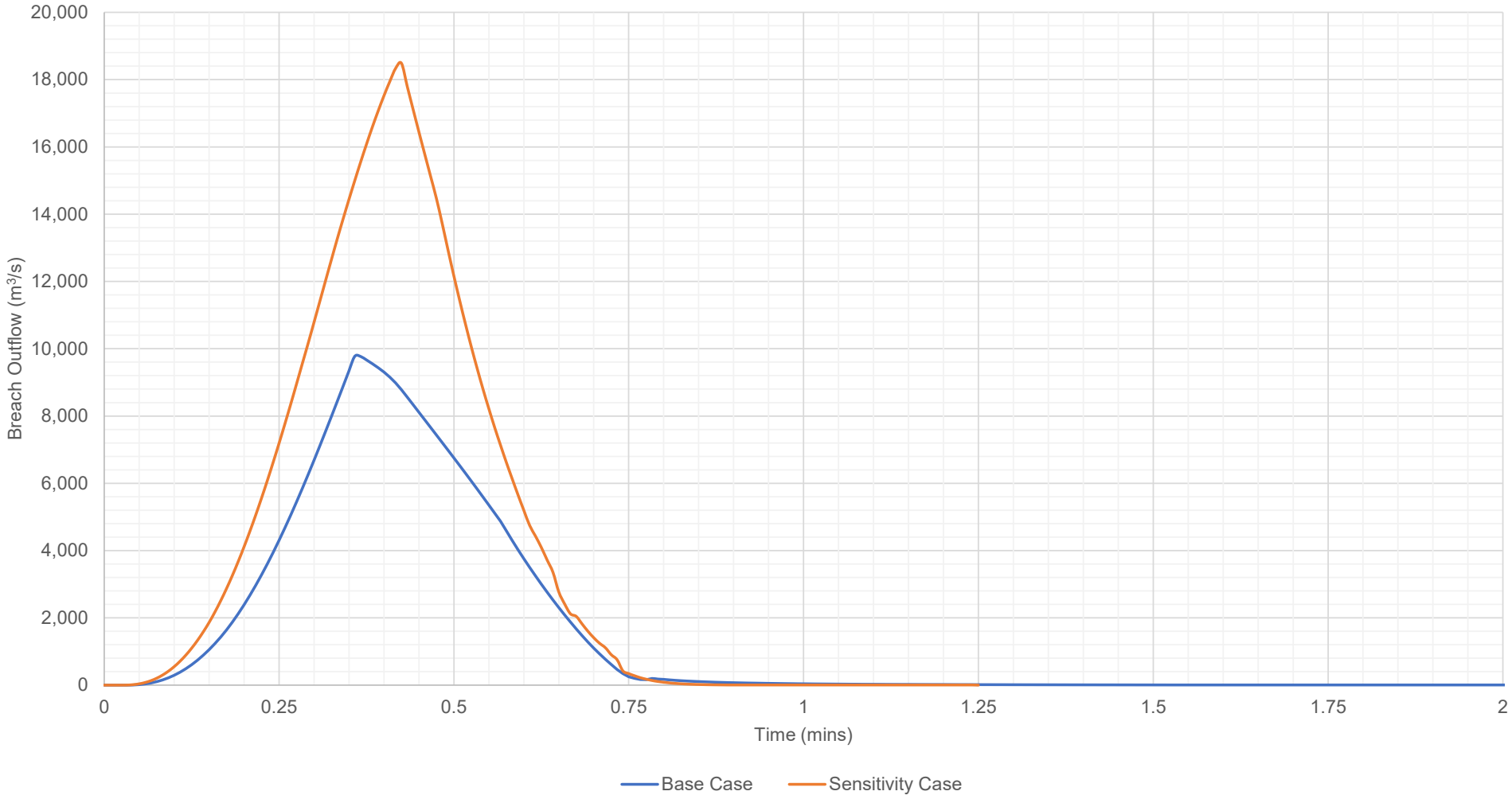
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DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF BREACH LAYOUT (SENSITIVITY CASE)

ATC WILLIAMS

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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DUGALD RIVER MINE

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

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 7

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

SALLY CREEK

LEICHHARDT RIVER

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

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TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM INUNDATION DEPTH (1 OF 2)

ATC WILLIAMS

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

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
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 9
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 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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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

PINNACLE CREEK
CABBAGE TREE 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

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)

ATC WILLIAMS

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

MINE AREA

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

REFER FIGURE 11

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

SALLY CREEK

LEICHHARDT RIVER

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 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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TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
MAXIMUM DEPTH TIMES VELOCITY (1 OF 2)

ATC WILLIAMS

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

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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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
N
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 13
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

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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DUGALD RIVER MINE
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

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

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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DUGALD RIVER MINE
TAILINGS STORAGE FACILITY - STAGE 3

SDF (BASE CASE)
TIME FOR 300 mm INUNDATION (2 OF 2)

ATC WILLIAMS

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

TAILINGS STORAGE FACILITY

MINE CAMP

MINE AREA

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

REFER FIGURE 15

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

SALLY CREEK

LEICHHARDT RIVER

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

EXTENT 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 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 (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

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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

PROPOSED HARMONY SOLAR FARM

LAKE JULIUS ACCESS ROAD

EXTENT 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

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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
N
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 19
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 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 (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

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

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

PINNACLE CREEK

CABBAGE TREE 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

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

TAILINGS STORAGE FACILITY

MINE CAMP

MINE AREA

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

REFER FIGURE 23

PROPOSED HARMONY SOLAR FARM

KAJABBI NORMANTON RD

SALLY CREEK

LEICHHARDT RIVER

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

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

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

MINE AREA

PROPOSED DIVERSION DRAIN

PROPOSED LITTLE EVA PIT

PROPOSED HARMONY SOLAR FARM

REFER FIGURE 25

SALLY CREEK

LEICHHARDT RIVER

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

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 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

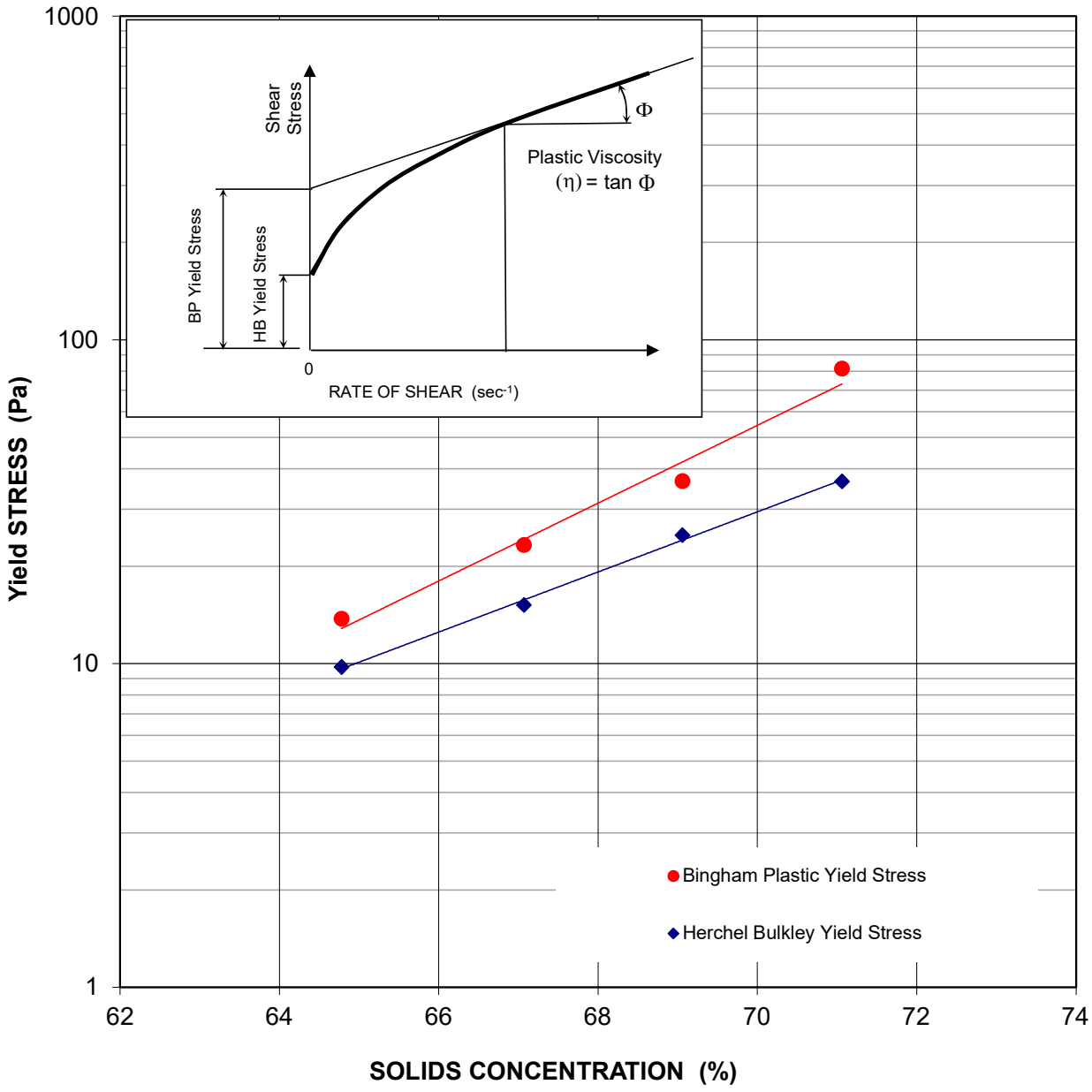
JOB NO. 250542
DATE: 19/06/2025
REVISION: A
SCALE: 1:30000 at A3

S:\Dugald\250542 - TSF Raise Design\Data and Calcs\Dam Break\QGIS\Dugald Stage 3 Dam Break.qgz

APPENDICES

APPENDIX A – RHEOLOGY TESTING

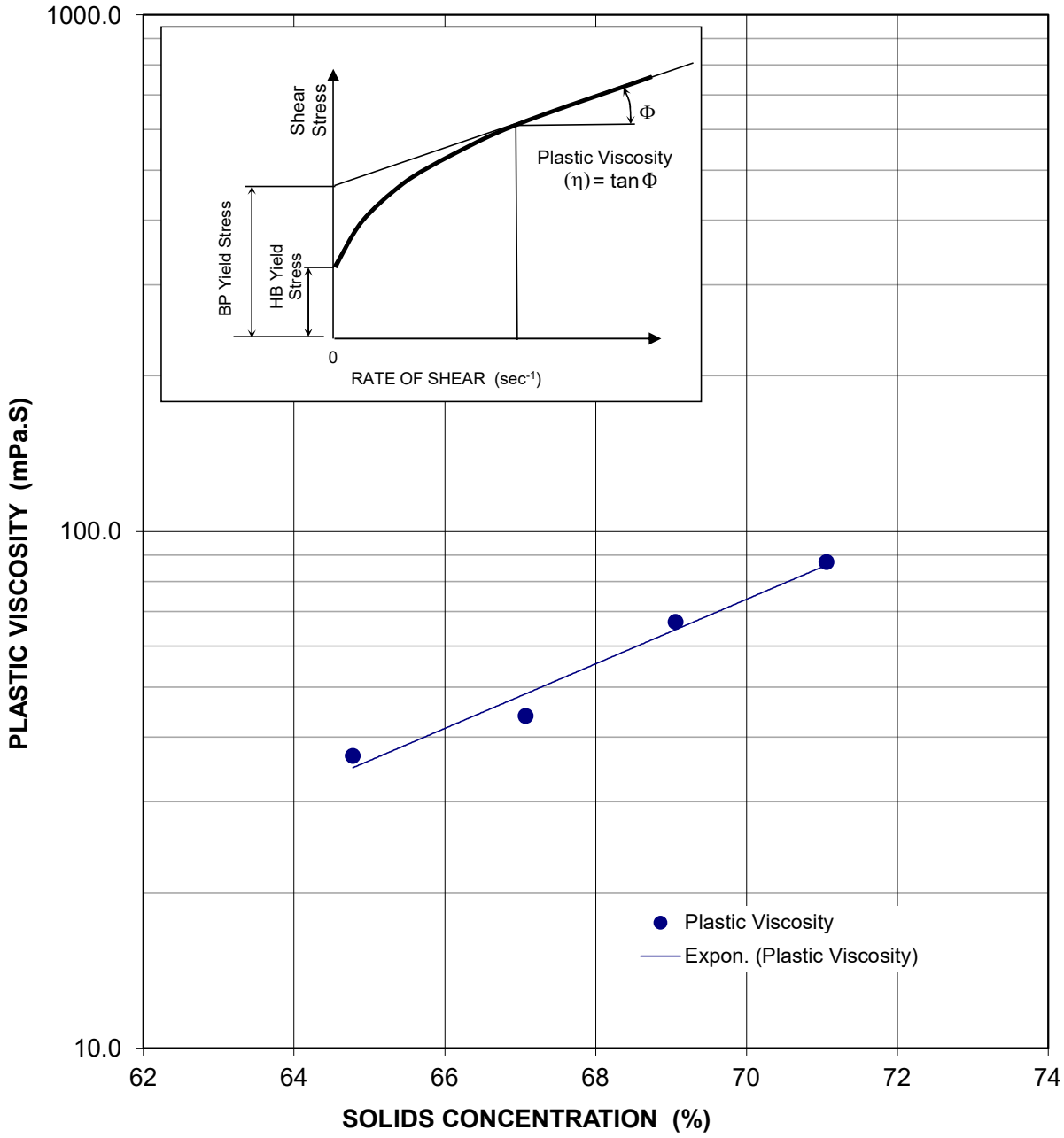
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



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

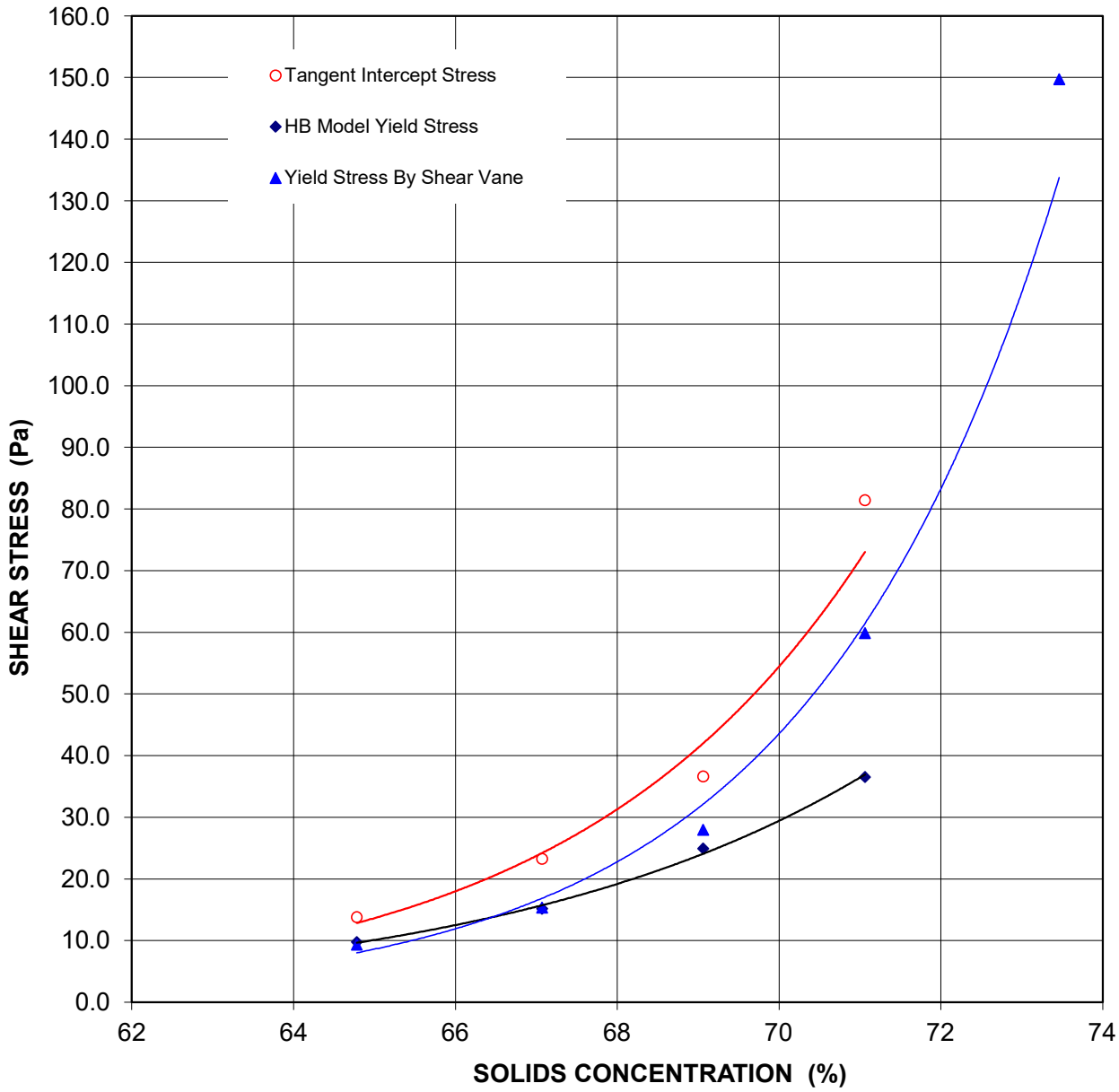
250542 - Dugald River TSF Raise Design
Sample No. 14325
PLASTIC VISCOSITY



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

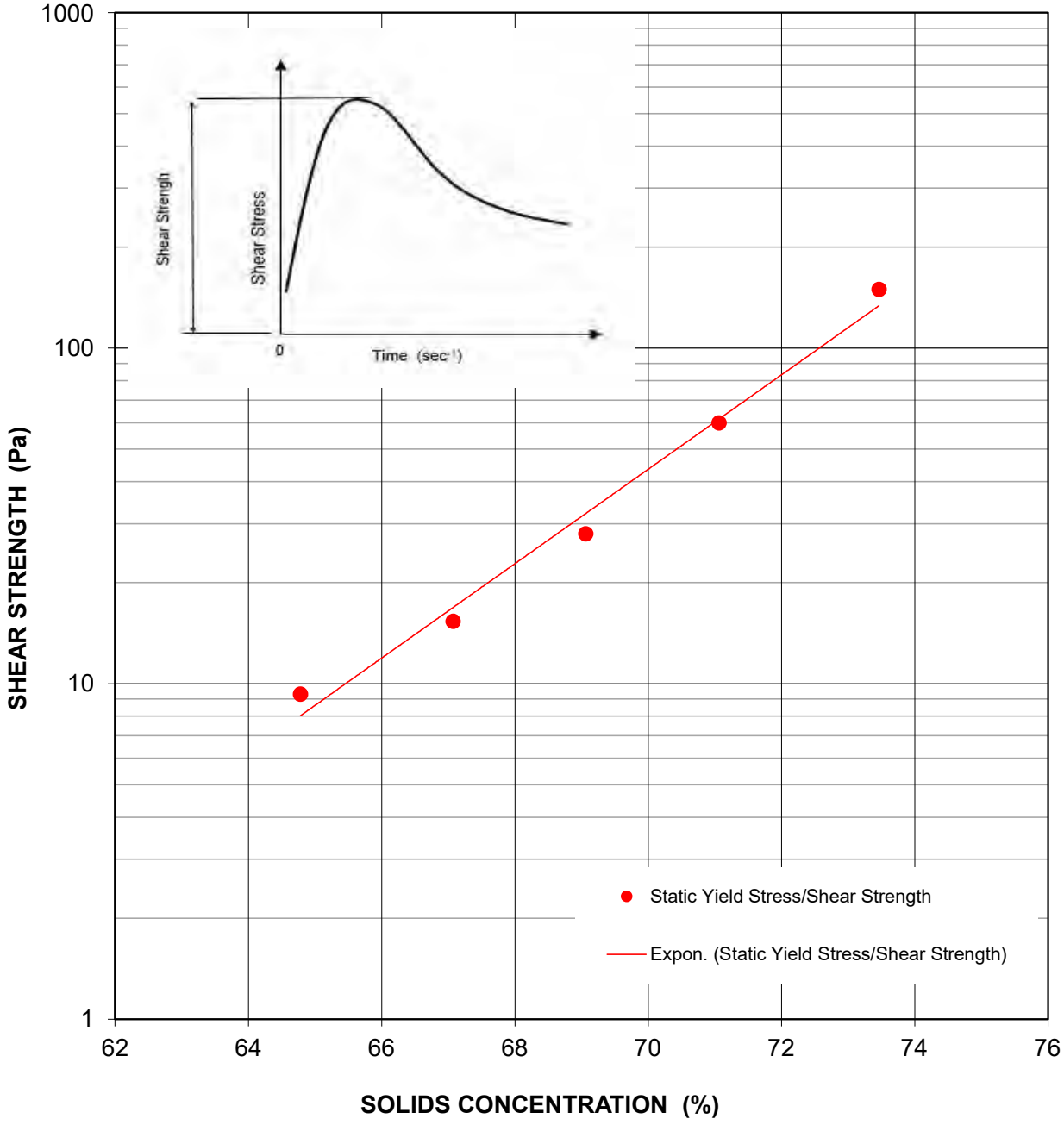
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRESS



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**

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

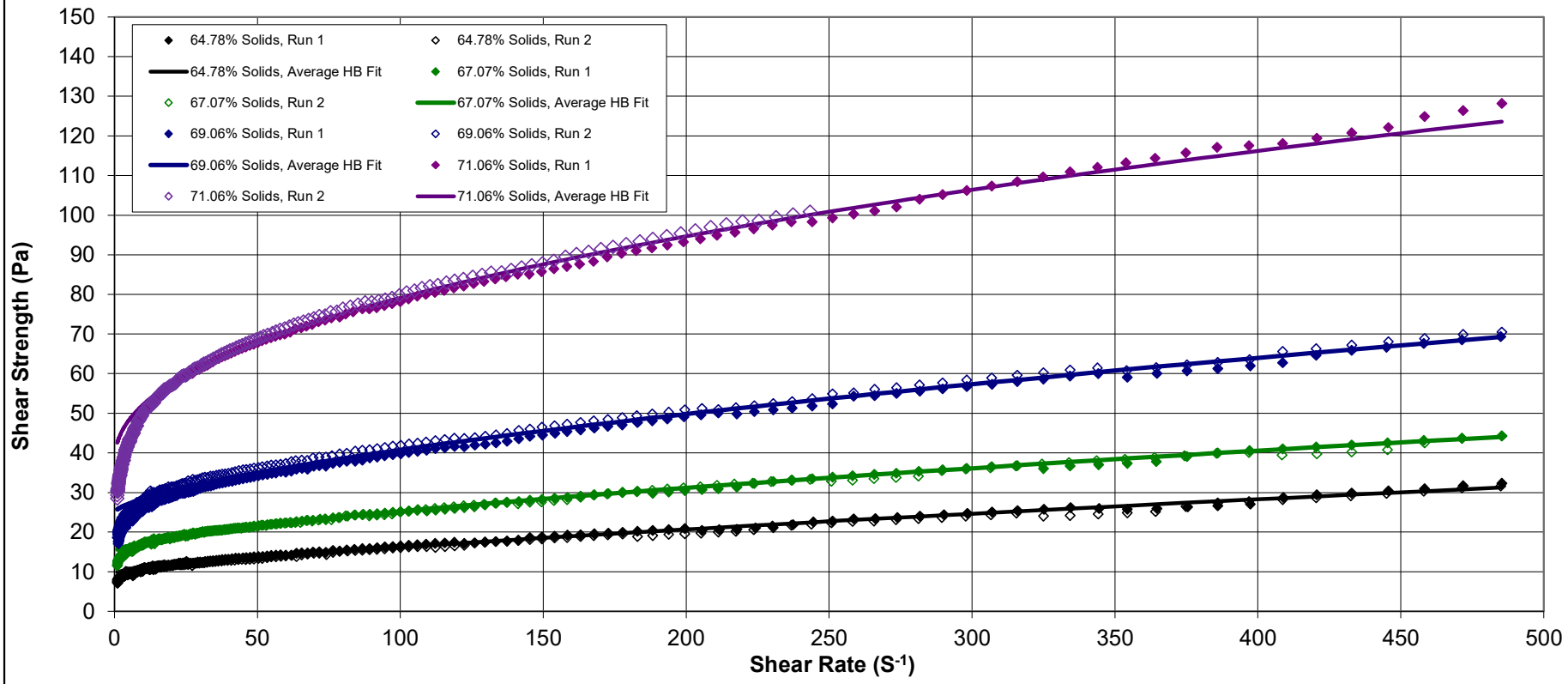
250542 - Dugald River TSF Raise Design
Sample No. 14325
SHEAR STRENGH



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

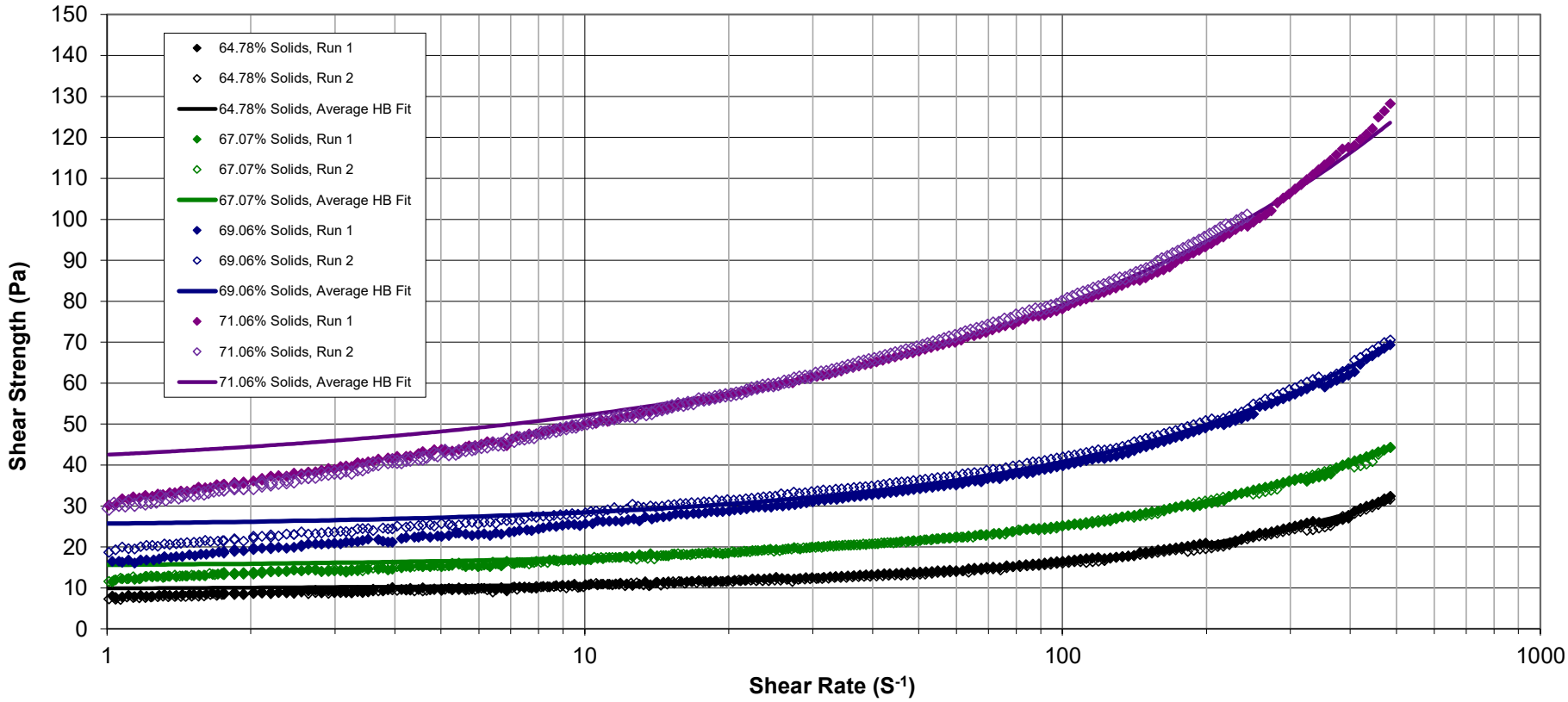
Dugald River TSF Raise Design

Tailings Sample No. 1 - Unflocculated

Rheology Testing

Date: 19/03/2025 **Job No:** 250542

Appendix B1



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MMG Limited

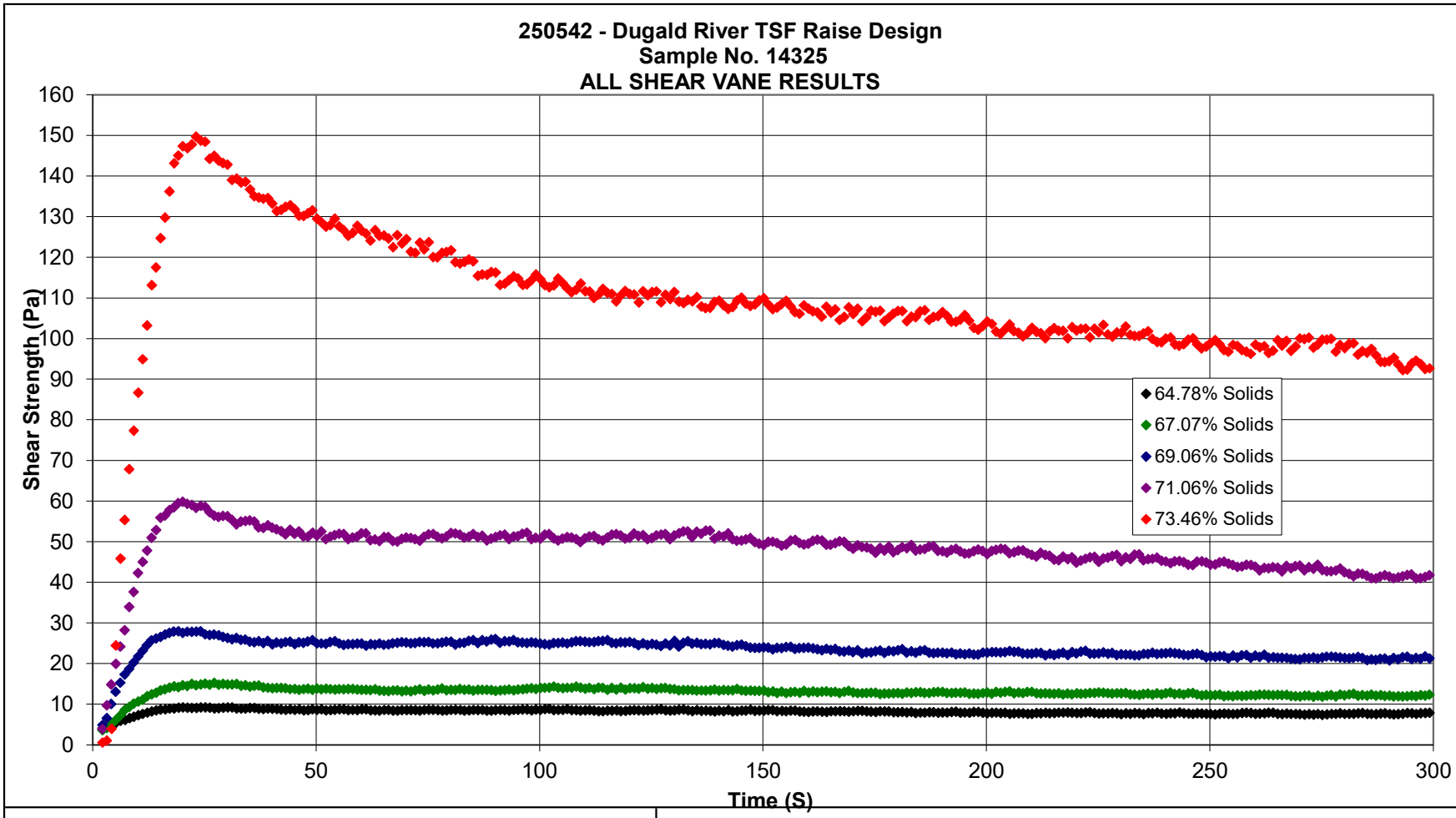
Dugald River TSF Raise Design

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

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

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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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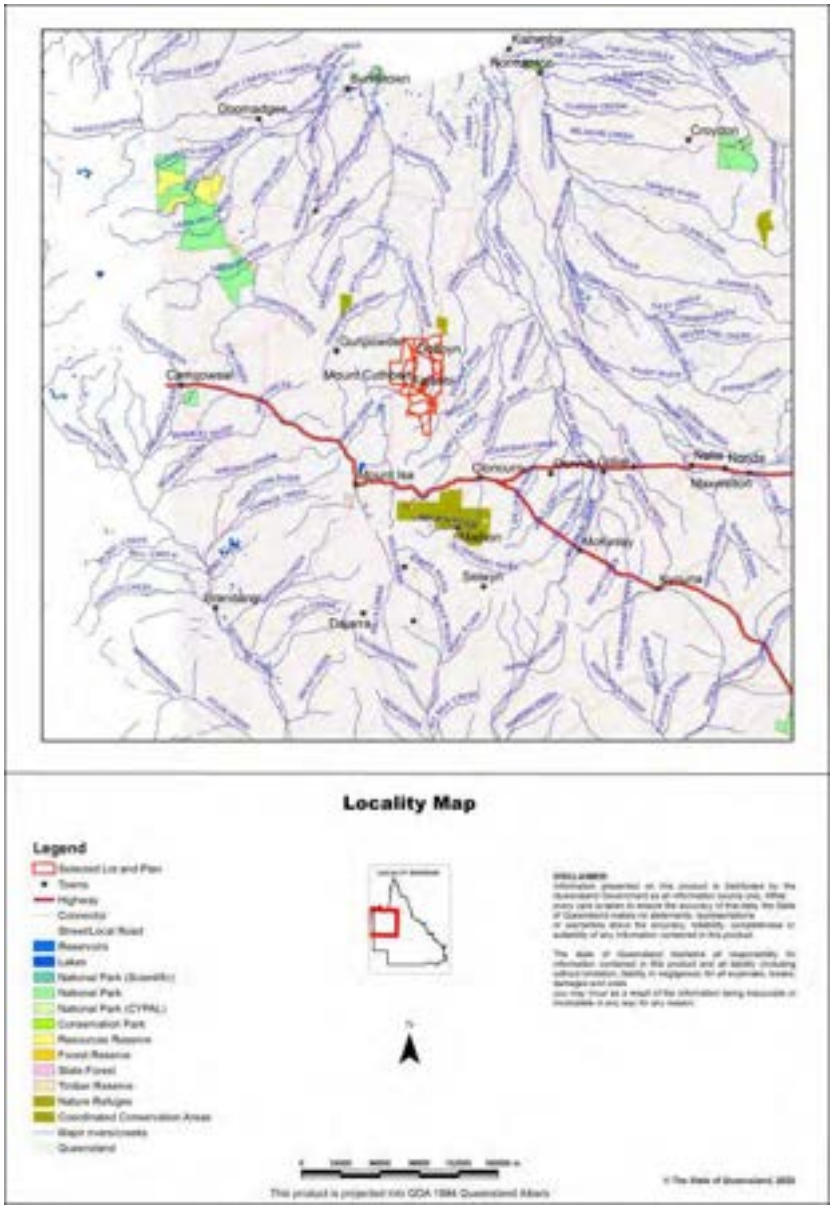
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Assessment Area Details

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

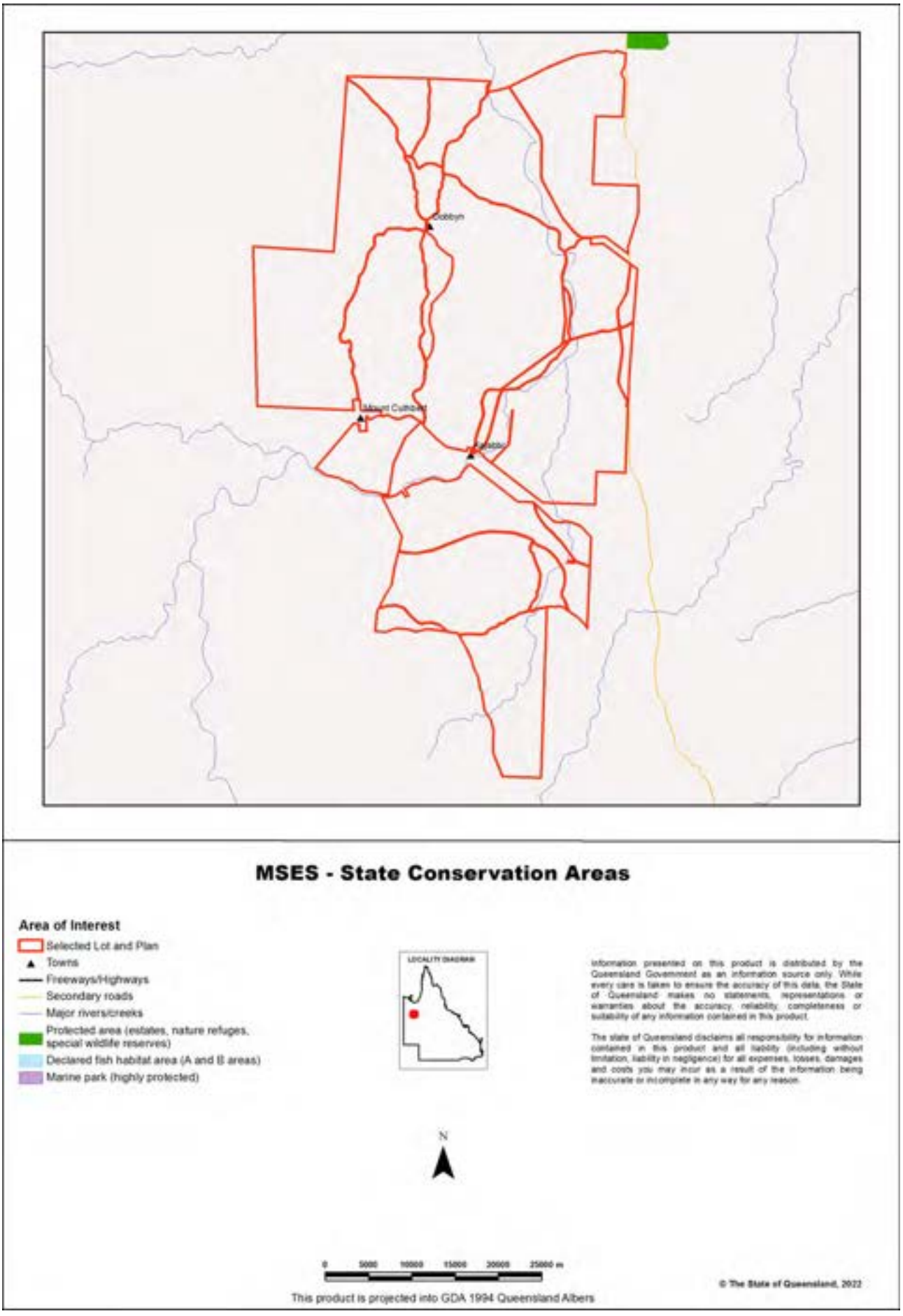
(no results)

9b. Legally secured offset areas - vegetation offsets through a Property Map of Assessable Vegetation

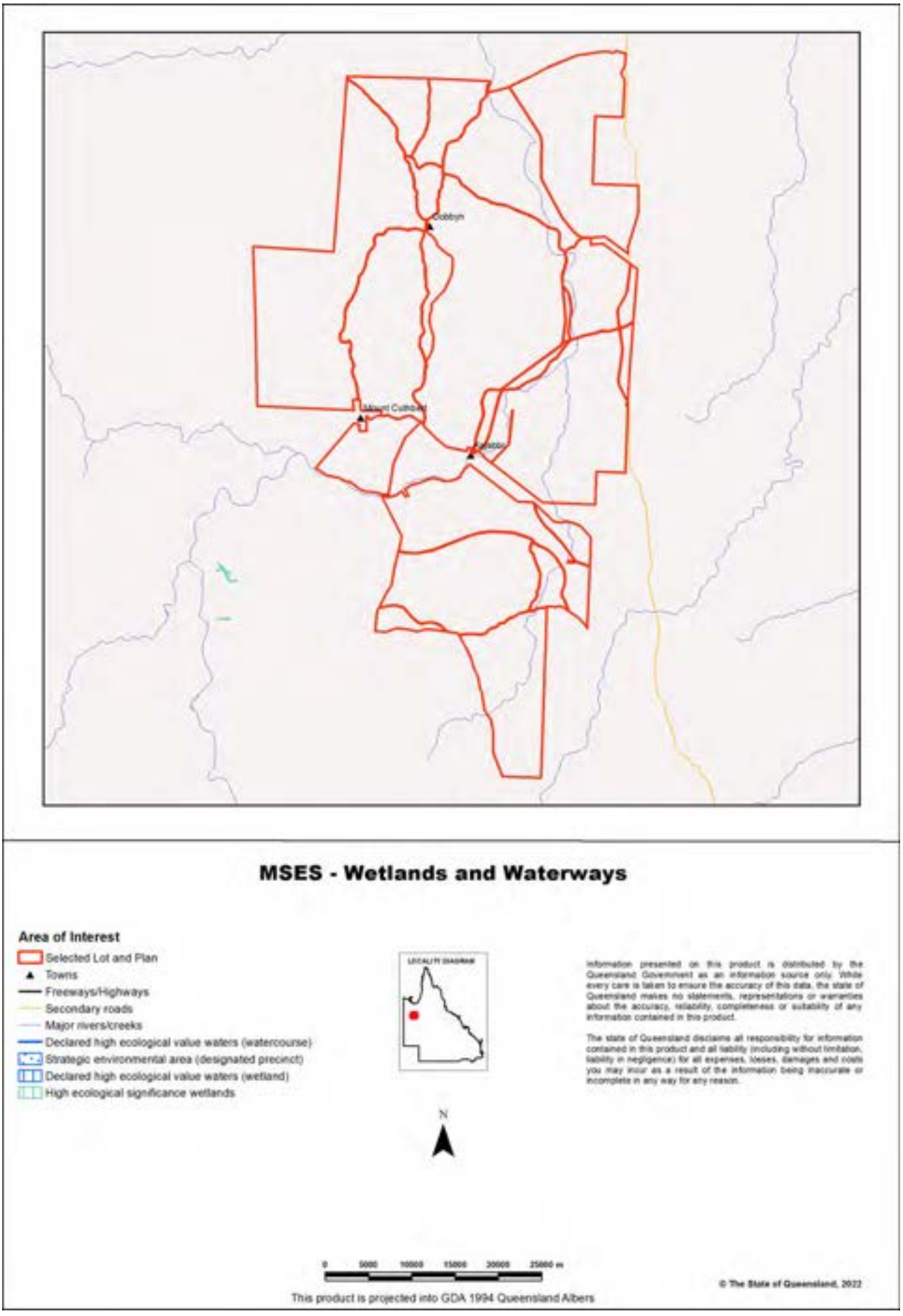
(no results)

Refer to **Map 5 - MSES - Offset Areas** for an overview of the relevant MSES.

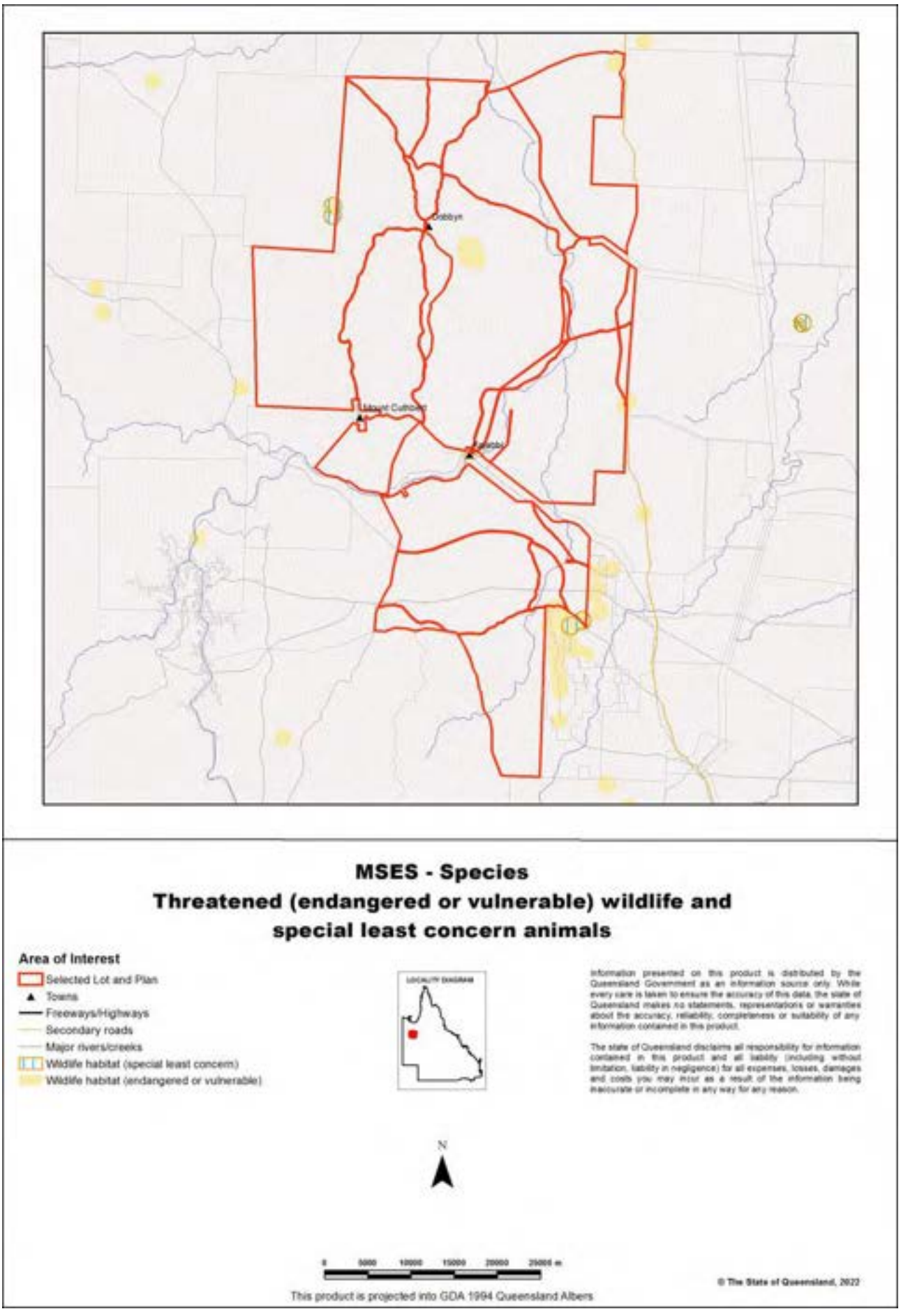
Map 1 - MSES - State Conservation Areas



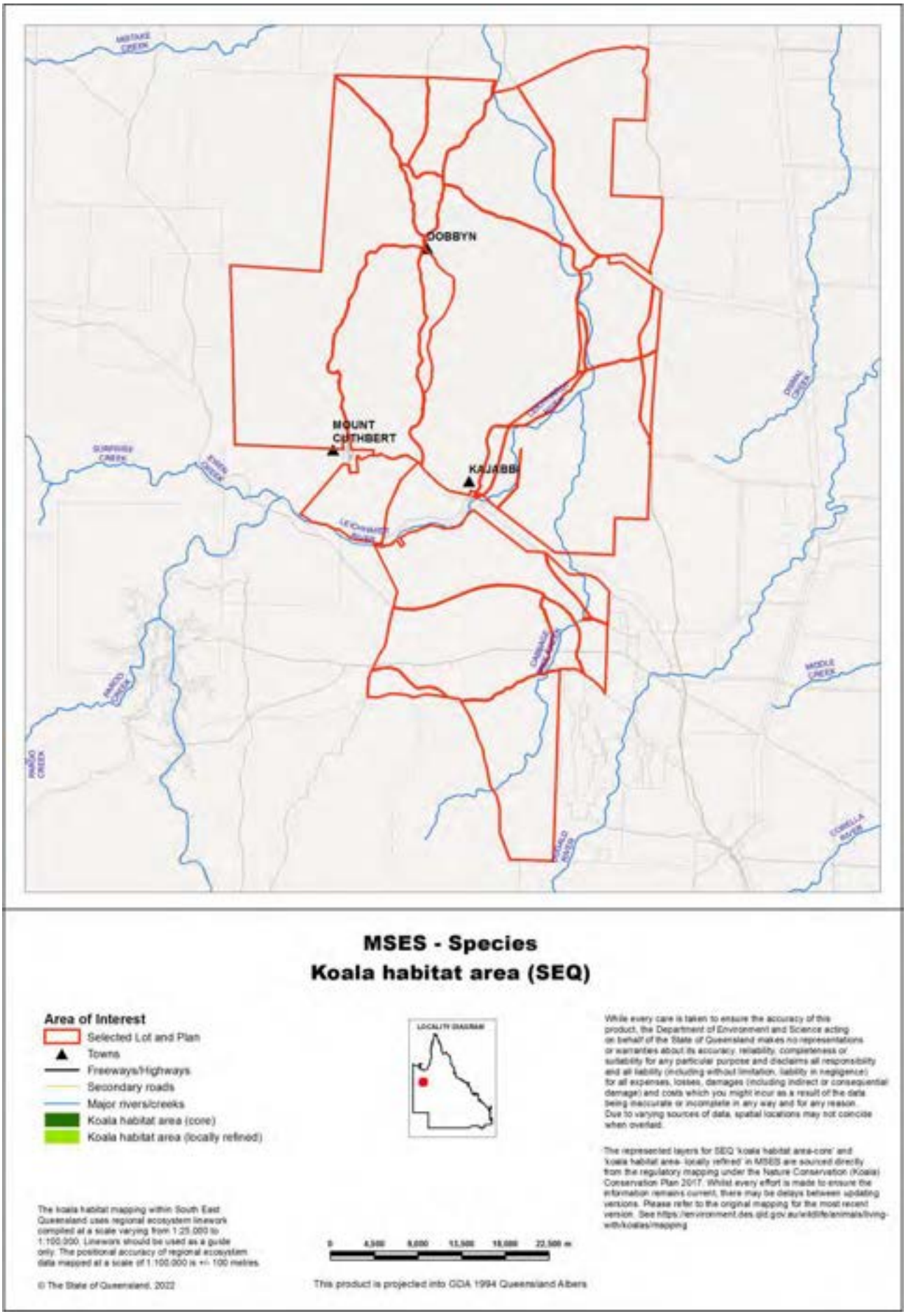
Map 2 - MSES - Wetlands and Waterways



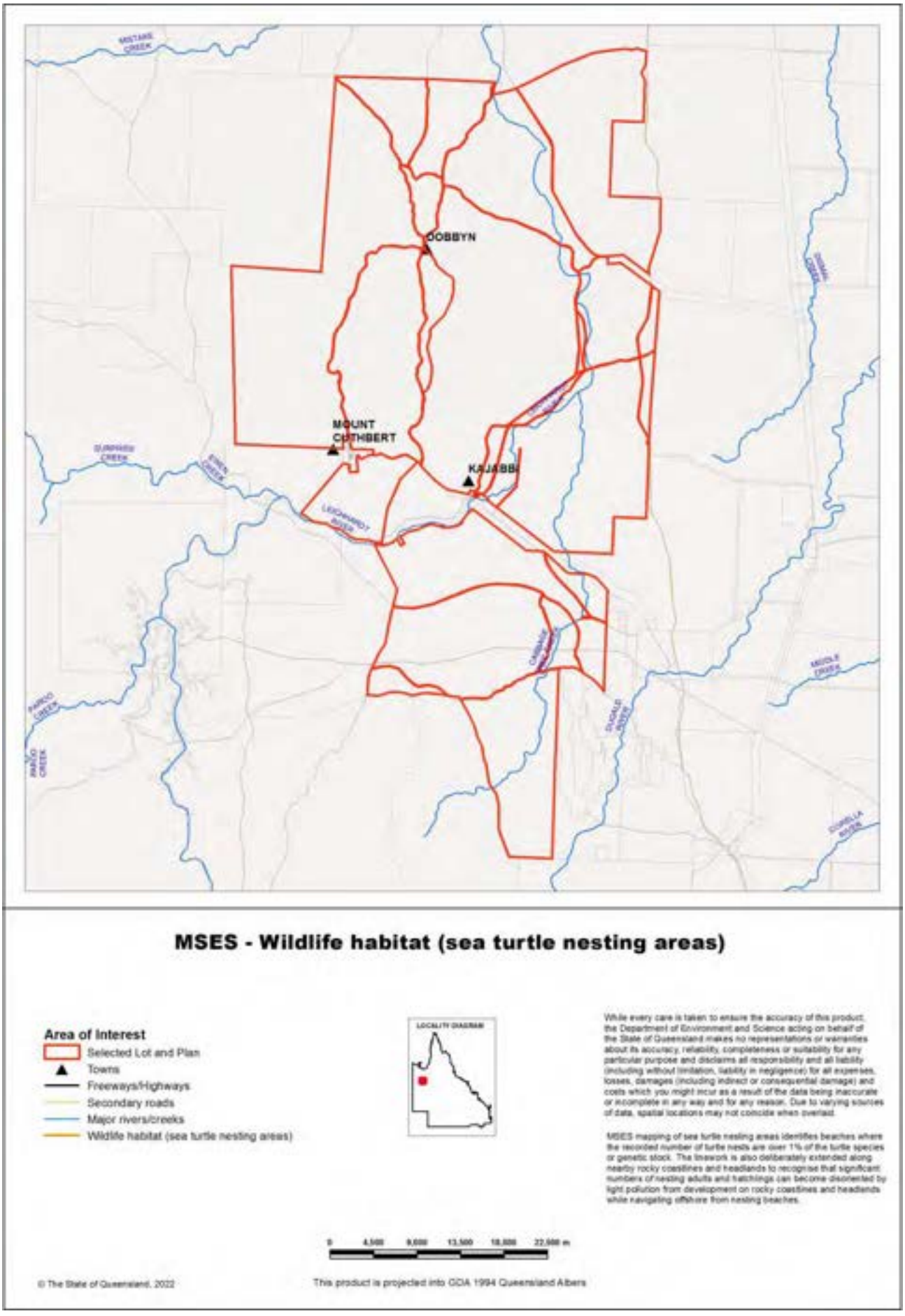
Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals



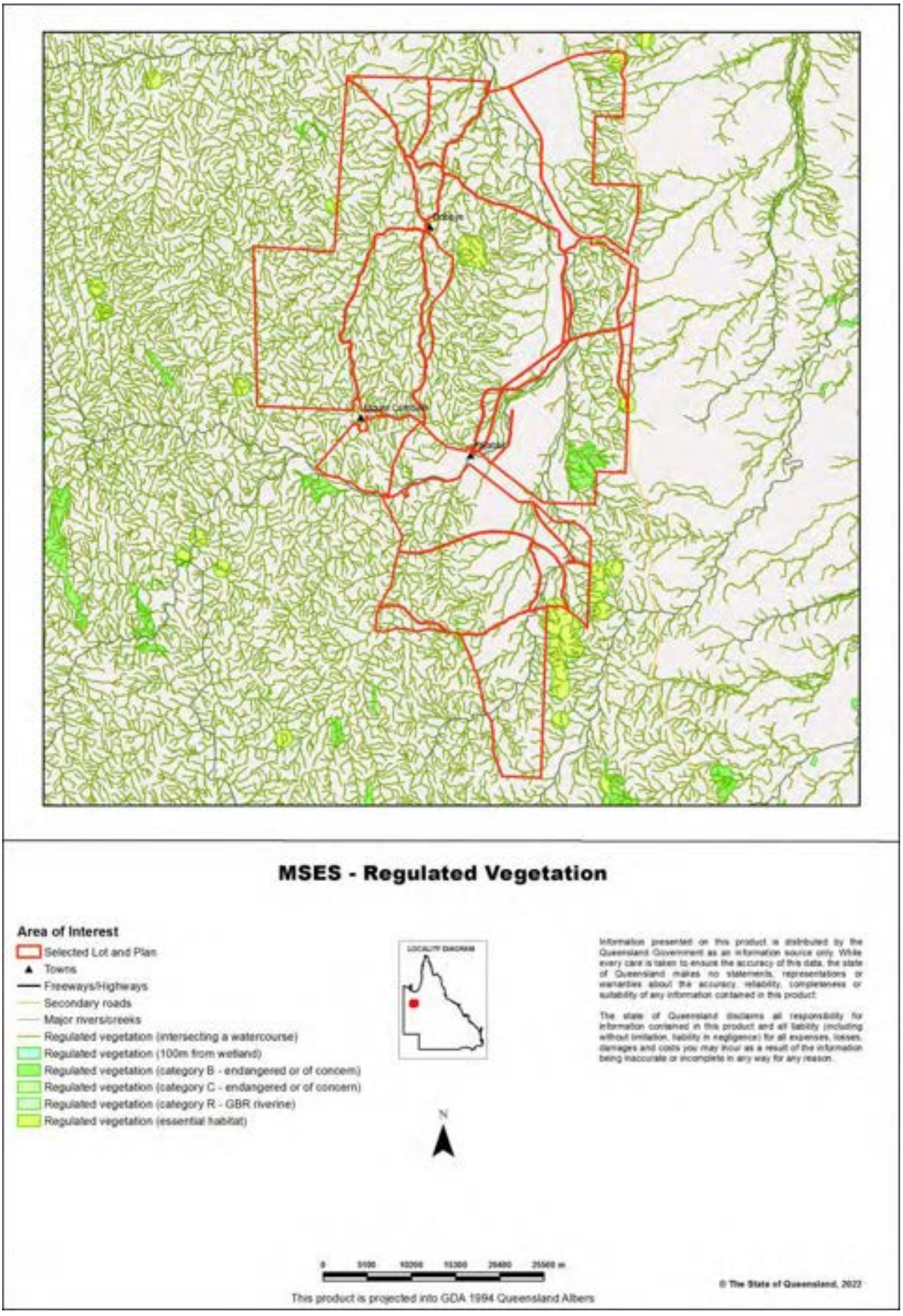
Map 3b - MSES - Species - Koala habitat area (SEQ)



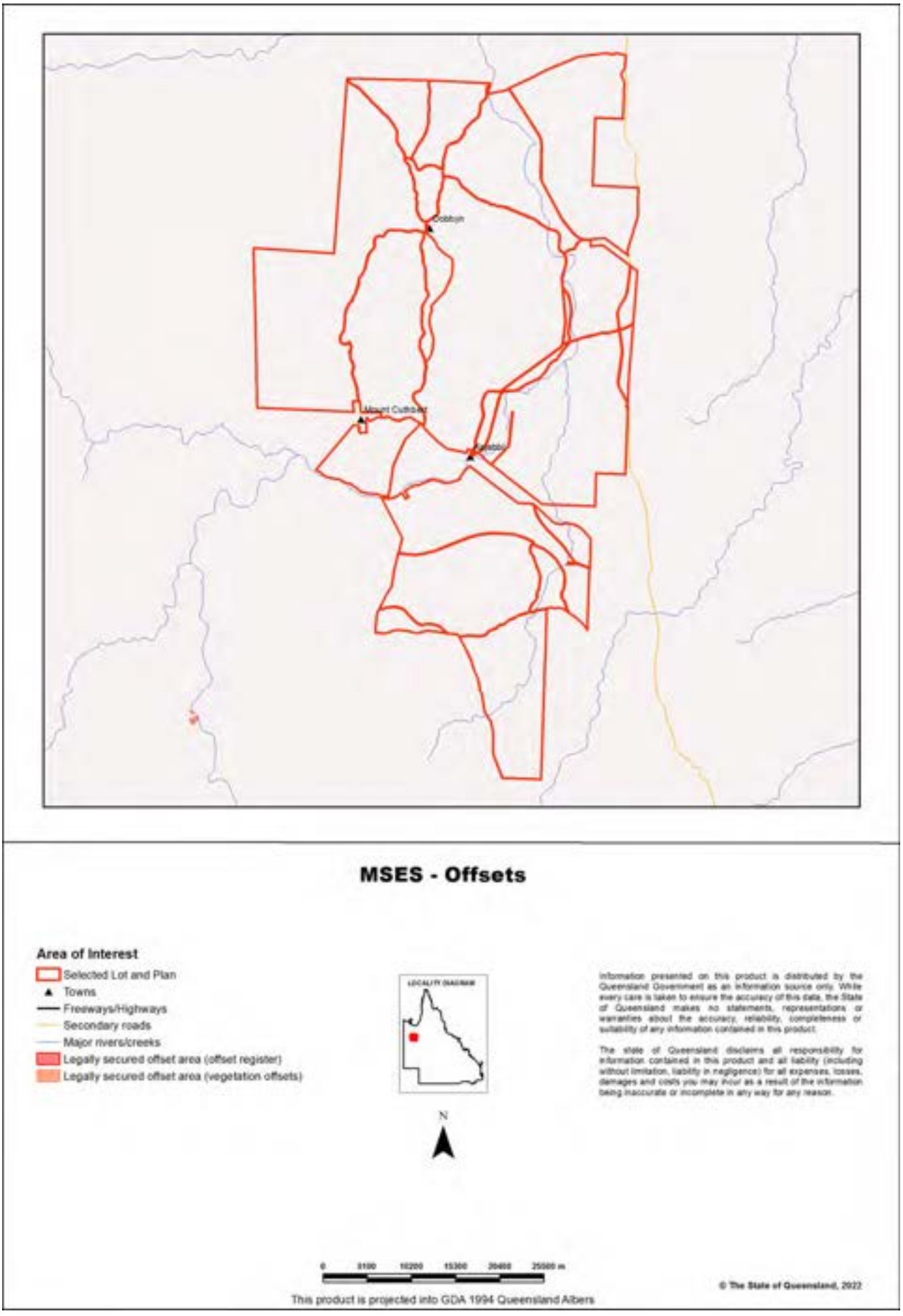
Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)



Map 4 - MSES - Regulated Vegetation



Map 5 - MSES - Offset Areas



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

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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

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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

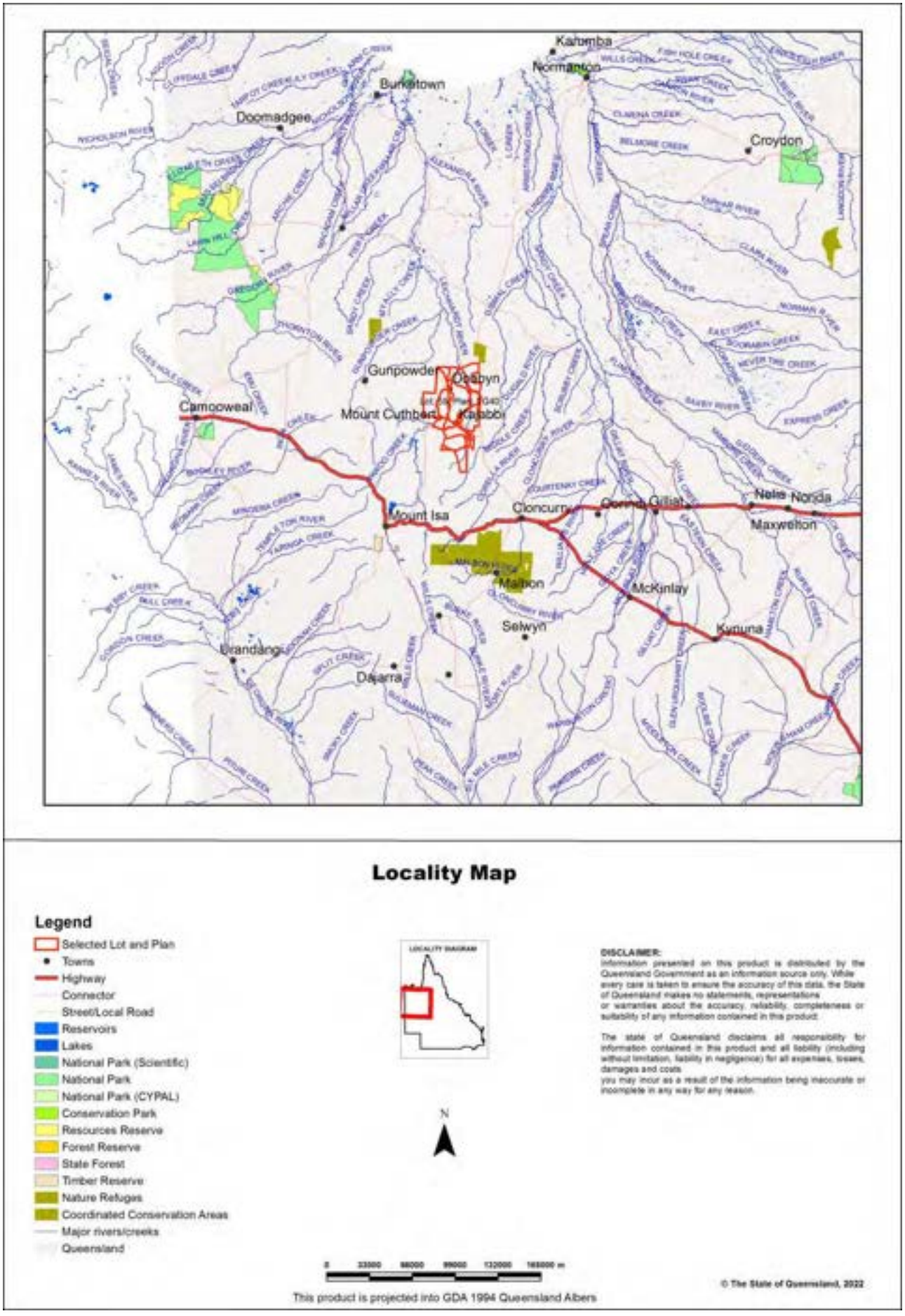
Table 25: Priority species recorded on, or within 4 km of the AOI - non-riverine

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

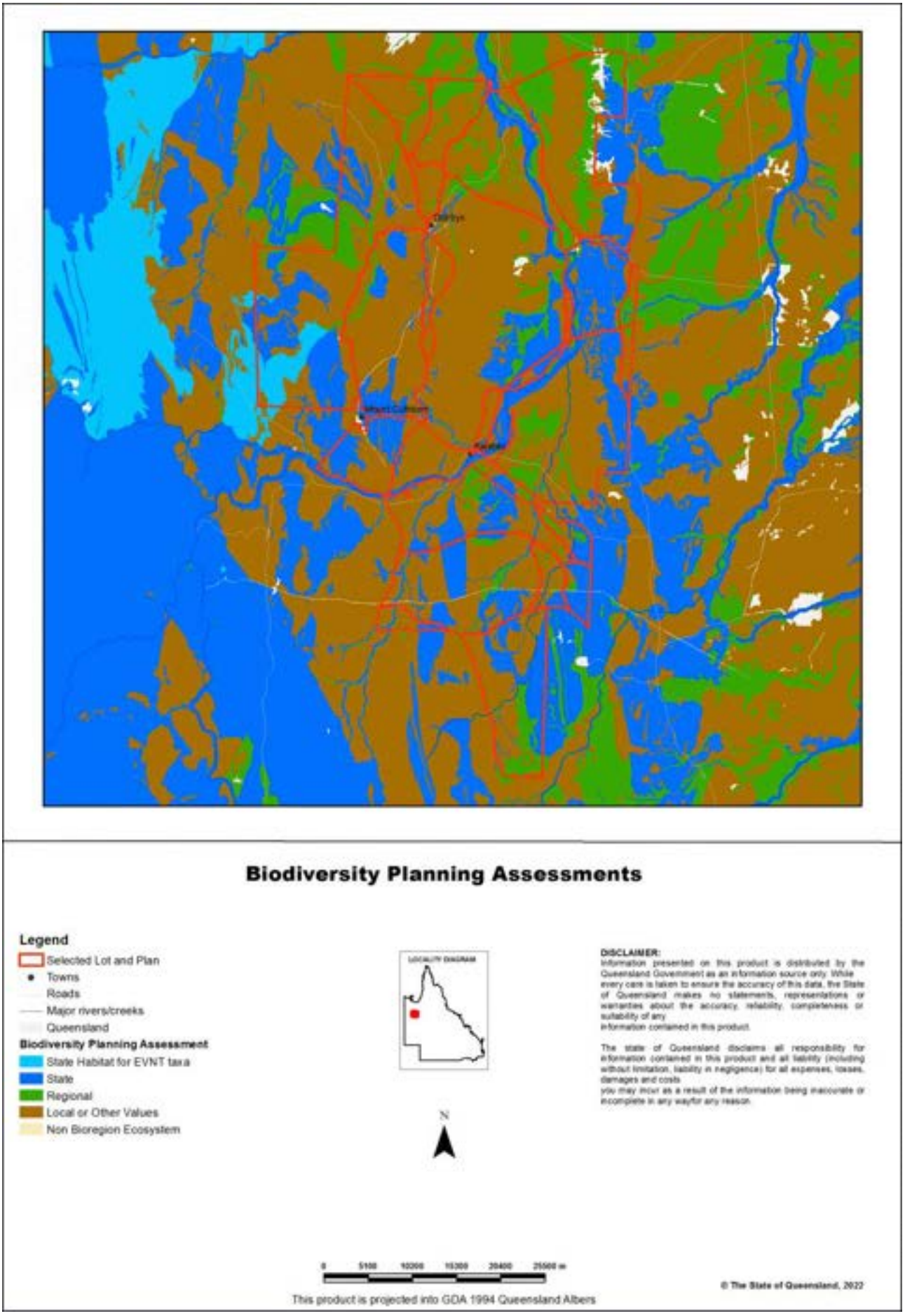
NB. Please note that the priority species records used in the above two tables are comprised of those adopted for the released individual ACAs. The ACA riverine and non-riverine priority species databases are updated from time to time to reflect new release of ACAs. At each update, the taxonomic details for all ACAs records are amended as necessary to reflect current taxonomic name and/or status changes.

Maps

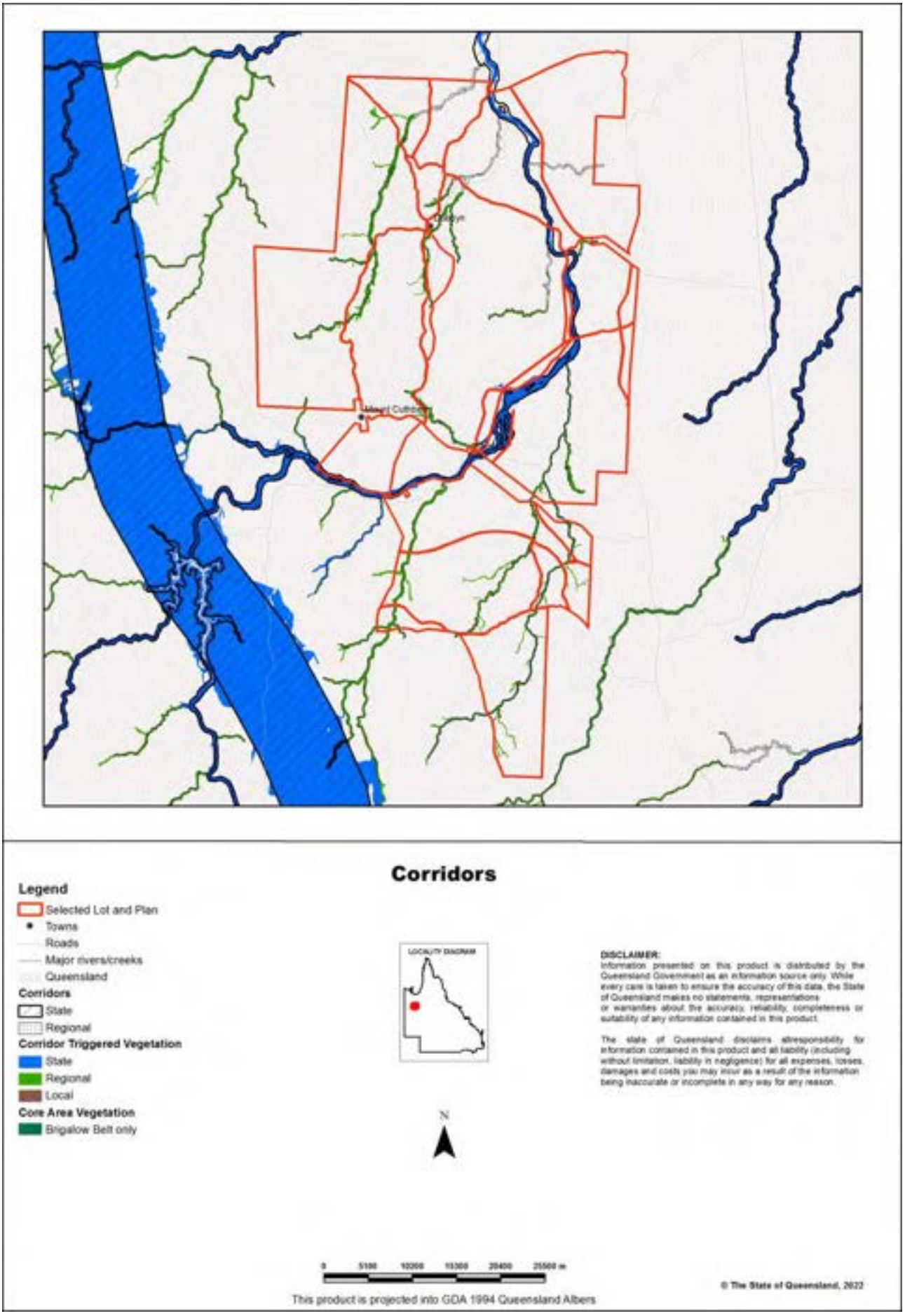
Map 1 - Locality Map



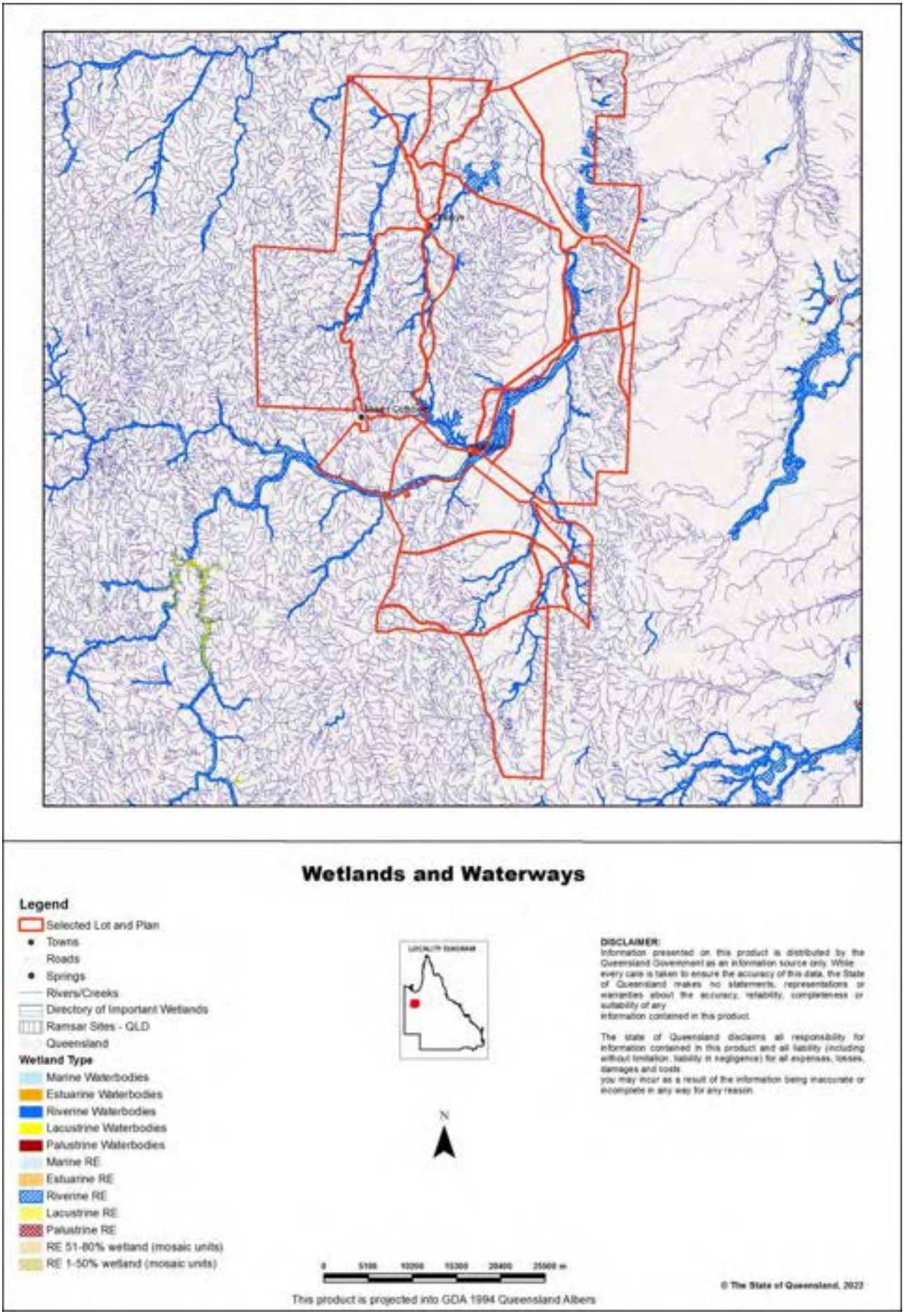
Map 2 - Biodiversity Planning Assessment (BPA)



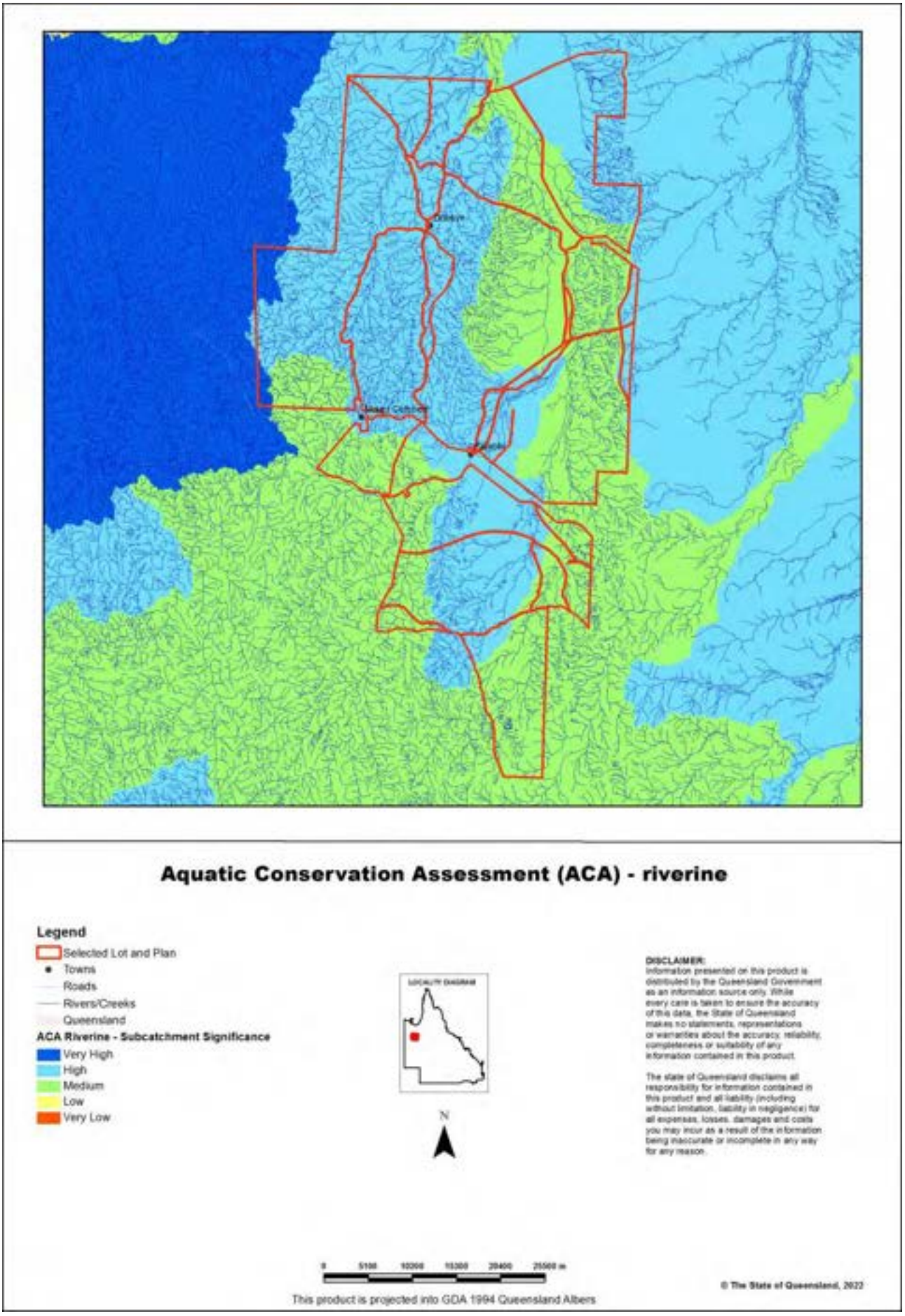
Map 3 - Corridors



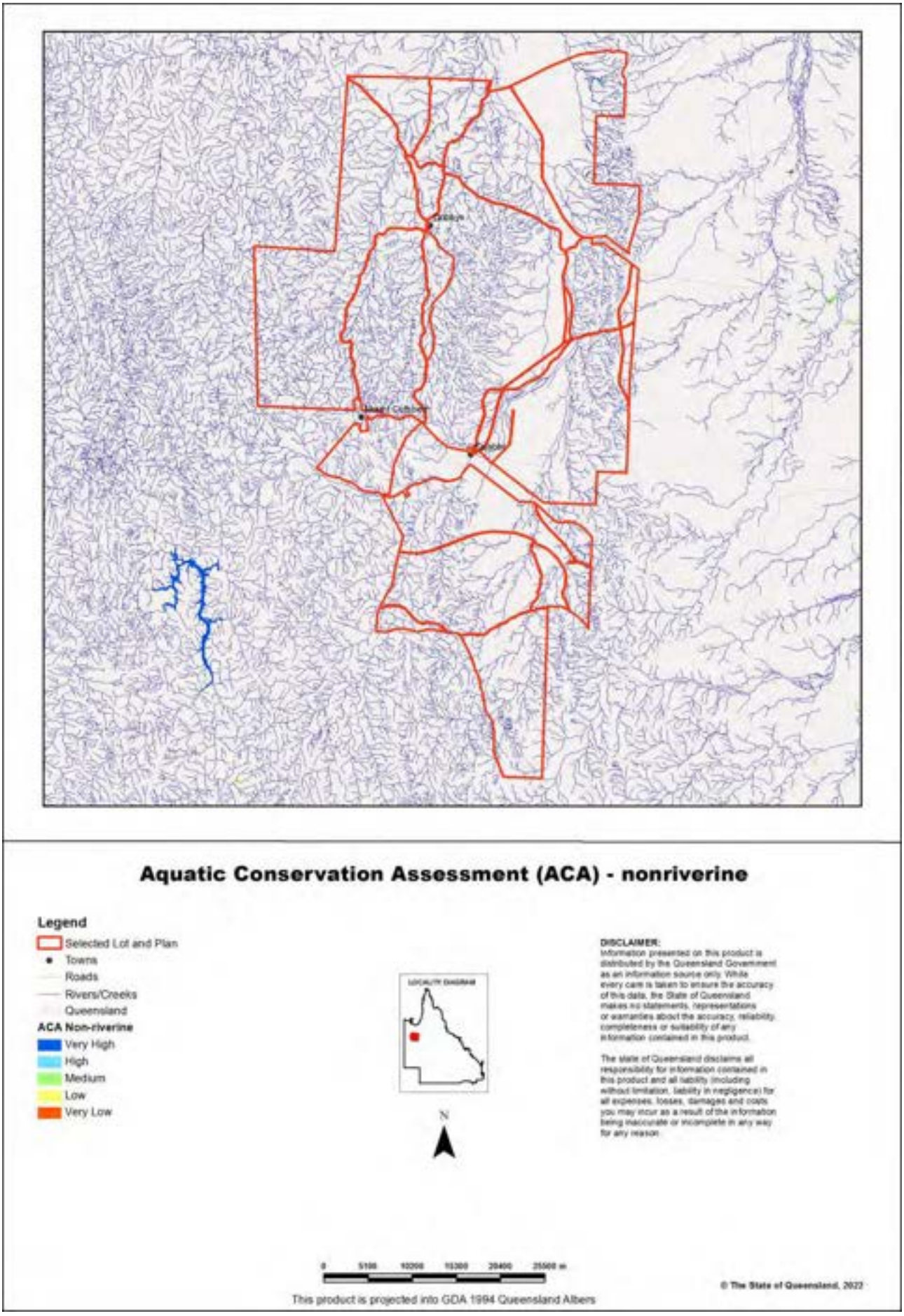
Map 4 - Wetlands and waterways



Map 5 - Aquatic Conservation Assessment (ACA) - riverine



Map 6 - Aquatic Conservation Assessment (ACA) - non-riverine



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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

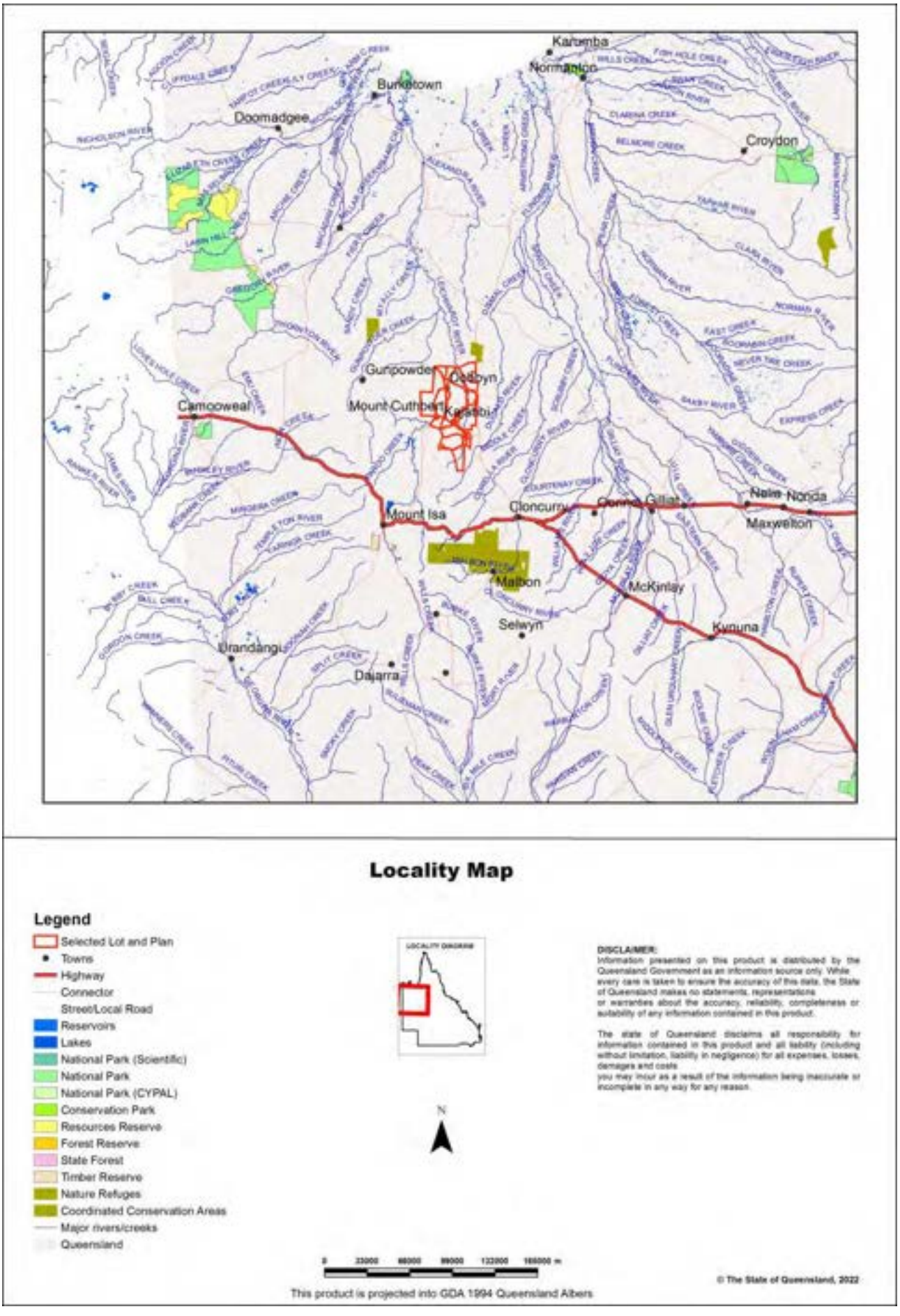
Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
1.10.4a	Available	Not currently available
1.11.2a	Available	Not currently available
1.11.3a	Available	Not currently available
1.11.3b	Available	Not currently available
1.11.7	Available	Not currently available
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

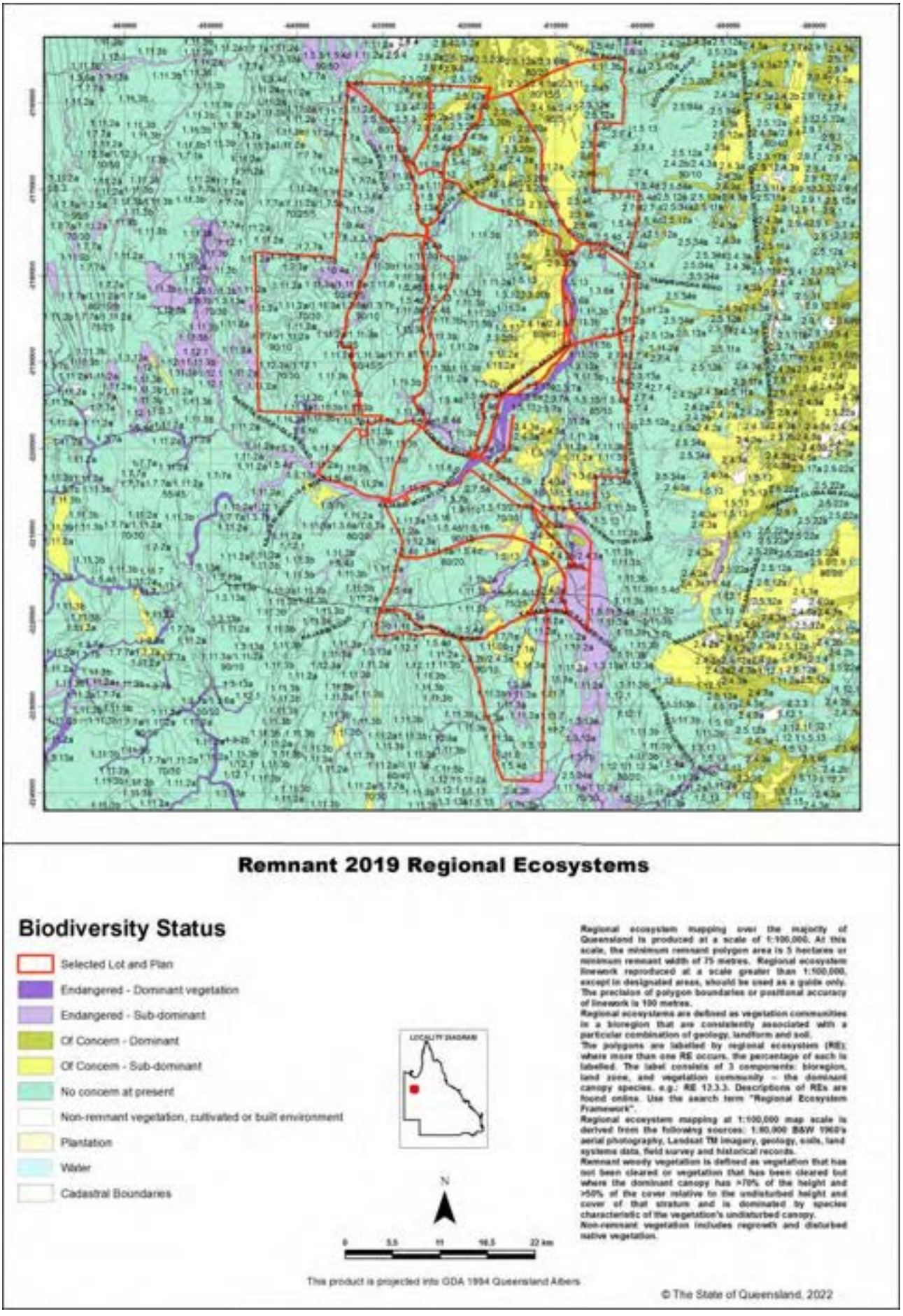
Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
2.9.2a	Not currently available	Not currently available
2.9.4	Not currently available	Not currently available
non-remnant	Not currently available	Not currently available
water	Not currently available	Not currently available

Maps

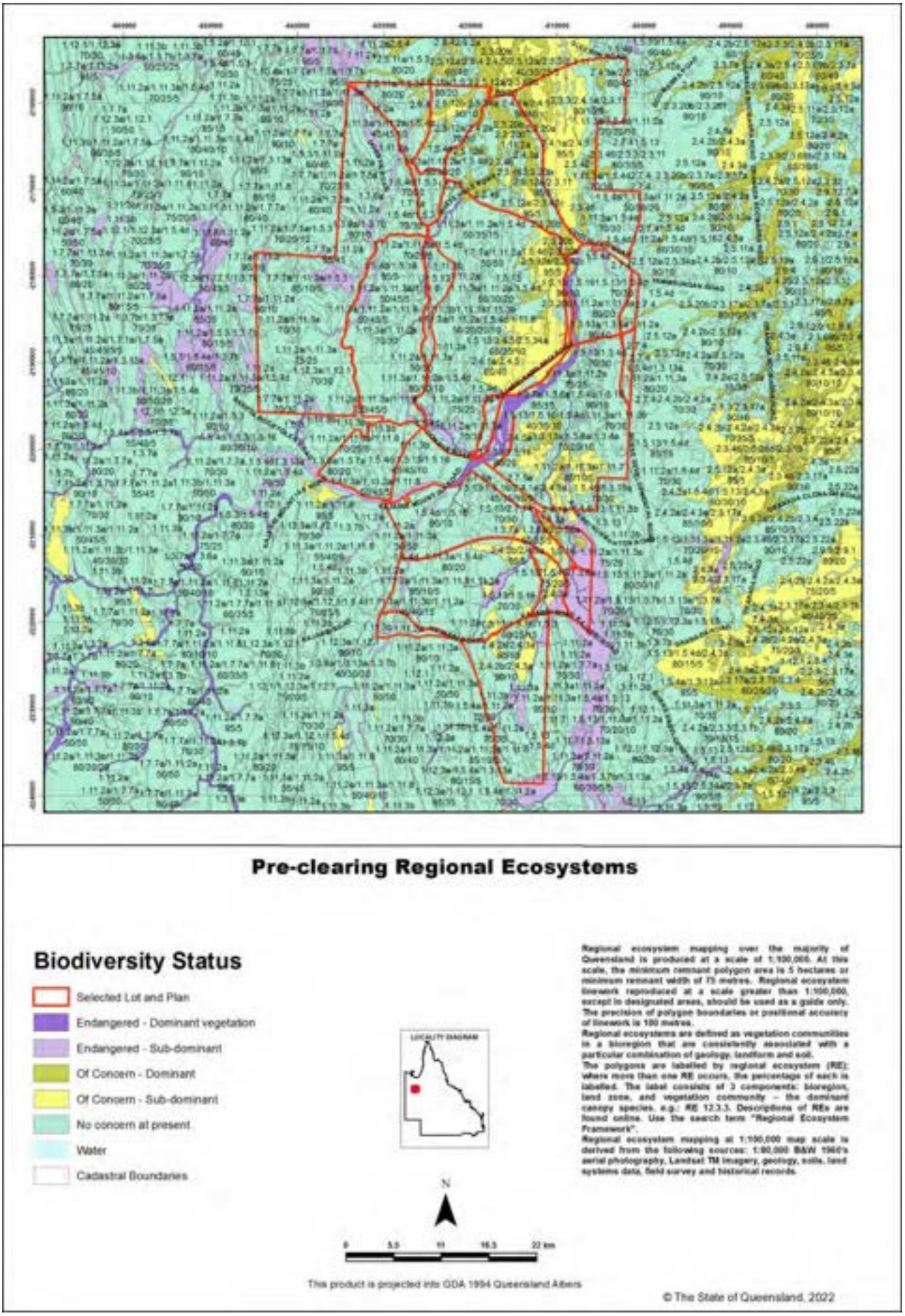
Map 1 - Location



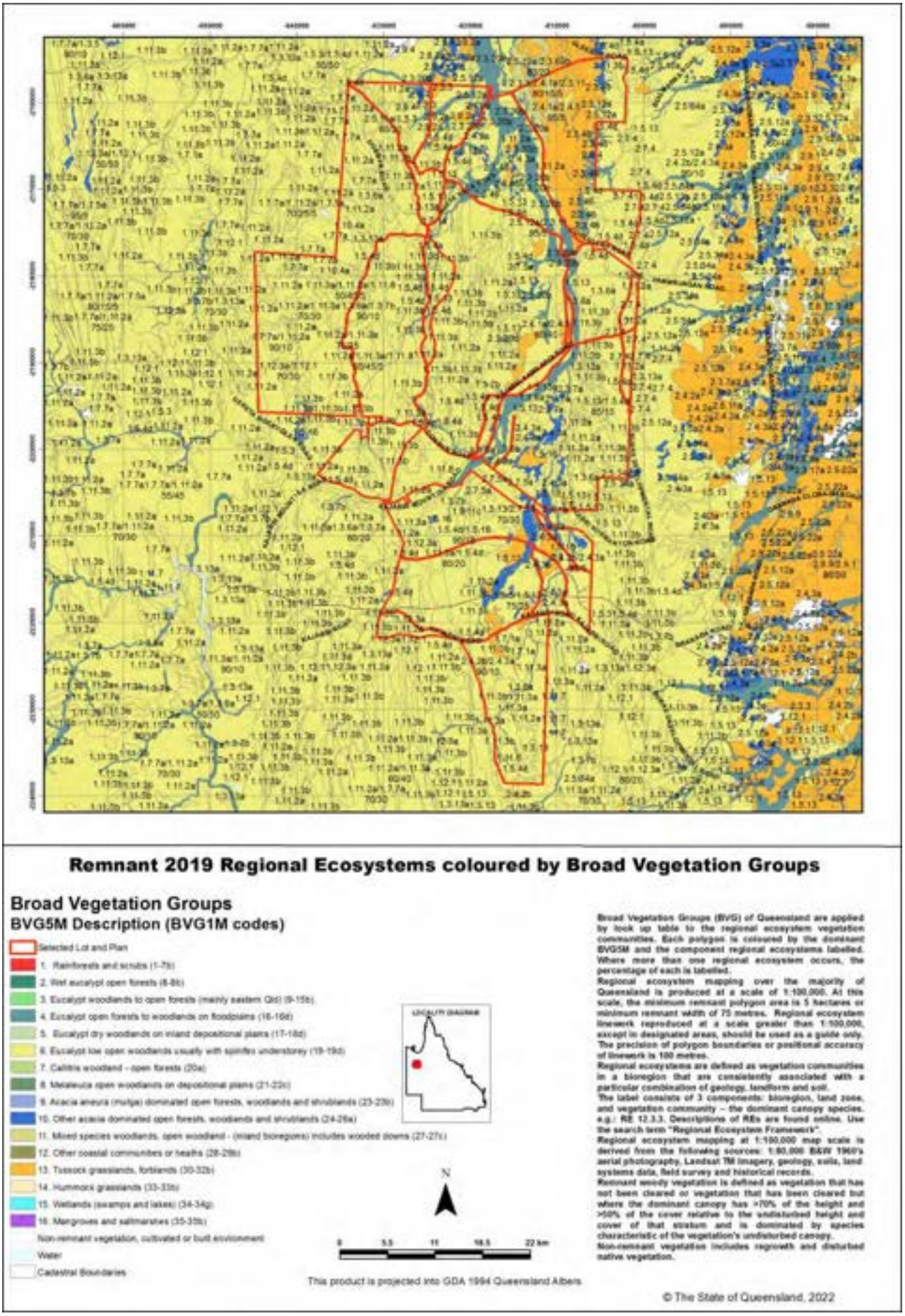
Map 2 - Remnant 2019 regional ecosystems



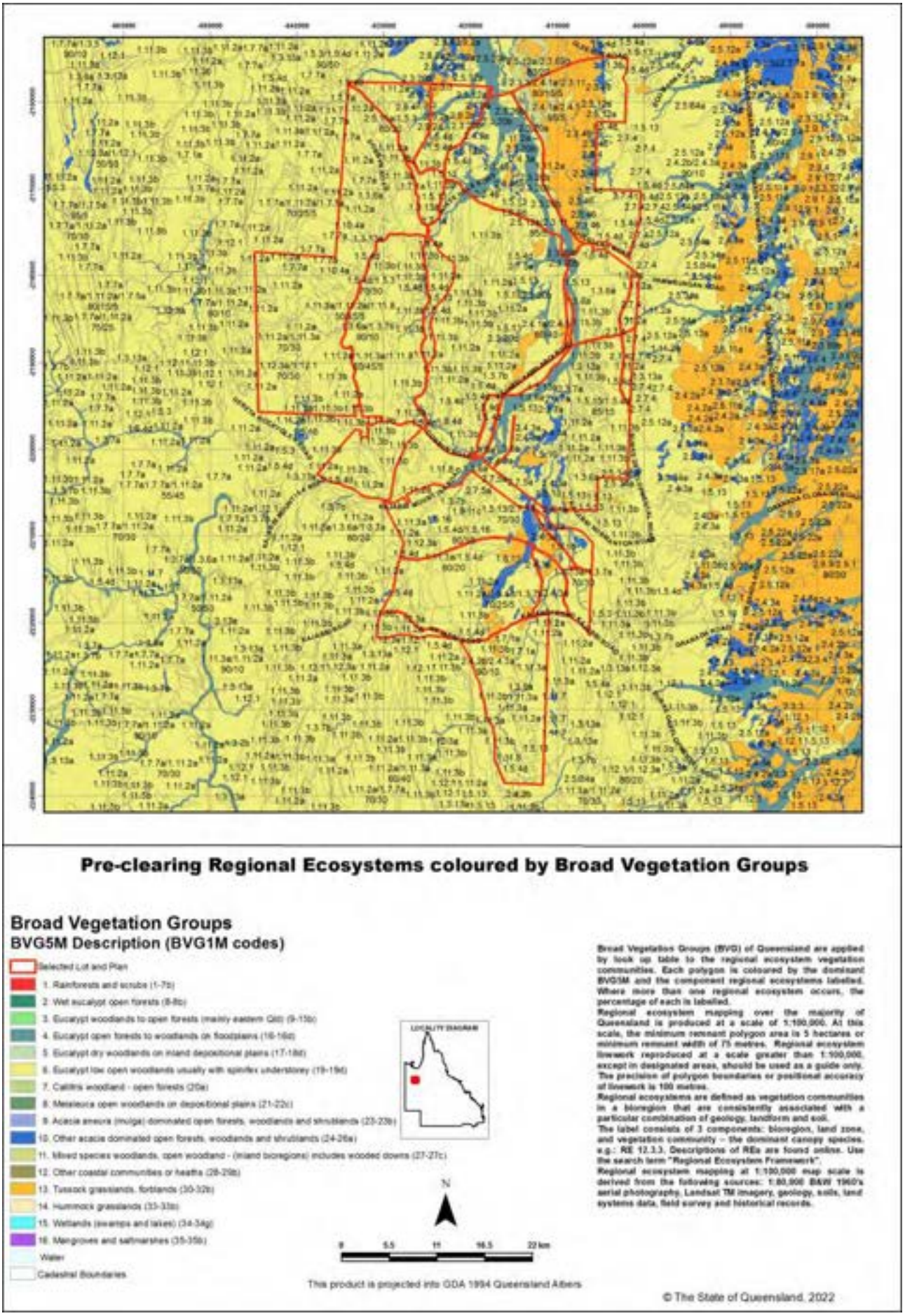
Map 3 - Pre-clearing regional ecosystems



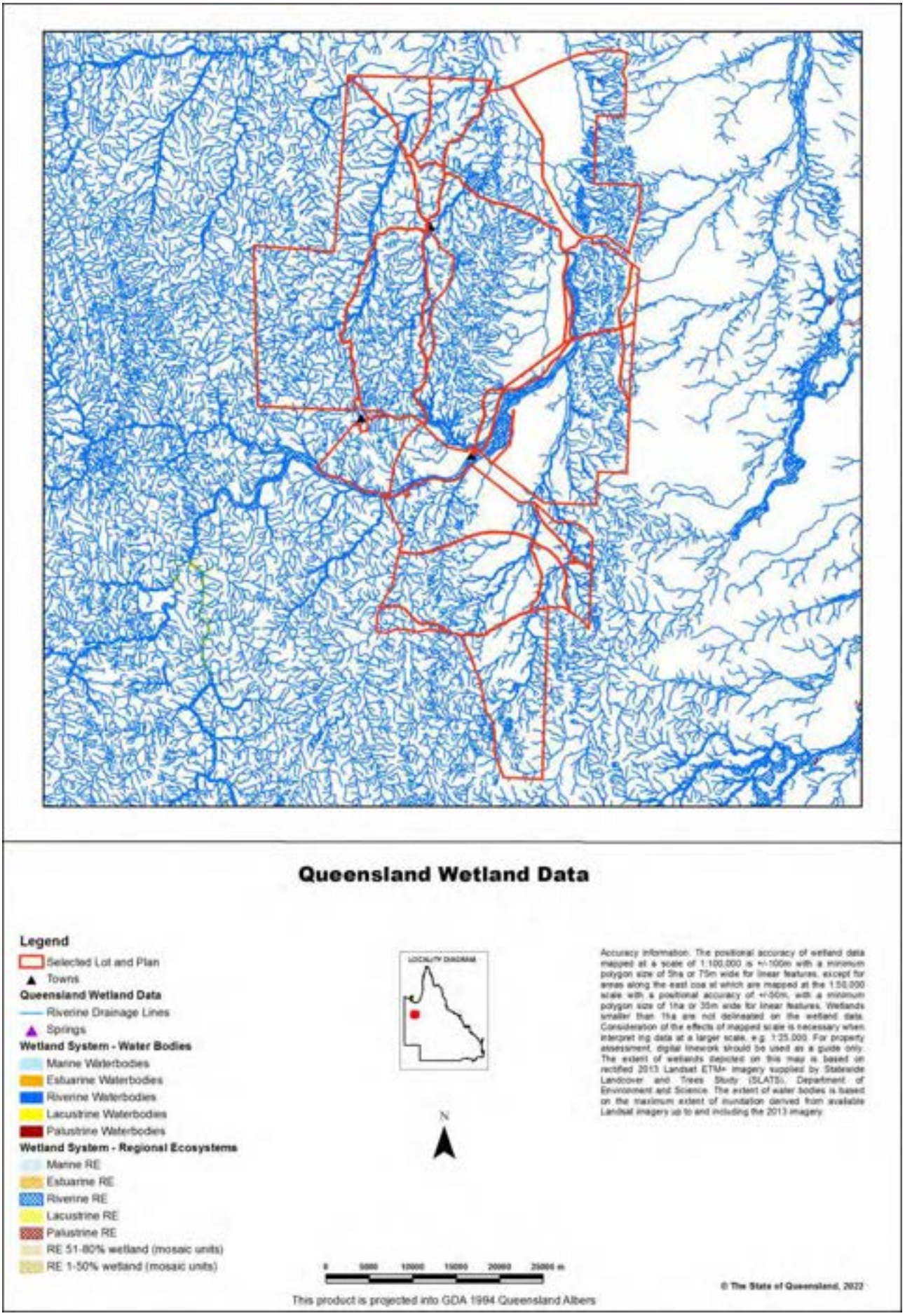
Map 4 - Remnant 2019 regional ecosystems by BVG (5M)



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

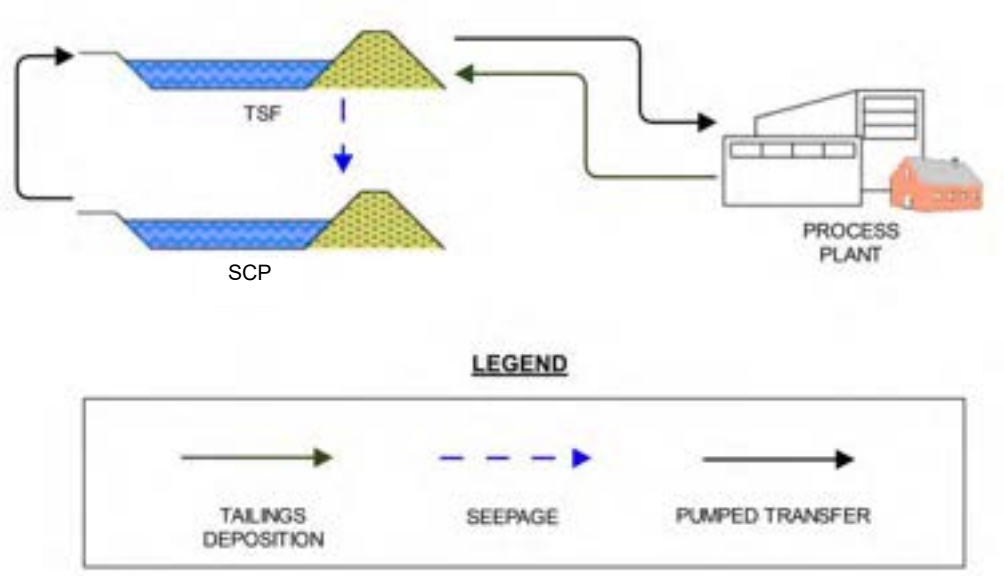
The water balance model has been developed using Goldsim 15. GoldSim enables the water balance model to incorporate deterministic and probabilistic framework modules. Processes in the water balance are modelled using a deterministic approach while the inherent variability of some of the inputs, i.e., 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.

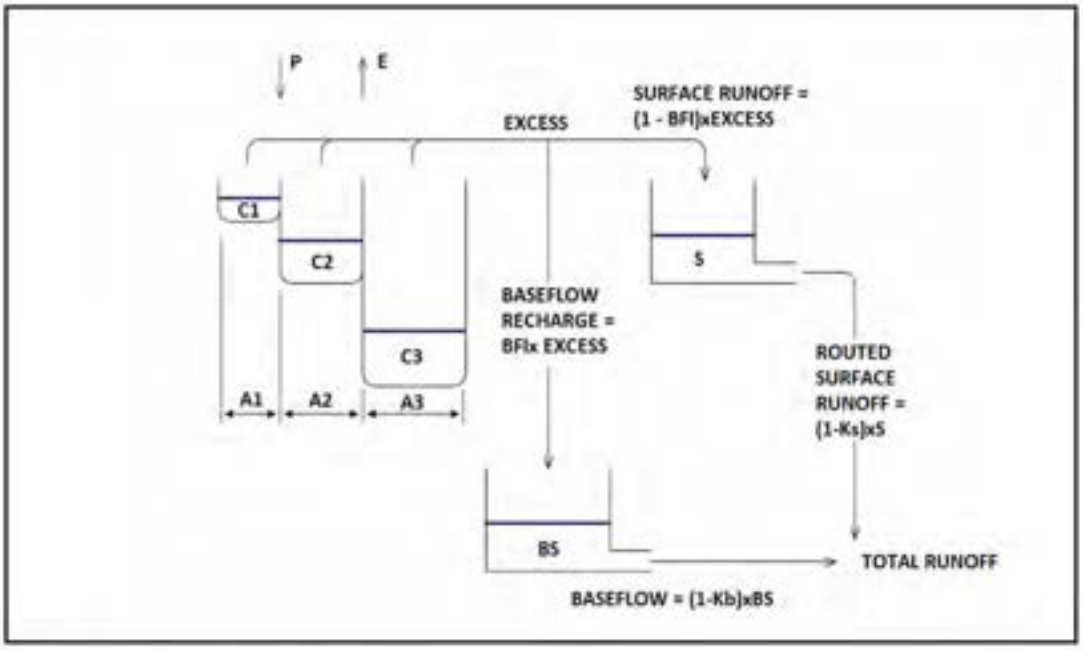
The catchment types and catchment areas contributing to the TSF have been designated using aerial imagery and site survey. The designated catchment areas are presented in **Table 6**.

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

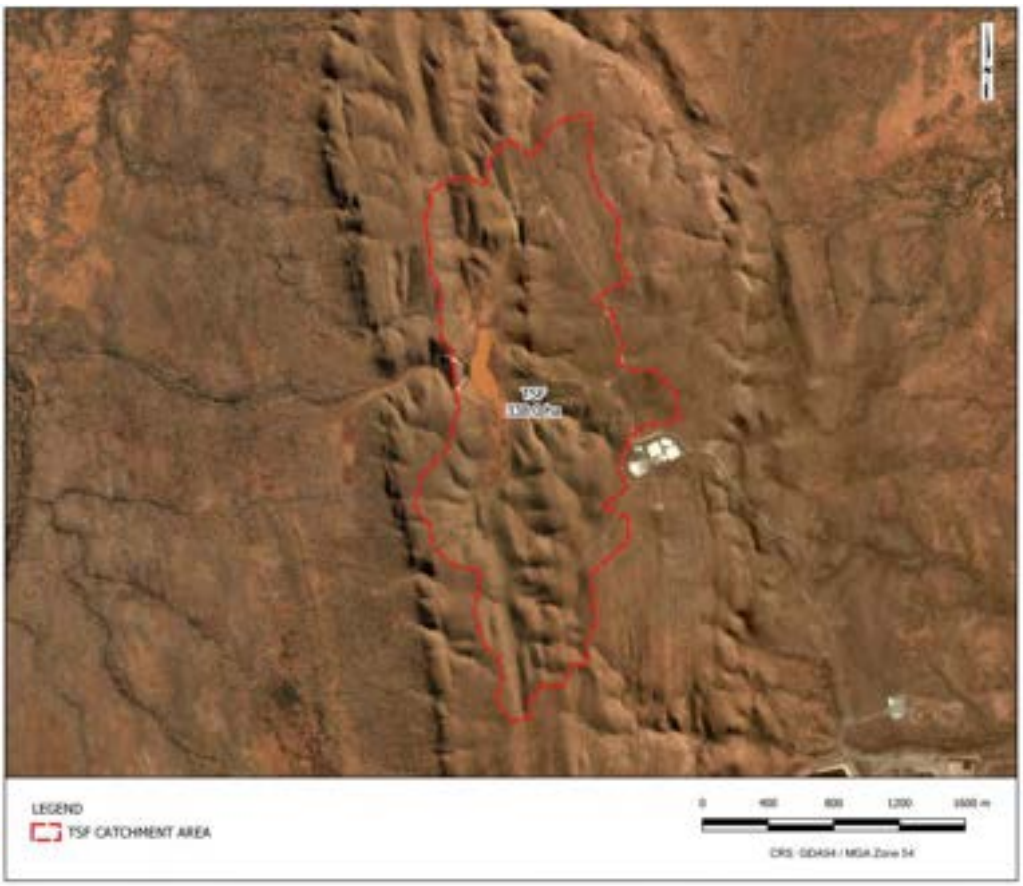
Catchment Type	Split Areas (sum=1.0)			Storage Capacities (mm)			Average Surface Stores	Ks (day-1)	BFI	Kb (day-1)
	A1	A2	A3	C1	C2	C3				
Natural	0.134	0.433	0.433	6	60	120	79 mm	0.05	0.1	0.1
Hardstand	1	0	0	15	10	10	15 mm	0	0.1	0.1
Stockpile	0.134	0.433	0.433	12	80	200	123 mm	0.2	0.5	0.9

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

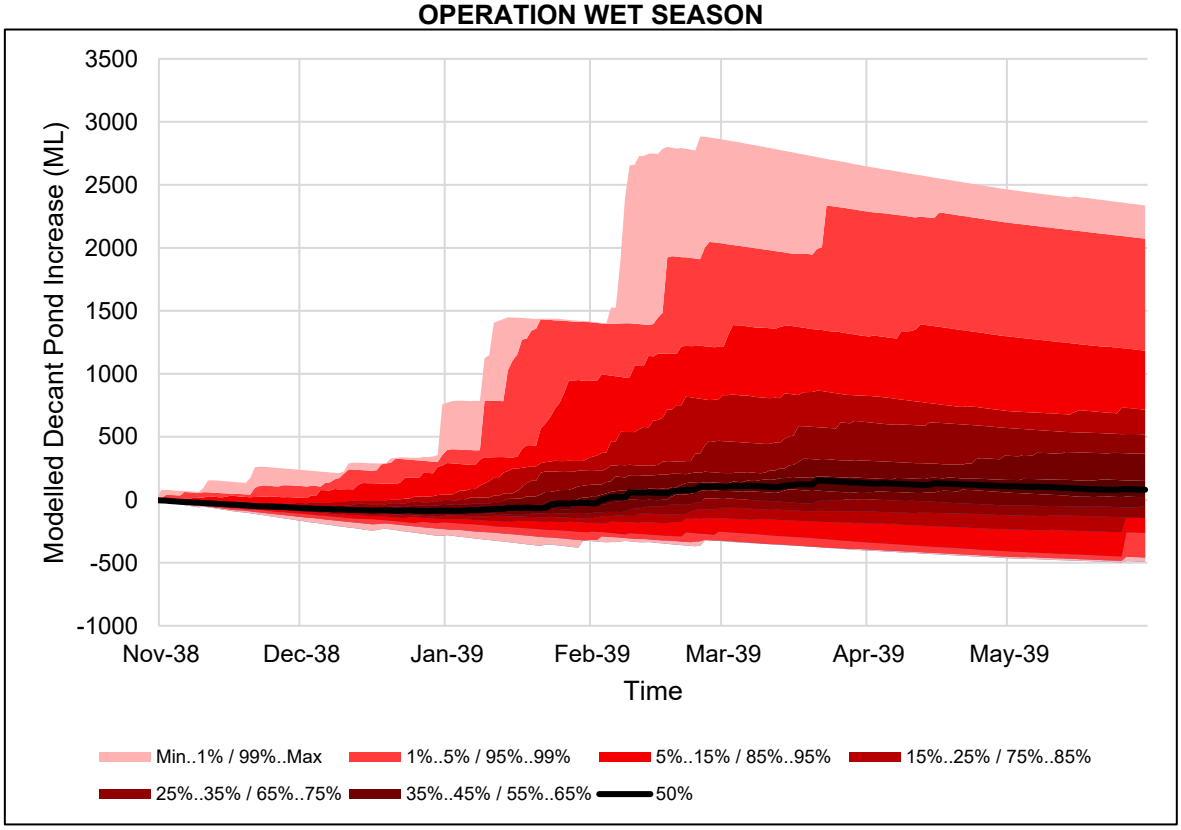
The DSA for the Stage 3 TSF has been calculated using the Method of Operational Simulation, as follows:

- 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

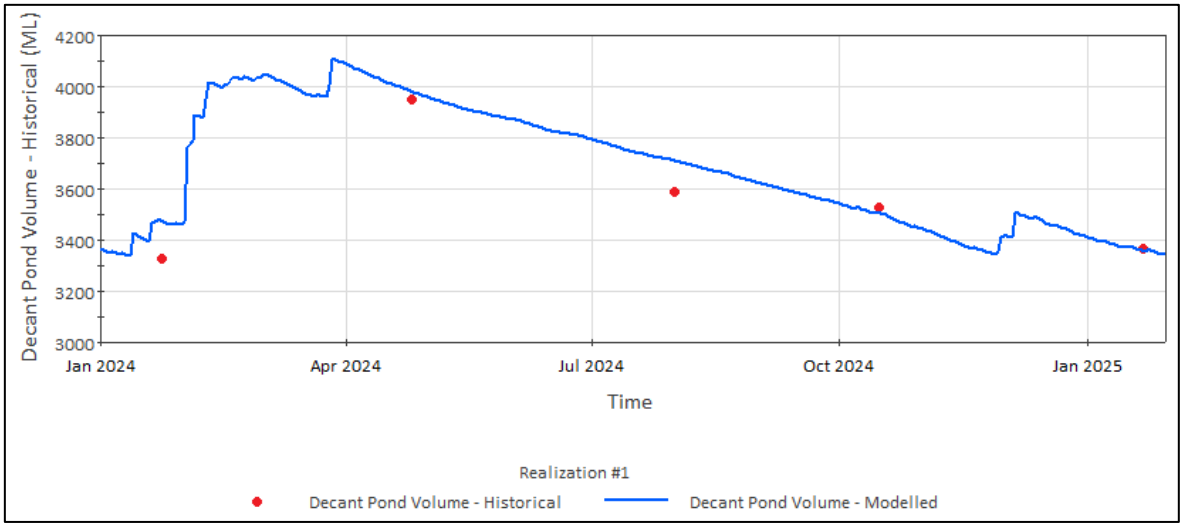
A review of the Design Simulation Margin (DSM) has been undertaken as part of the TSF Operational Simulation assessment. The review process involved analysing results of previous WBM calibration efforts. The monitored water inventories within the TSF, generated from bathymetric survey, were compared 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.

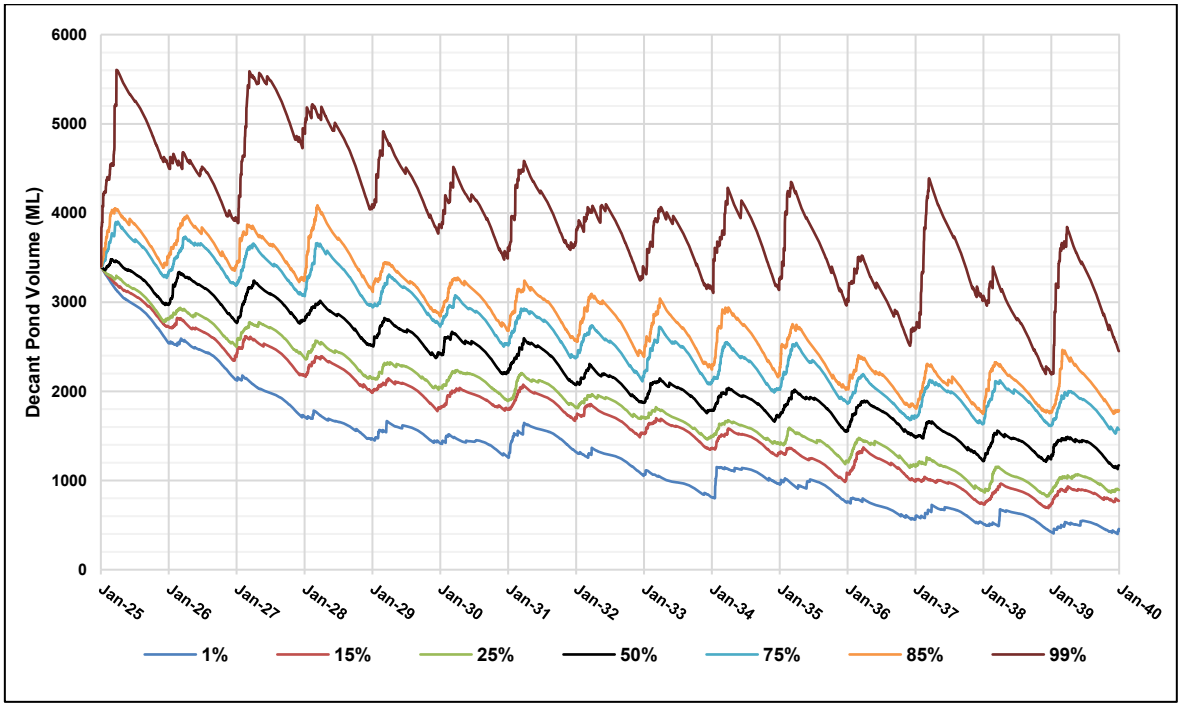
A comparison of the modelled decant pond volumes at the end of the simulation is summarised in **Table 12**.

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.

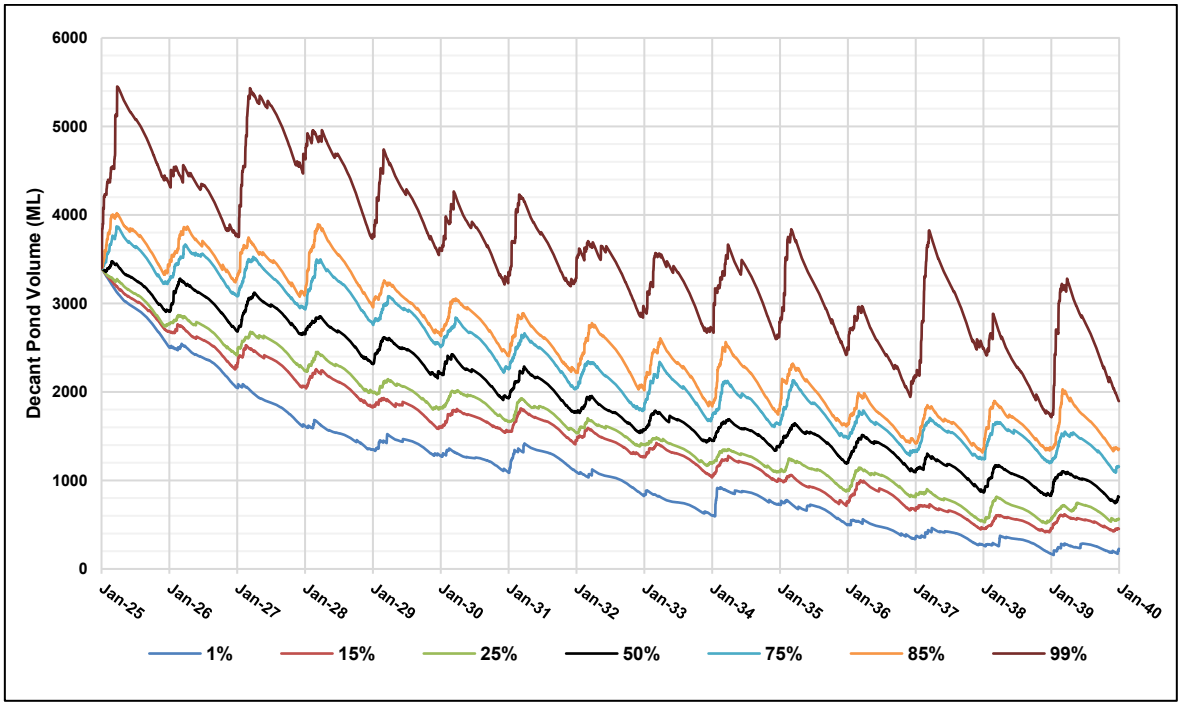
The results from Scenario 3 indicate that the role of the evaporator fans in drawing down the decant pond volumes is significant.

GRAPH 3 – SCENARIO 1 (BASELINE) DECANT POND VOLUME

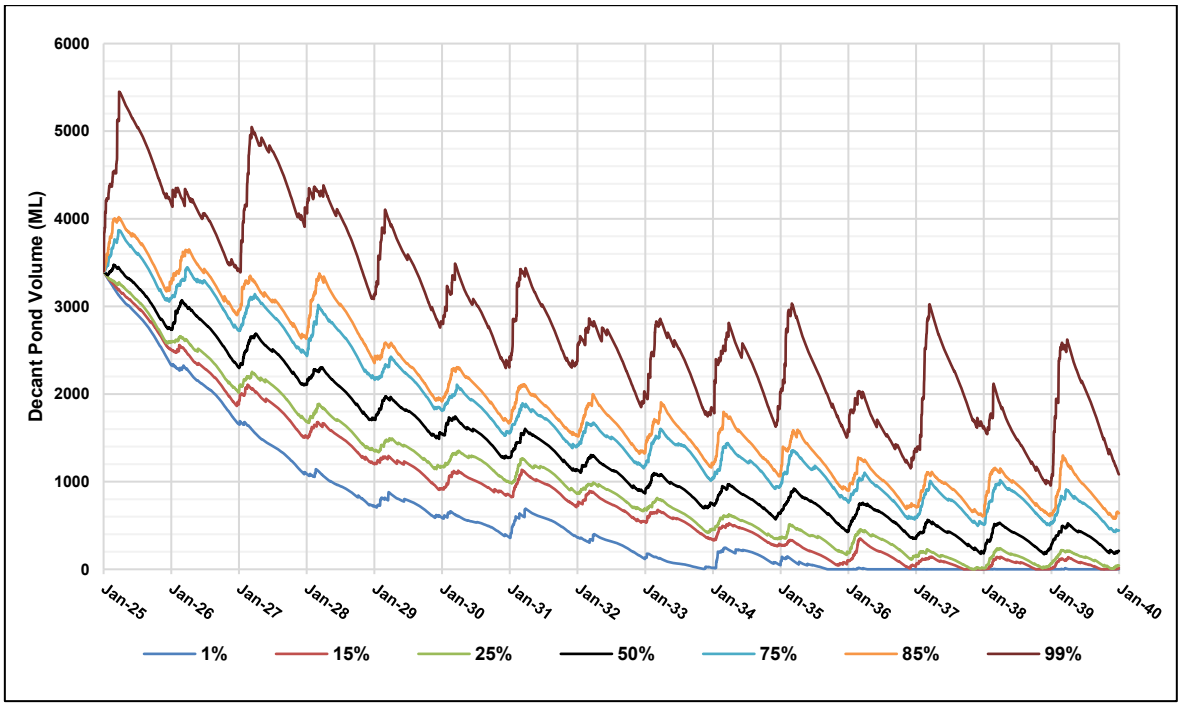


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GRAPH 4 – SCENARIO 2 (CLIMATE CHANGE) DECANT POND VOLUME



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**.

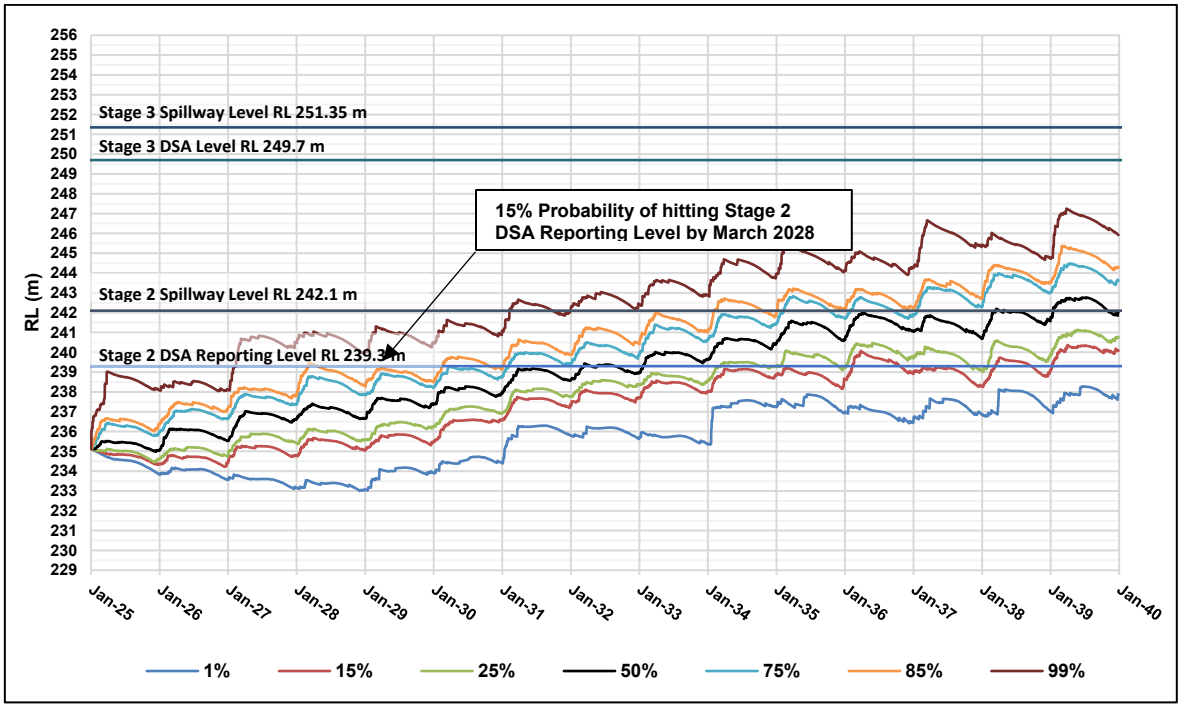
The results indicate that for Scenario 1 and 2, there is a 15% probability that the Stage 2 DSA Reporting Level is exceeded by March 2028.

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.

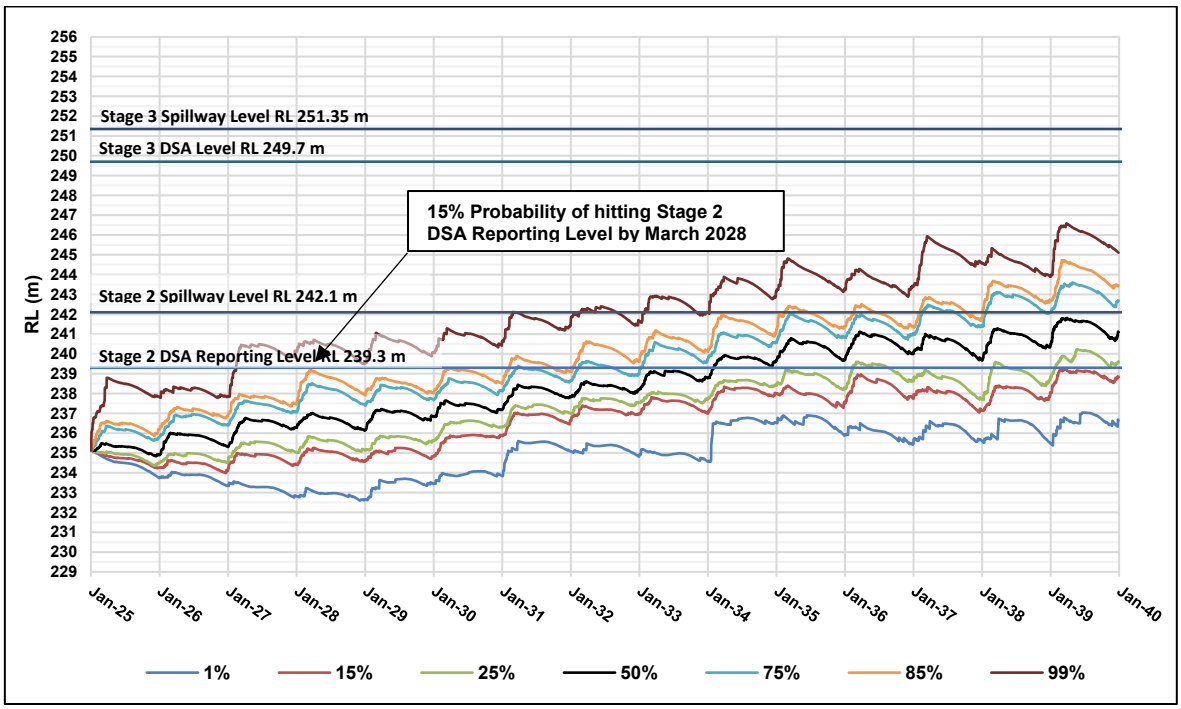
The results from all Scenarios indicate that the Stage 3 DSA Reporting Level is not exceeded for any of the water balance realisations (maximum probability plots not shown for clarity). It is thus unlikely that the Stage 3 DSA Reporting Level will be exceeded during the operational life of the facility.

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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

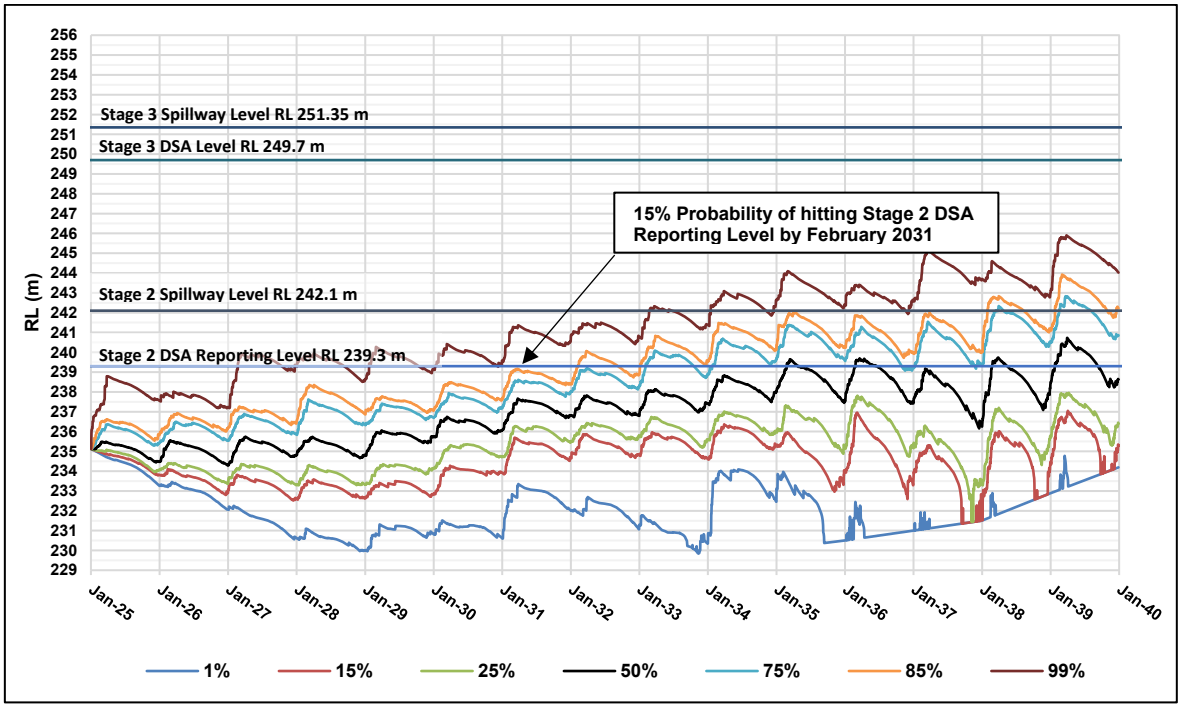


TABLE 13 – DECANT POND LEVEL SUMMARY

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.

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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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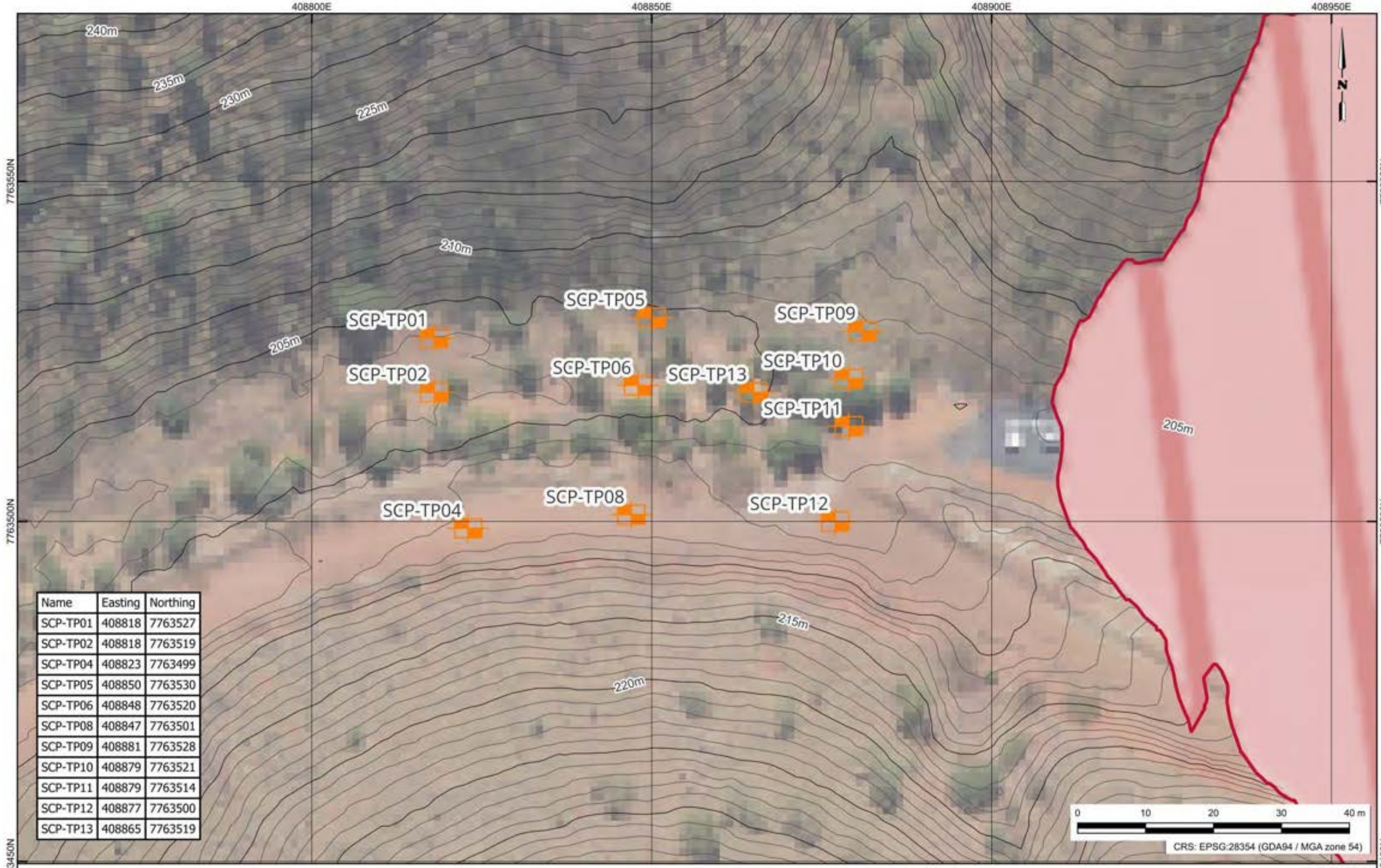
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ATTACHMENTS

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ATTACHMENT 1 – TEST PITTING LOCATIONS

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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

ATC WILLIAMS

www.atcwilliams.com.au

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)				





MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP02

ATC WILLIAMS

www.atcwilliams.com.au

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							
										COLLUVIAL; sandy GRAVEL (GP): medium dense, poorly graded, angular, coarse sized, medium grained sand, orange - brown, dry, with cobbles and boulders, MW.				
						208	1		GP		D	MD		
													Base of pit highly fractured. Clean cut-off surface not achieved	
										SCP-TP04 refusal at 1.9m (Virtual refusal due to minimal progress)				





MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP04

ATC WILLIAMS

www.atcwilliams.com.au

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	





MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP05

ATC WILLIAMS

www.atcwilliams.com.au

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

ATC WILLIAMS

www.atcwilliams.com.au

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		
						208	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	
										SCP-TP08 refusal at 1.7m (Virtual refusal due to minimal progress)				





MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP08

ATC WILLIAMS

www.atcwilliams.com.au

Job No: 250542

Date: 16/04/2025

ATTACHMENT B

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

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP09

ATC WILLIAMS

www.atcwilliams.com.au

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	Base of pit highly fractured. Clean cut-off surface not achieved	
		ng via pit side				206 205	1			**SCP-TP10 refusal at 1.8m (Virtual refusal due to minimal progress)**				





MMG DUGALD RIVER

TAILINGS STORAGE FACILITY

SEEPAGE COLLECTION SYSTEM INVESTIGATION

TEST PIT SCP-TP10

ATC WILLIAMS

www.atcwilliams.com.au

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

www.atcwilliams.com.au

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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ATC WILLIAMS PTY LTD
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Mordialloc, VIC, 3195
melbourne@atcwilliams.com.au
atcwilliams.com.au
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**.

TAILINGS.WATER.WASTE.

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**.

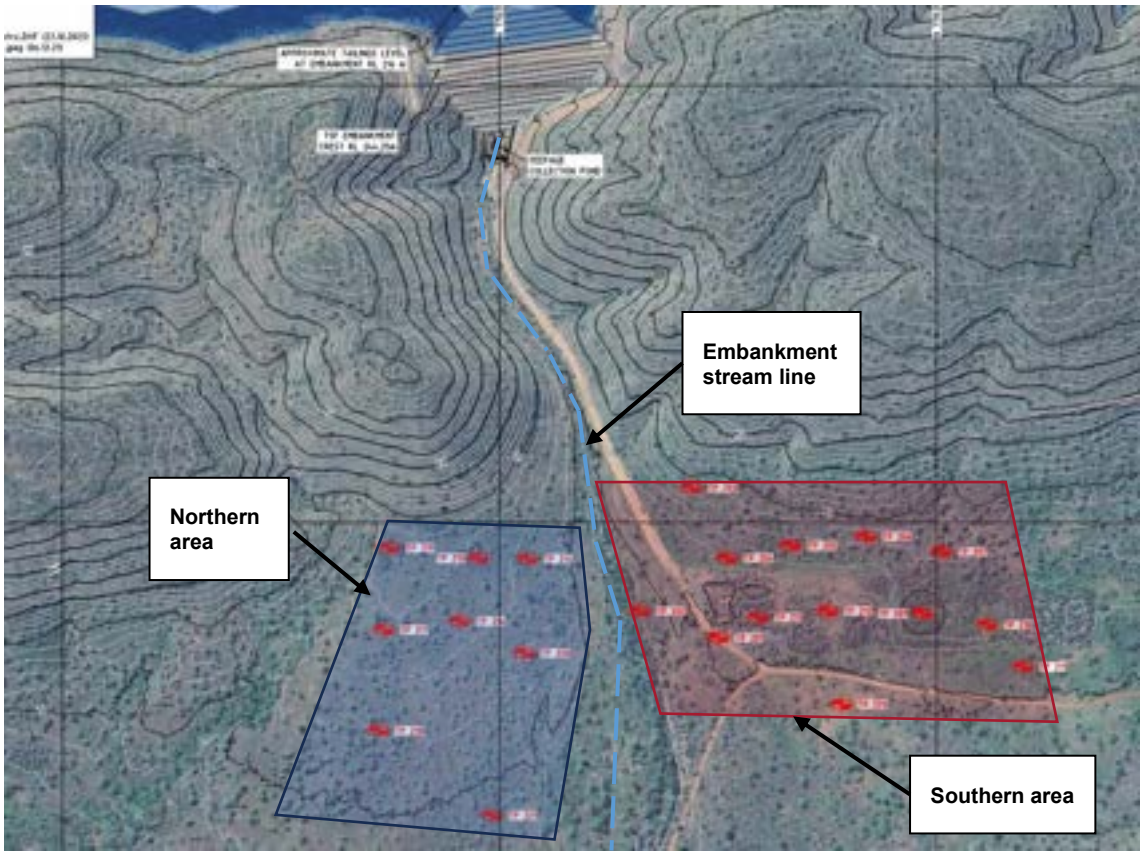
Test pitting was performed using a Kubota U27-4 excavator, operated by Nathan Elliott (MMG). The investigation was supervised by Dale Ross (ATCW Senior Associate Engineer). A total of 22 (twenty-two) test pits were excavated. No soil samples were specified or taken for laboratory testing. Field dry strength 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

TAILINGS.WATER.WASTE.

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

TAILINGS.WATER.WASTE.

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.

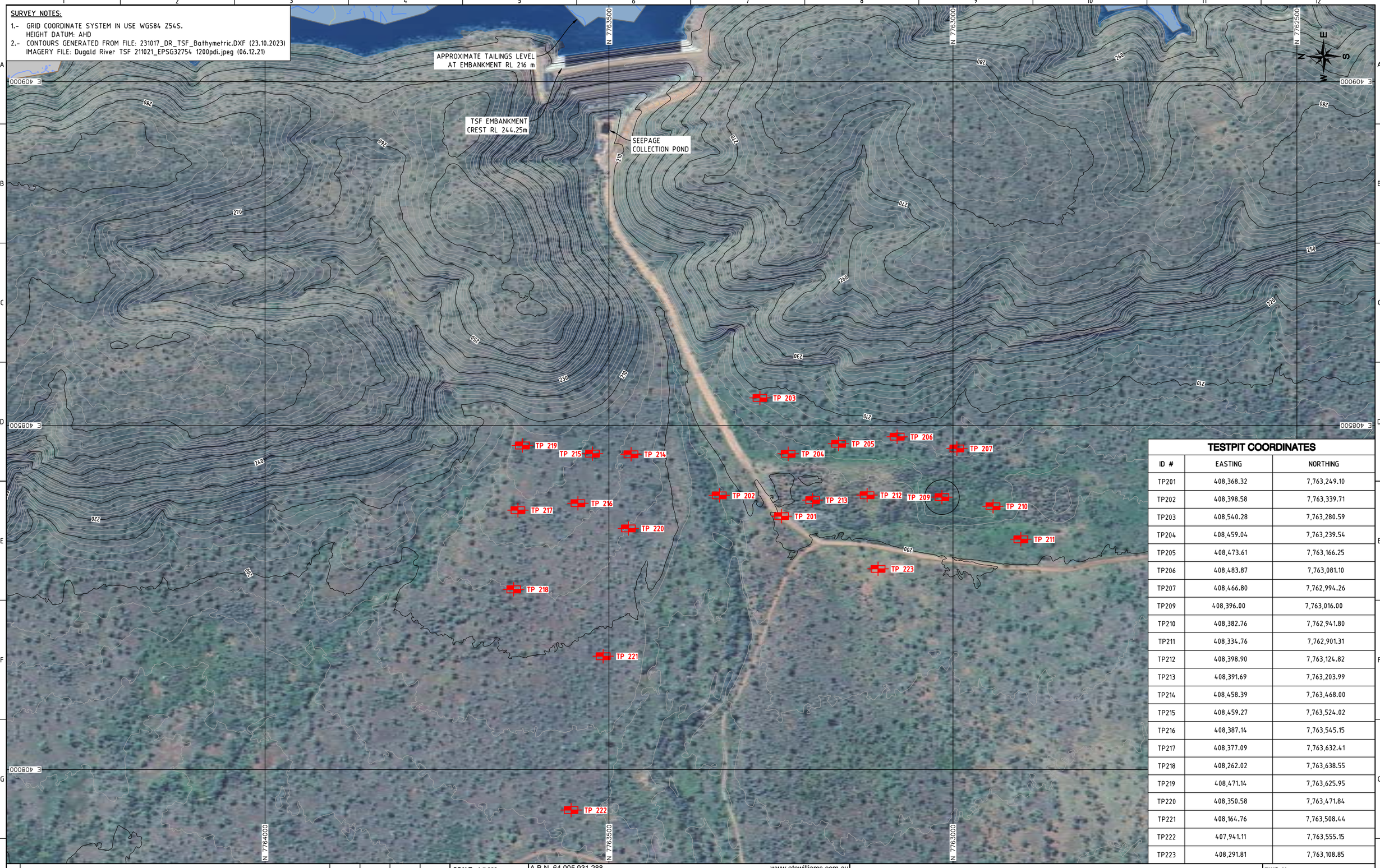
TAILINGS.WATER.WASTE.

ATTACHMENT 1: FIGURES

TAILINGS.WATER.WASTE.

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	08.08.24
DESIGN	DR
DRAWN	HJ
CHECKED	DR
APPROVED	CN

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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

J:\2008\108003 Dugald River\67 Raise Detailed Design\CADD\CAD\Figures\Figure 1 - Zone 2 Borrow Investigation.dwg

Printed on: Wednesday, 28 August 2024 04:06:12 PM

ATTACHMENT 2: TEST PITTING LOGS

TAILINGS.WATER.WASTE.

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

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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

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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

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Date

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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			Sheet	1 OF 1
Location	West of TSF	East	408457.0 m		
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

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Date

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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

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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					Test pit terminated at engineer's request Hole Terminated at 1.60 m			
			2									
			3									
			4									

Sketch & Other Observations

Comments

Checked

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

Checked

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	*0.30*				GM	Silty GRAVEL (GM), with cobbles, dense, medium grained sand, coarse gravel, brown	D	D	0.00: Not suitable for Zone 2 material
									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

Checked

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

Checked

Date

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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				
Location	West of TSF	East	408448.0 m	Sheet	1 OF 1
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			0.00: Potential use as Zone 2 (1.7m thickness)
				0.60					0.6m fine grained proportion of material increasing	D	D	
			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

Checked

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

Checked

Date

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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

Checked

Date

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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

Checked

Date

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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

Checked

Date

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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			Sheet	1 OF 1
Location	West of TSF	East	408223.0 m		
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

Checked

Date

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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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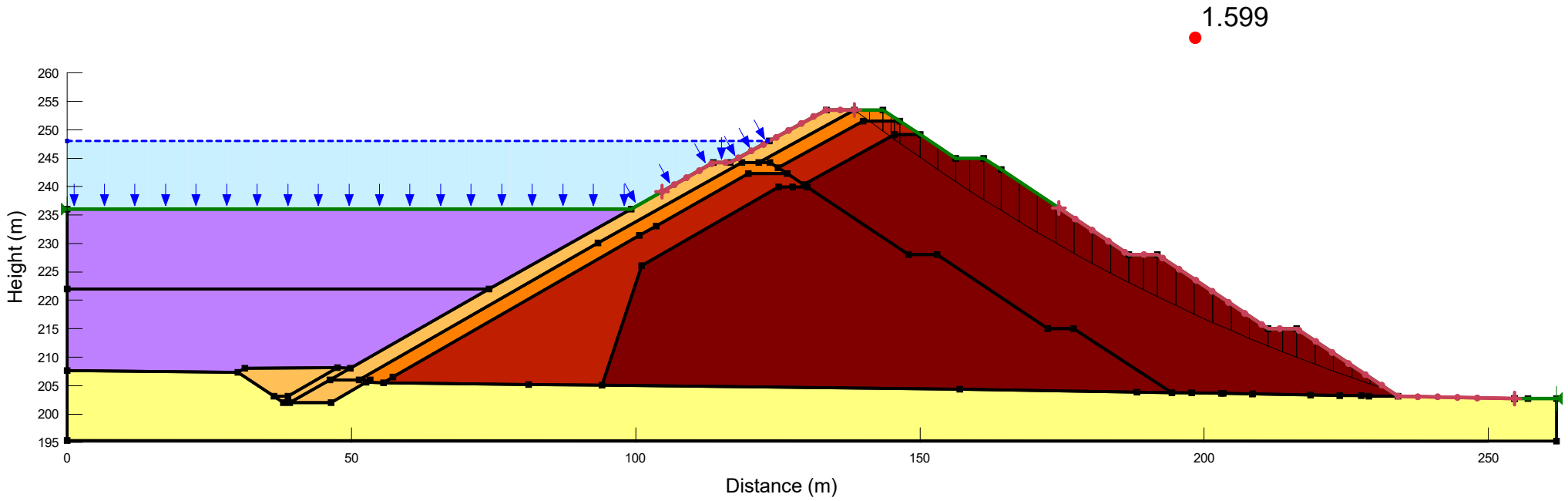
MMG LIMITED **DUGALD RIVER** **ZONE 2 BORROW INVESTIGATION**	**TEST PIT 223**
ATC WILLIAMS www.atcwilliams.com.au	**Job No:** 108003.67 **Date:** 16/07/2024 **APPENDIX B**

APPENDIX F – STABILITY ANALYSES

TAILINGS.WATER.WASTE.

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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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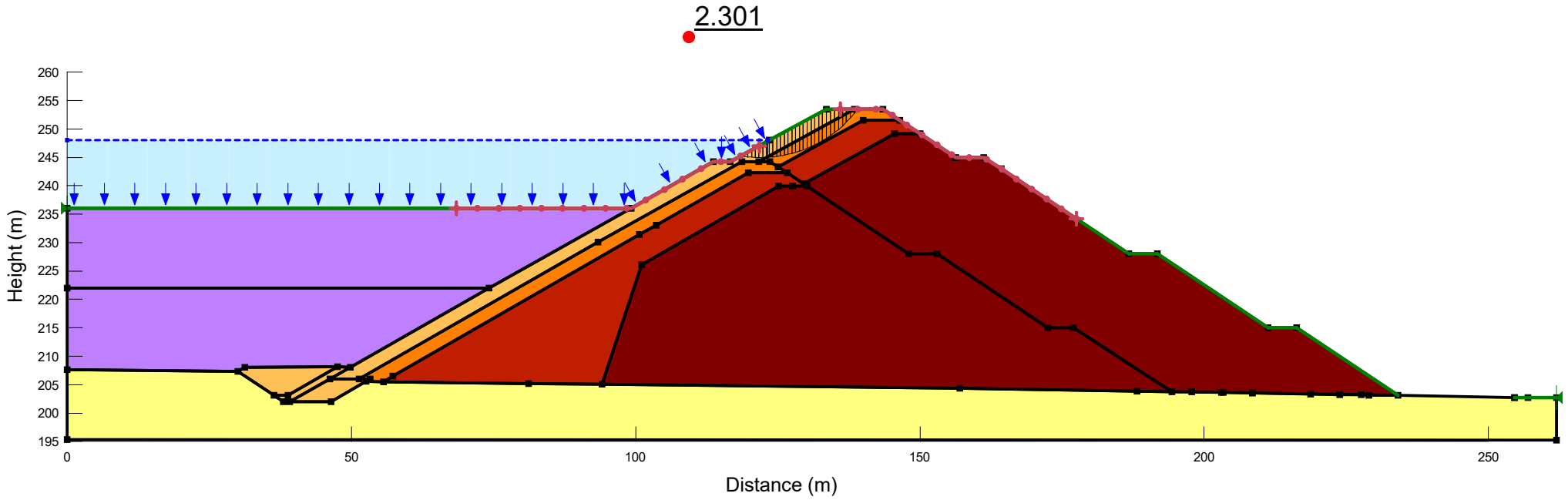
STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Long Term - Downstream

Date: 29/08/2025	Job No: 250542	Appendix F1

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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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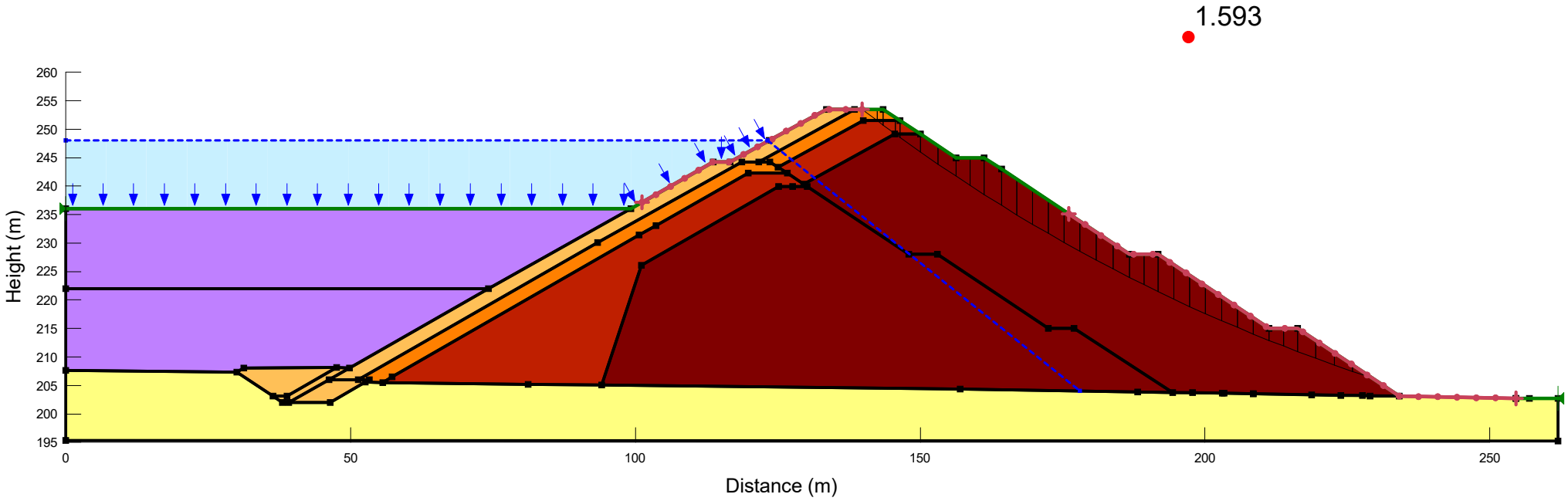
STAGE 3 RAISE DETAILED DESIGN

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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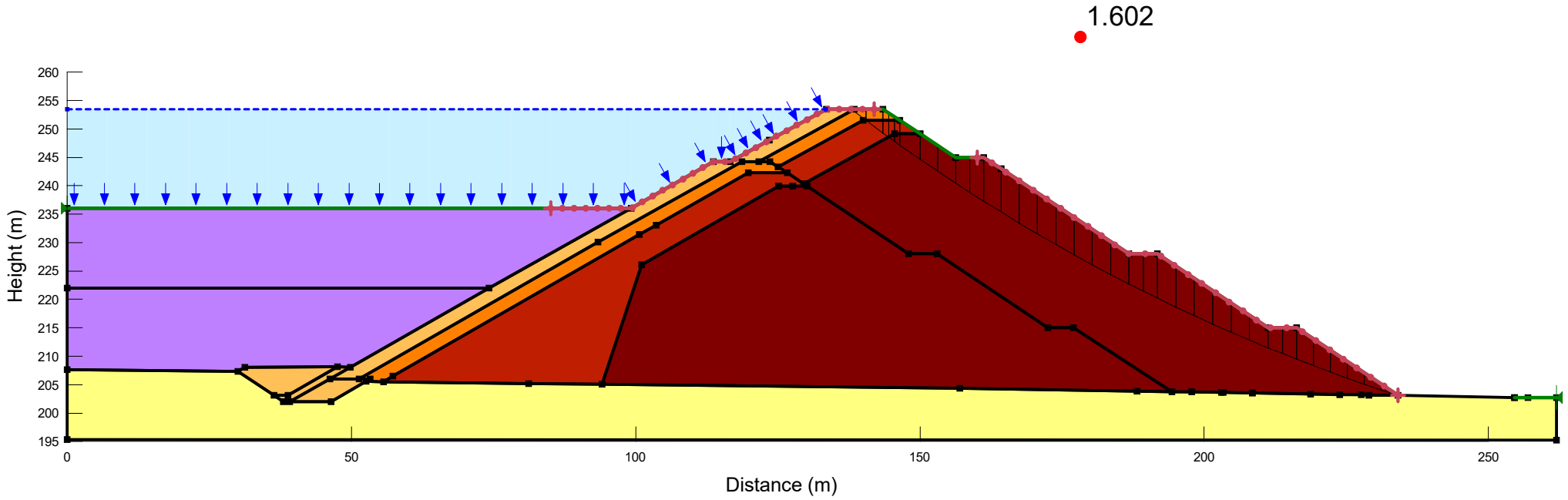
STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Liner Leak - Downstream

Date: 29/08/2025	Job No: 250542	Appendix F3

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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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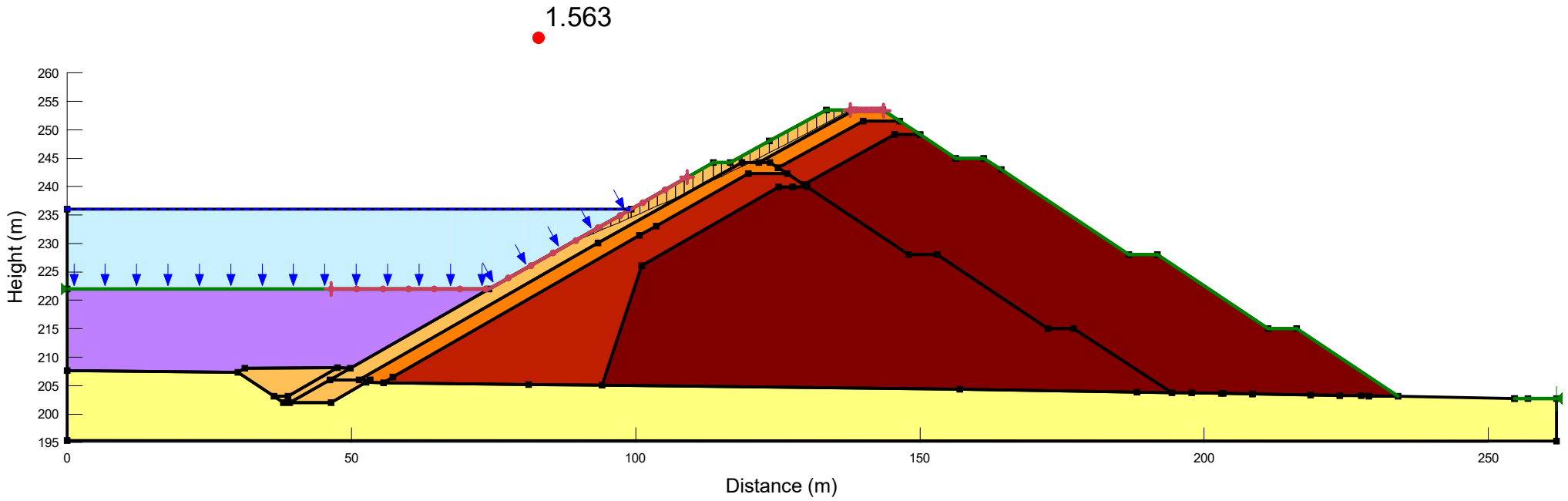
STAGE 3 RAISE DETAILED DESIGN

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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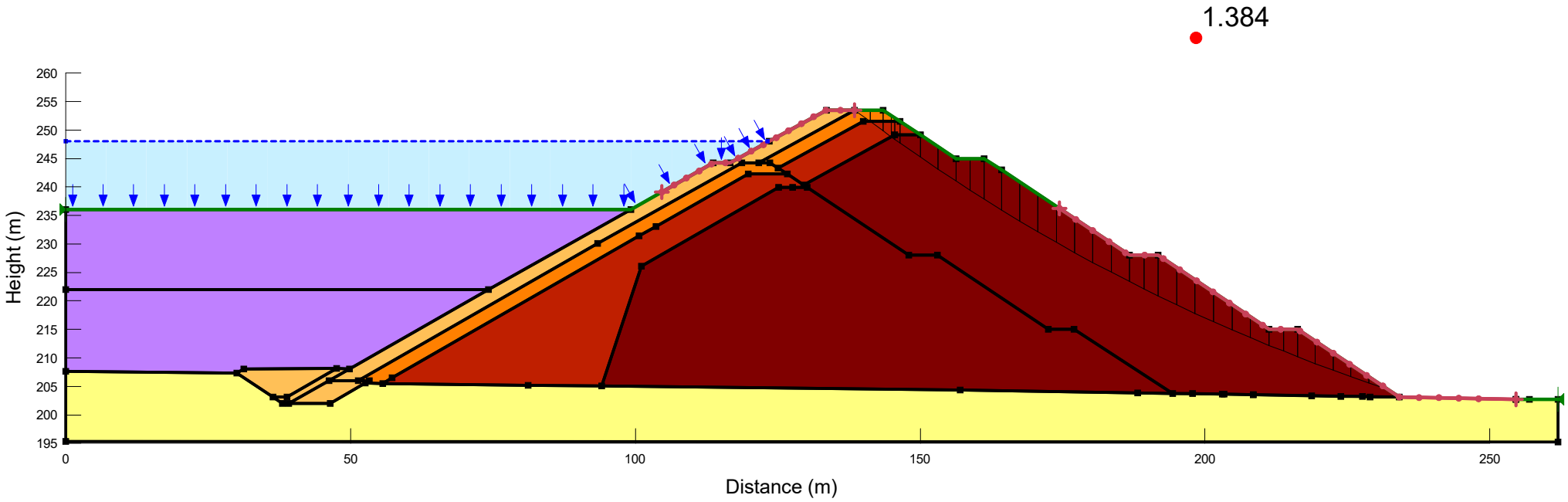
STAGE 3 RAISE DETAILED DESIGN

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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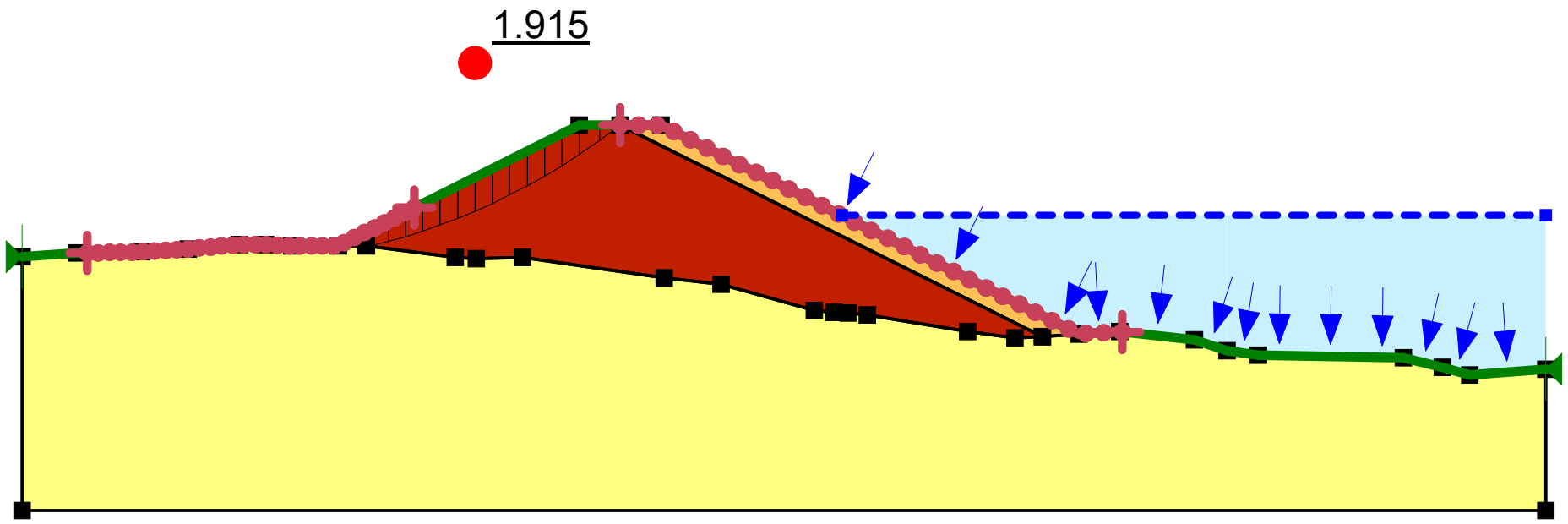
STAGE 3 RAISE DETAILED DESIGN

TSF Embankment - Post Seismic - Downstream

Date: 23/09/2025	Job No: 250542	Appendix F6

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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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MMG DUGALD RIVER

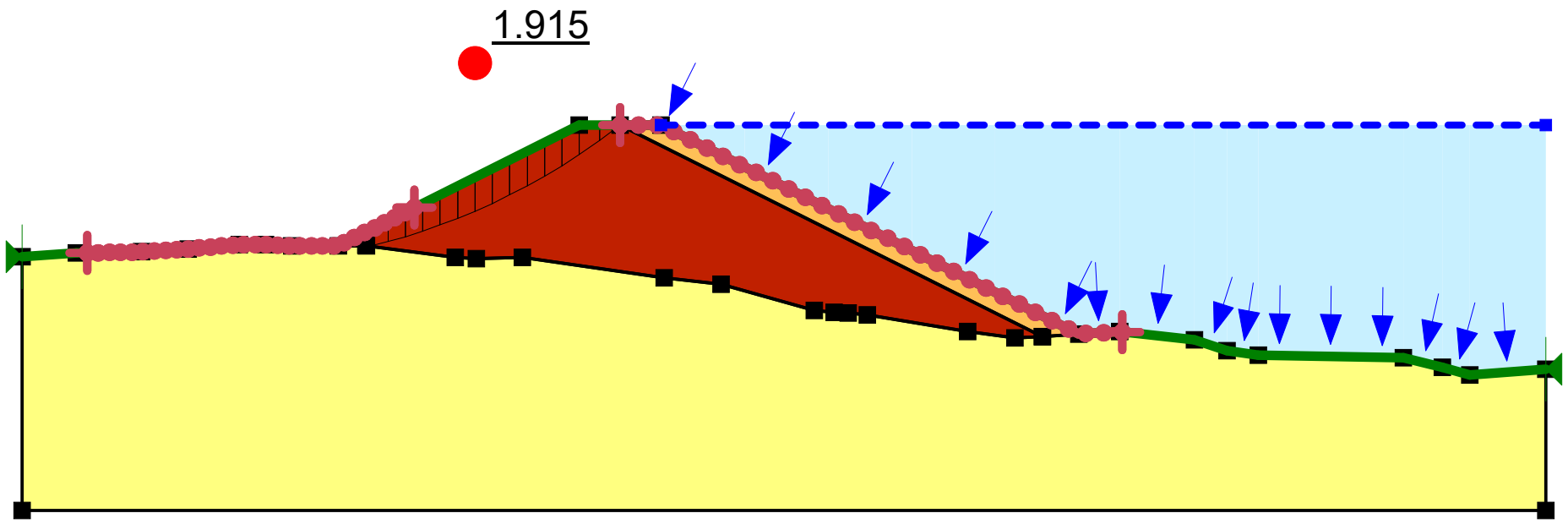
STAGE 3 RAISE DETAILED DESIGN

Northern Discharge Bund - Long Term - Downstream

Date: 29/08/2025	Job No: 250542	Appendix F7

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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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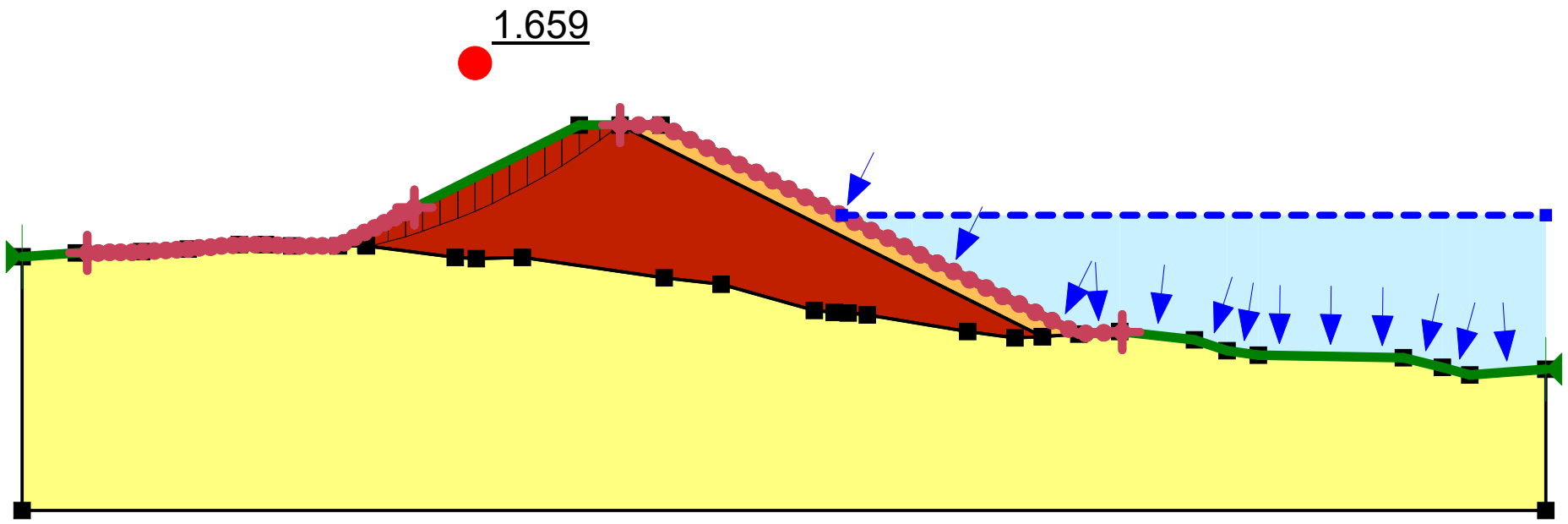
STAGE 3 RAISE DETAILED DESIGN

Northern Discharge Bund - Dam Crest Flood - Downstream

Date: 29/08/2025	Job No: 250542	Appendix F8

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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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MMG DUGALD RIVER

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

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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



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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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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.

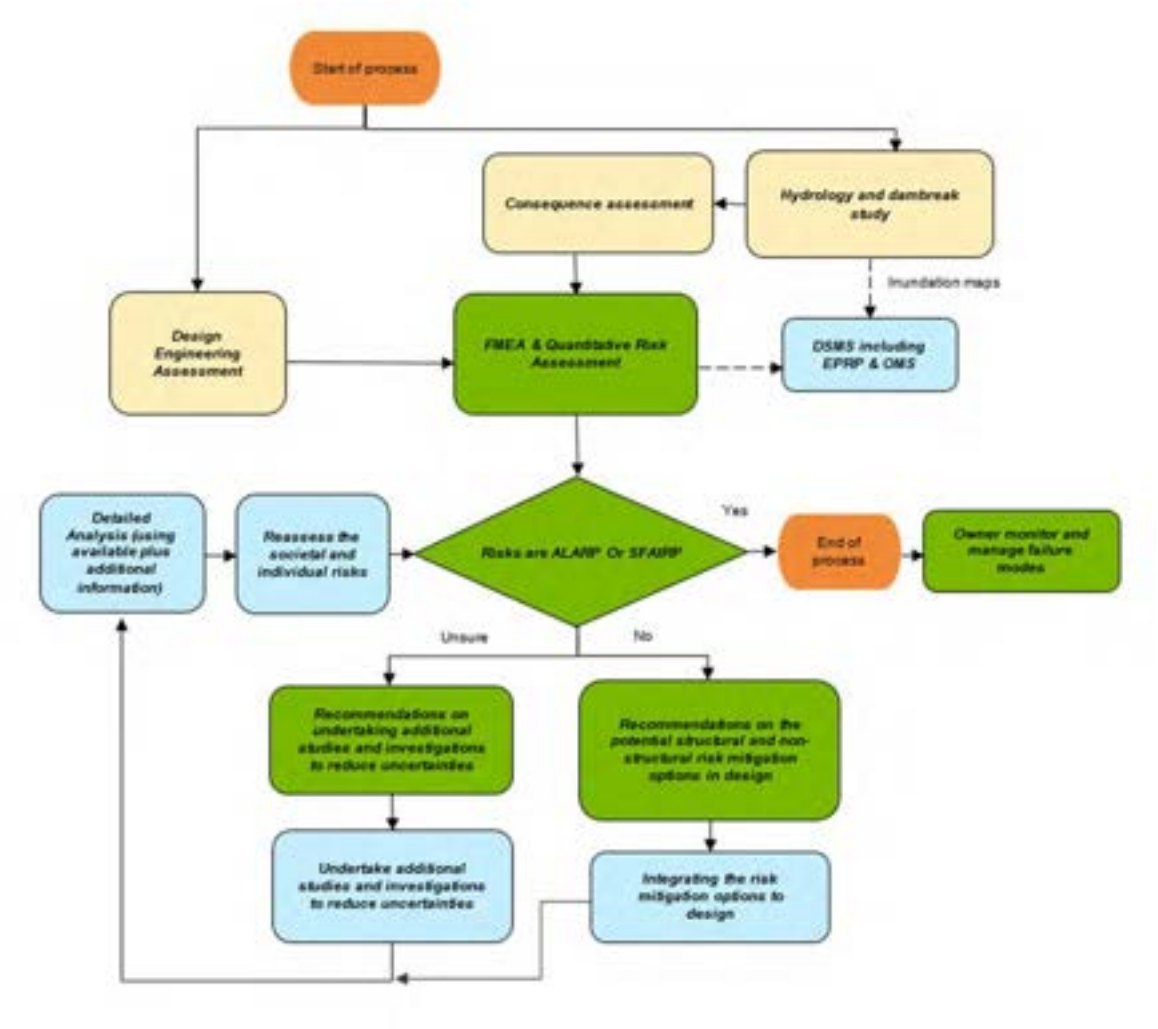
ATCW has been involved in the design and construction of the existing Dugald River TSF and is responsible for delivering the Detailed Design of the Stage 3 Raise of the TSF. Considering the familiarity of key team members with the dam, no site inspection was undertaken as part of this risk assessment.

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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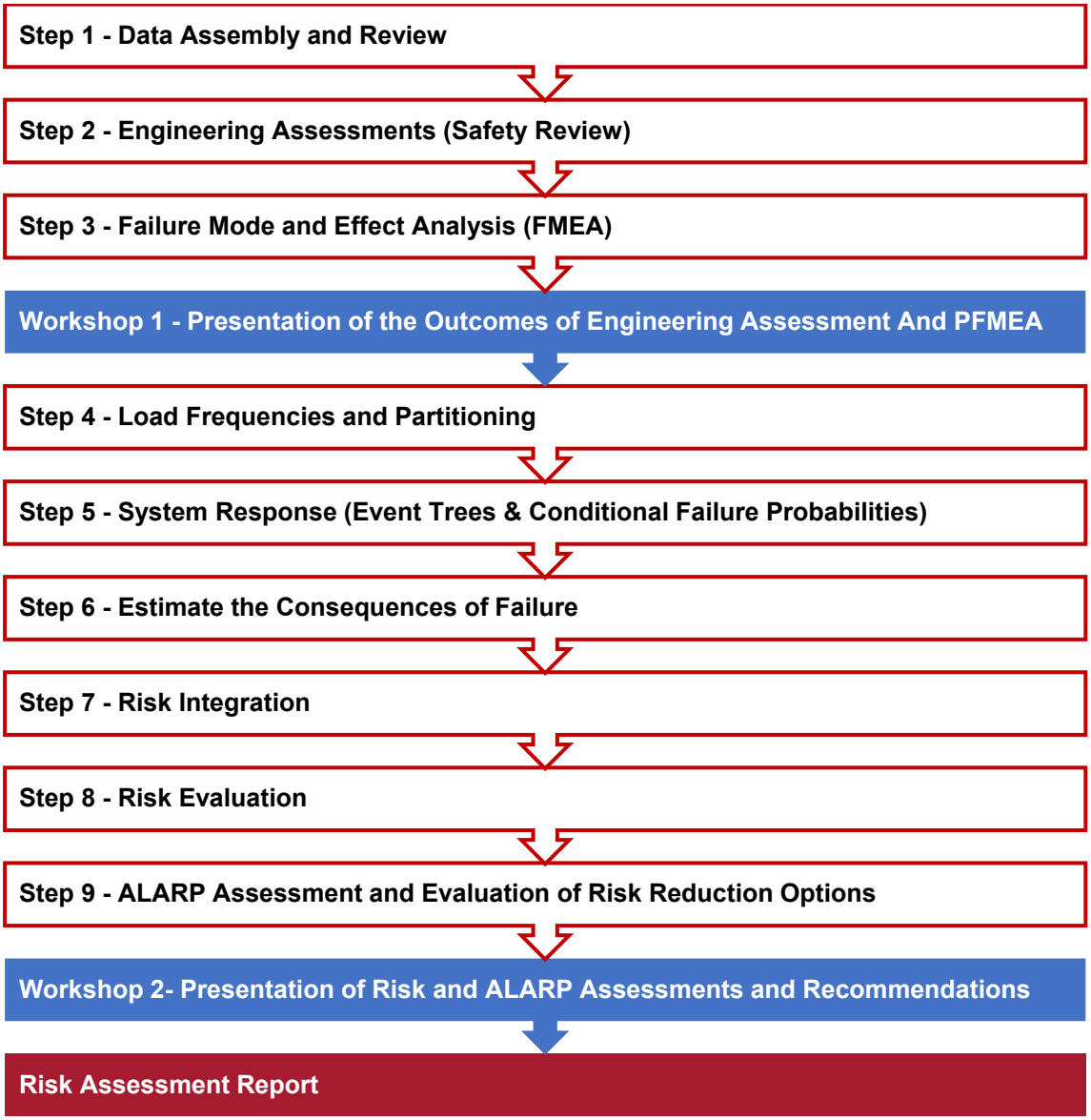
2 RISK ASSESSMENT METHODOLOGY

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

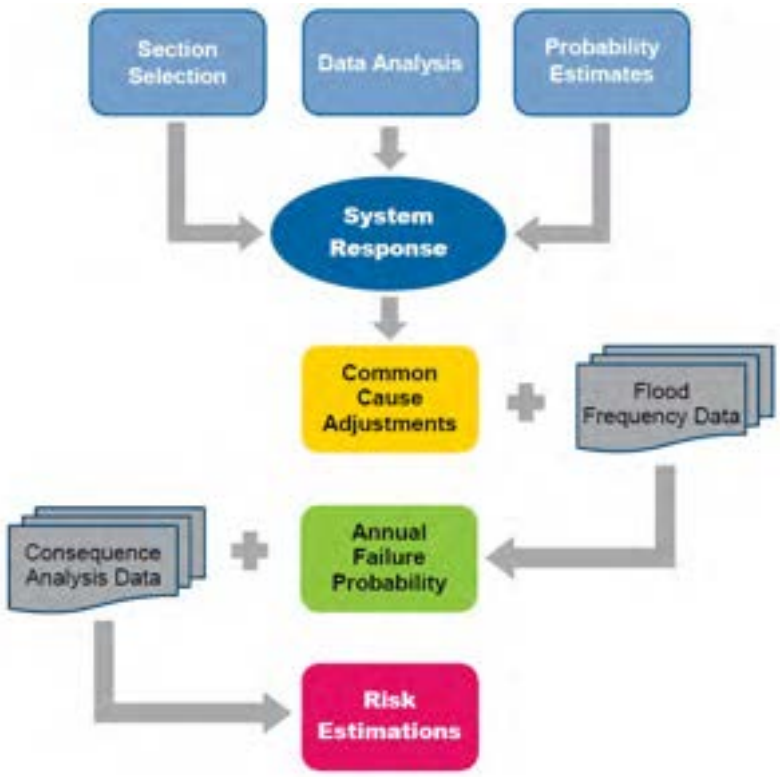
The consequences of dam failure are an essential part of the risk analysis process. The Potential Loss of Life (PLL) values are determined during the dam break and consequence category assessment studies. They are reviewed as an element of this risk assessment study. The review outcomes assign the PLL 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.

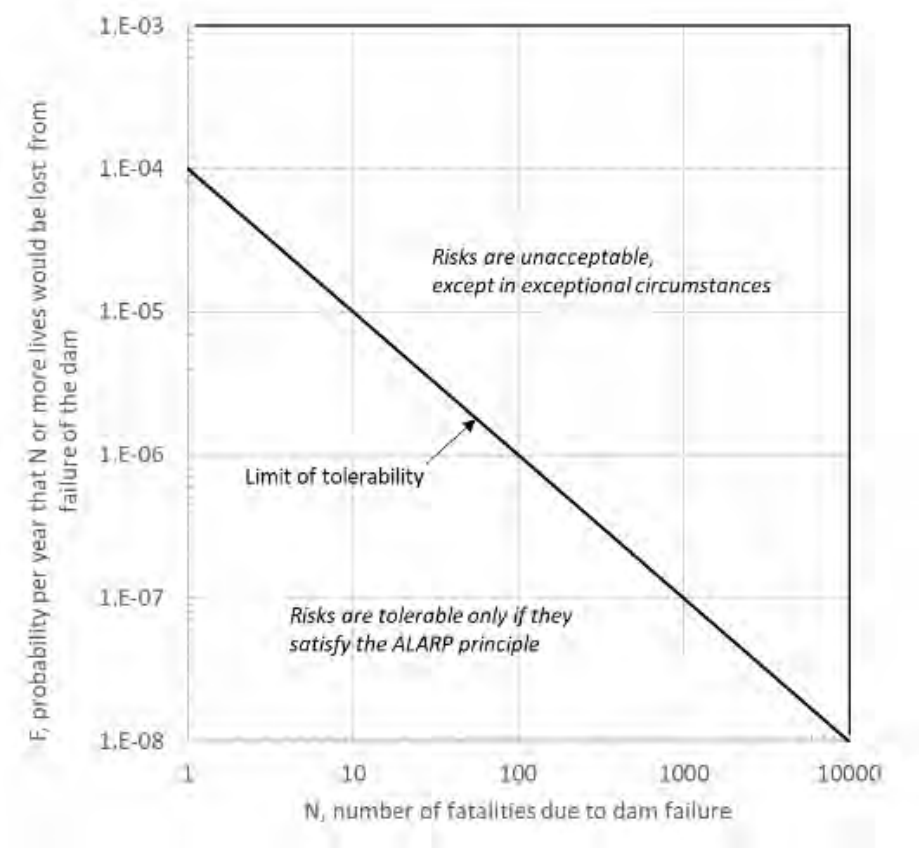
2.9 Step 8 - Risk Evaluation

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

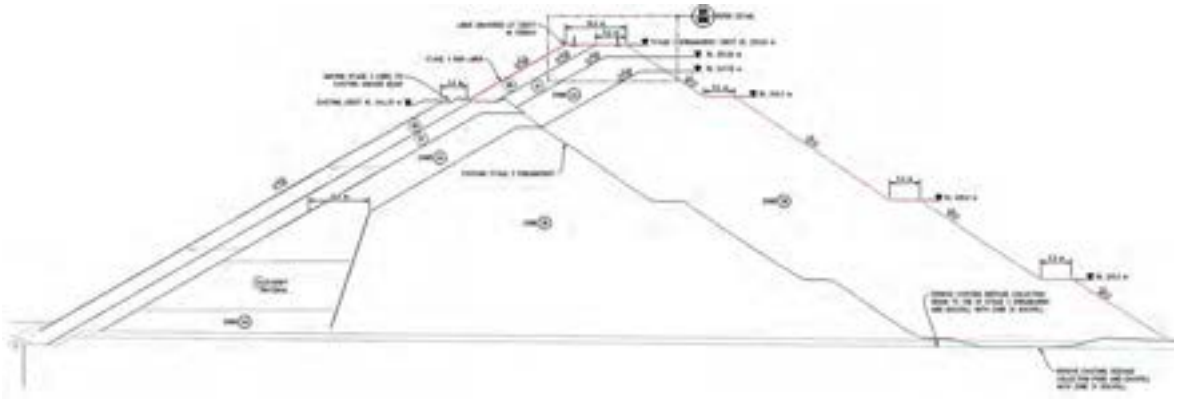
The embankment cross-sections to be considered for the risk assessment have been selected based on the following factors:

- 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.

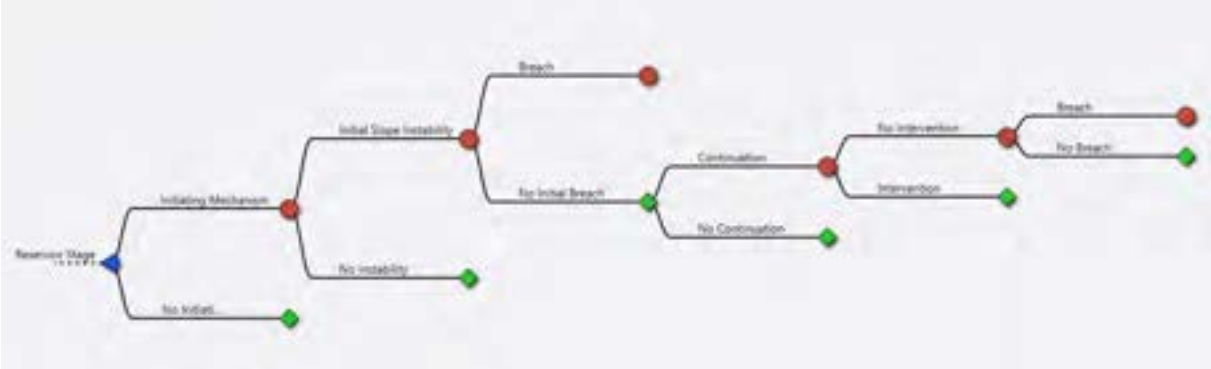
Conditional probabilities are typically estimated by professional judgment and using industry-accepted methods and references. Where professional judgement is required to assign subjective probabilities, the probability mapping scheme presented in ANCOLD **[1]** can be referenced as reproduced in **Table 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

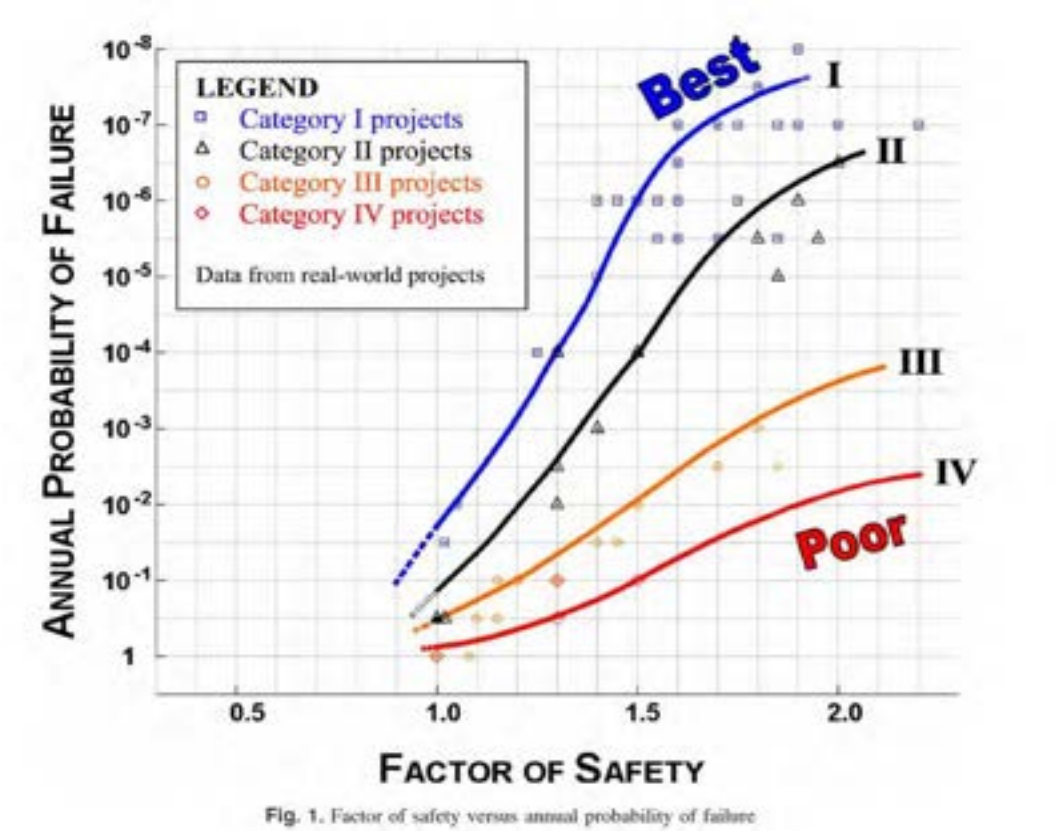


Fig. 1. Factor of safety versus annual probability of failure

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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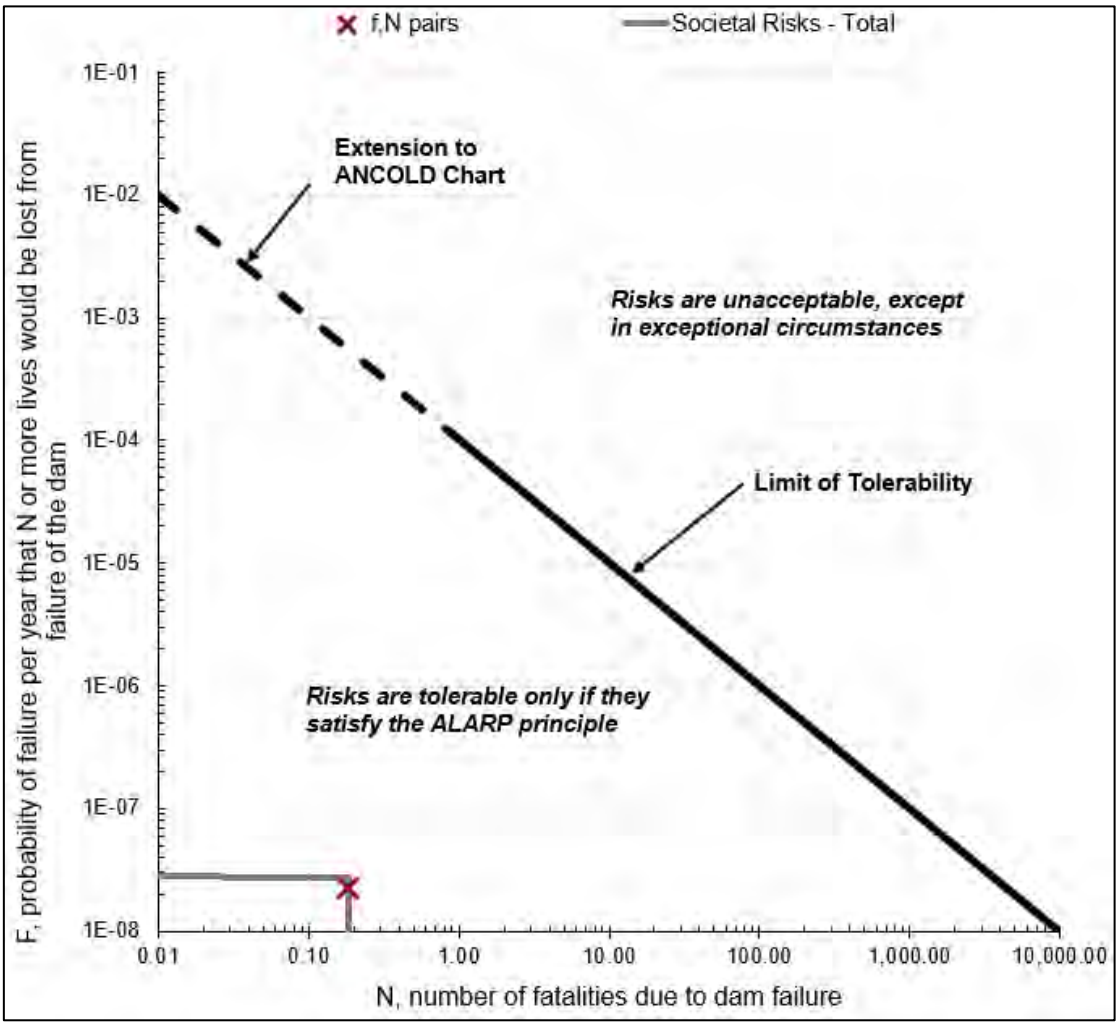
- The Individual Risk is assessed to be 1.03E-09 for the MMG personnel, and 1.33E-10 for the Harmoney personnel. Consequently, the MMG personnel represent the group most at risk, with a total Individual Risk imposed by the Stage 3 TSF of **1.03E-09**. The Individual Risk estimate satisfies the ANCOLD 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

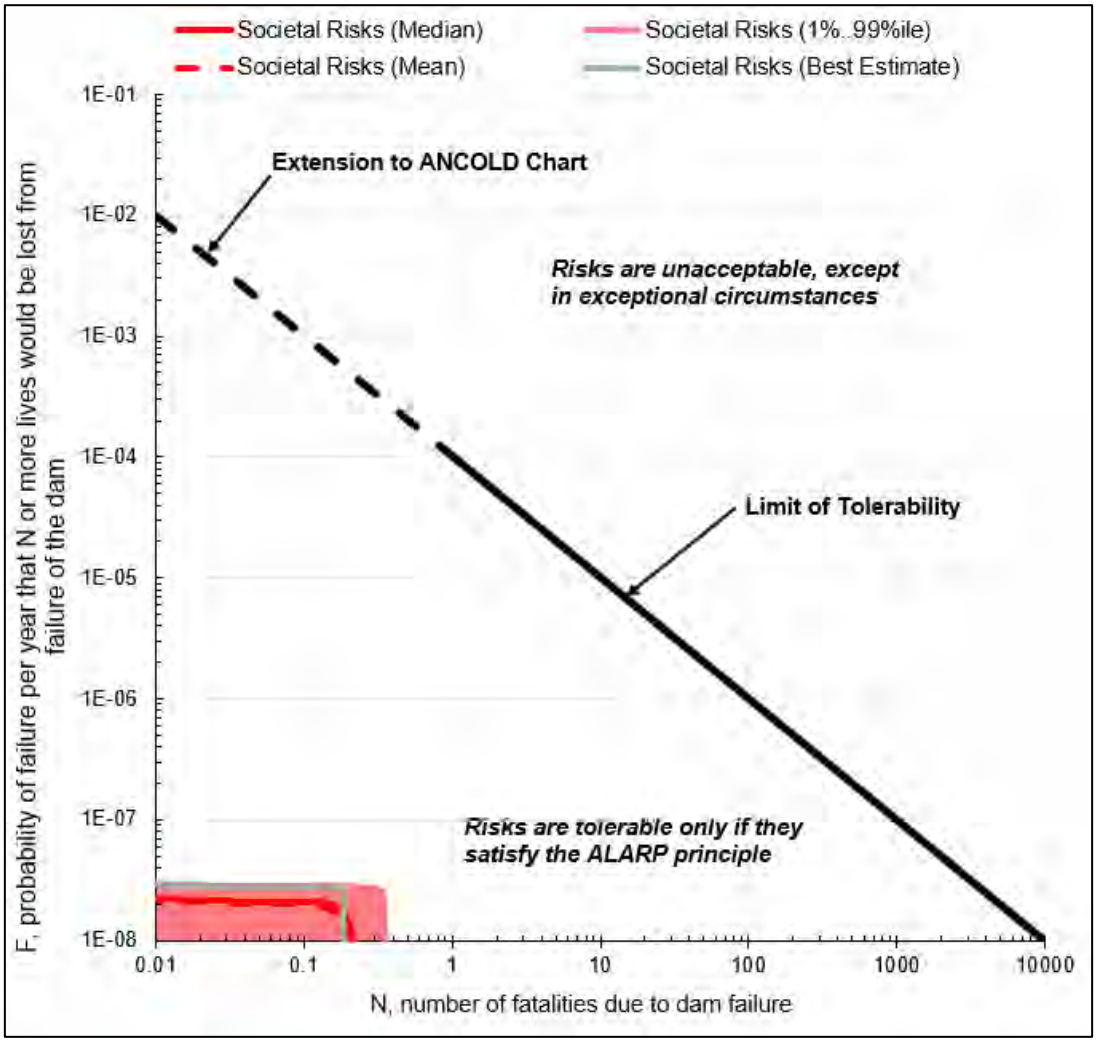
TABLE 19 – INPUTS TO MONTE CARLO UNCERTAINTY SIMULATION (CONSEQUENCE OF FAILURE)

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

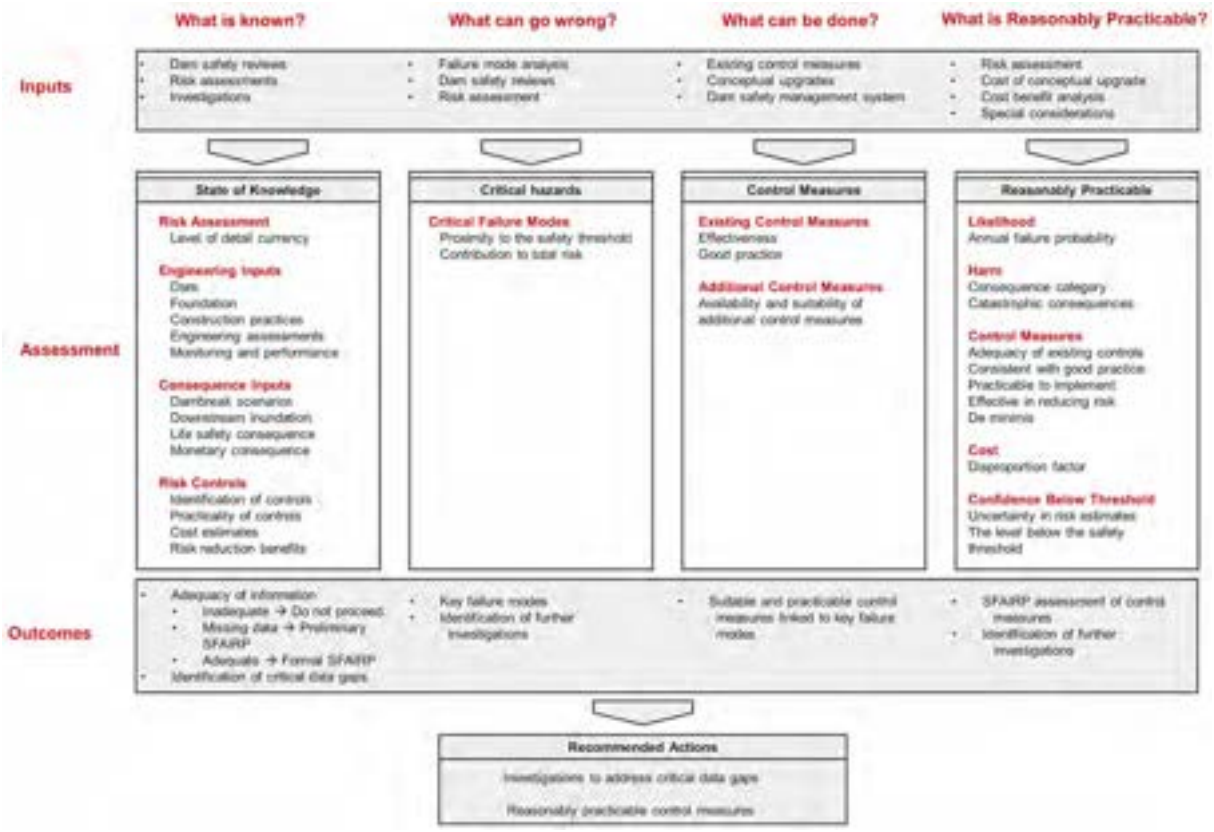
To demonstrate that the risks are "as low as reasonably practicable" (ALARP), the methodology described in Commentary C11-7 of the ANCOLD Guidelines on Risk Assessment **[1]** has been adopted.

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.

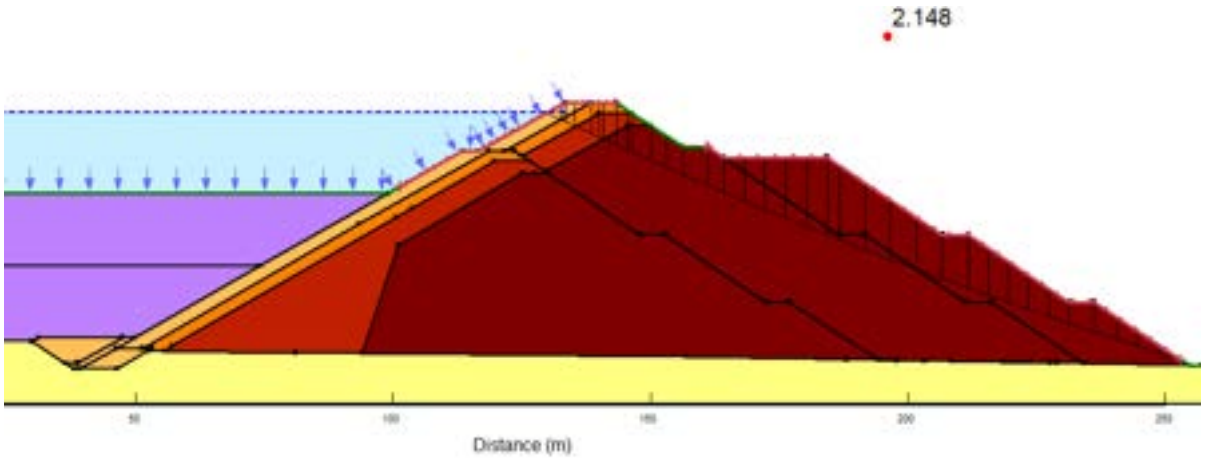
Implementation of this additional control measure has been assessed to increase the Factor of Safety (FoS) for slope stability, increasing it from 1.74 to 2.15 as shown in **Diagram 7** for the maximum flood partition. Similar magnitudes of increases to the FoS apply to the remaining flood partitions.

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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